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An exploration of movement and handling by physiotherapists in a rehabilitation setting: a motion analysis study.

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An exploration of movement and handling by physiotherapists in a rehabilitation setting: a motion analysis study

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A thesis submitted in partial fulfilment of the requirements of the Robert Gordon University for the degree of Doctorate of Physiotherapy

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Abstract

Katharine Sarah Johnson

Doctorate of Physiotherapy

An exploration of movement and handling by physiotherapists in a rehabilitation setting: a motion analysis study

Background: Work-related musculoskeletal disorders (WRMSD) affect between 56-80% of physiotherapists, with patient handling often reported as a risk factor. Physiotherapists use therapeutic handling to aid patient rehabilitation. Therapeutic handling involves the physiotherapist "guiding, facilitating, manipulating or providing resistance" to the patient. Therapeutic handling can subject physiotherapists to high loading forces during patient handling.

Aims: The aims of this doctoral thesis were to quantify physiotherapists' movement during therapeutic patient handling tasks, assess risk of injury against a frequently used ergonomic tool, and investigate whether there may be a relationship between patient handling and WRMSD.

Methods: This research employed a descriptive cross-sectional study design and a positivistic approach to explore and quantitatively measure physiotherapist movement. A portable 3-dimensional motion analysis system, Xsens MTw Awinda, was used to measure physiotherapist movement during patient treatments in a neurological setting. The physiotherapists' movement and posture were quantified, described, and assessed using the Rapid Upper Limb Assessment (RULA) tool. The incidence and personal impact of WRMSD were investigated with the extended Nordic Musculoskeletal Questionnaire (NMQ-E) and potential patient tasks of risk were discussed.

Key Findings: The physiotherapists used four main positions during patient handling tasks: 1) kneeling; 2) half-kneeling; 3) standing; and 4) sitting. Eight patient handling tasks were identified: 1) Lie-to-sit; 2) sit-to-lie; 3) sit-to-stand; 4) upper limb; 5) lower limb; 6) trunk; 7) standing; and 8) walking facilitation. Kneeling or sitting positions were used by the physiotherapists most often during lie-to-sit, sit-to-lie, sit-to-stand, upper limb, trunk, and standing facilitation tasks. Standing was the most common physiotherapist position during lower limb and walking tasks. Kneeling, half-kneeling and sitting positions demonstrated greater neck extension, which scored highly with the RULA and indicating potential risk of injury. Standing demonstrated more cervicothoracic flexion than kneeling and sitting, which demonstrated greater lumbosacral flexion than standing. The physiotherapists' hips and knees often maintained end range flexion when kneeling or half-kneeling which is discouraged in ergonomics literature. The low back was the most frequent anatomical area of WRMSD with 60% of the physiotherapists having experienced discomfort there within their career. Physiotherapists were found to temporarily have changed jobs, sought professional help or taken medication for their shoulder, elbow or low back discomfort. However, none of the physiotherapists had taken sick leave in the last 12 months.

Conclusions: This research found that tasks were more often performed in kneeling or sitting positions than in standing. Moving and handling guidance considers the handler in a standing position; guidance should therefore start to consider the handler in the variety of positions found in clinical practice. Ergonomic assessments, such as the RULA, consider the trunk as one joint. This research investigated three trunk joints, with different postures found at the cervicothoracic and lumbosacral junctions. Future research should appreciate how the position of the handler can impact trunk posture. More research needs to be conducted to qualitatively investigate physiotherapists' perceptions and experiences of patient handling. This research has provided a detailed exploration into therapeutic handling the neurological setting which can be used to guide future research.

Key Words: physiotherapy; manual handling; therapeutic handling, neurological rehabilitation; ergonomics; work-related musculoskeletal disorders

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To all my research participants and patient volunteers, thank you for participating. Without your help I would not have this research to present. You were all so interested and engaged, which was greatly appreciated. As a physiotherapist is it rare to have the opportunity to passively observe other physiotherapist treatments, especially for ten days. I learned a lot from observing your practice, which helped me develop as a clinician as well as a researcher. I must also thank my NHS and private colleagues who I have worked with while completing my doctorate. You provided a much needed weekly break from my research, and also allowed me to learn and practice physiotherapy, which is invaluable.

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Outputs

Presentations

JBI EU Symposium and SPIDER multiplier event June 2021. Short oral presentation on scoping review findings.

RGU Educators Conference August 2022. Oral presentation on methods and key findings of motion analysis study.

Other Planned Outputs

Journal publication – Physiotherapy: Manual patient handling in the healthcare setting: A scoping review. (Under peer review)

Poster submission – NHS Scotland Half-Day National AHP Research Virtual Conference; November 2022.

List of Abbreviations

WRMSD	Work Related Musculoskeletal Disorder
HCP	Healthcare Practitioner
AHP	Allied Health Professional
UK	United Kingdom
MHOR	Manual Handling Operations Regulations
HSE	Health and Safety Executive
NHS	National Health System
SMHPS	Scottish Manual Handling Passport Scheme
US	United States
ICF	*International Classification of Functioning, Disability and Health*
SPHM	Safe Patient Handling and Mobility
NIOSH	National Institute for Occupational Safety and Health
US	United States
PNF	Proprioceptive Neuromuscular Facilitation
CIMT	Constraint-Induced Movement Therapy
NRC	National Research Council
IOM	Institute of Medicine
RULA	Rapid Upper Limb Assessment
REBA	Rapid Entire Body Assessment
OWAS	Ovako Working posture Assessment System
LMM	Lumbar Motion Monitor
EMG	Electromyography
3D	3-Dimensional

IMU	Inertial Measurement Unit
RGU	Robert Gordon University
HDI	Human Development Index
FRSM	Fluid Resistant Surgical Mask
PPE	Personal Protective Equipment
NIPCM	National Infection Prevention and Control Manual
HCPC	Health Care Professions Council
NMQ	Nordic Musculoskeletal Questionnaire
NMQ-E	Extended Nordic Musculoskeletal Questionnaire
ICC	Intraclass Correlation Coefficient
MEMS	Micro-electromechanical Systems
ROM	Range of Motion
ISB	International Society of Biomechanics
ASIS	Anterior Superior Iliac Spine
Fps	Frames per second
BoS	Base of Support

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1. INTRODUCTION

1.1 Introduction to Chapter

This chapter will introduce and set the context for this thesis. The focus of this thesis is therapeutic handling, performed by physiotherapists in a neurological setting. Key terms and concepts will be introduced in relation to the research which focuses on physiotherapist movement and patient handling during neurological treatments. This introductory chapter will define moving and handling in healthcare, the current measures and legislation surrounding manual handling. The chapter will then define work related musculoskeletal disorders (WRMSD) and discuss the personal and wider impacts of these. The chapter will then introduce physiotherapy, neurological rehabilitation and key approaches to patient rehabilitation. Finally, this chapter will introduce motion analysis and ergonomics, and how these can be used within a healthcare setting.

1.2 Moving and Handling in Healthcare

Healthcare practitioners (HCP) comprise a wide range of qualified professionals and support staff including doctors, nurses, midwives, carers and allied health professionals (AHPs) (Francis and Presseau 2019). All HCPs routinely manually assist patients with transferring from bed to chair, personal care tasks such as washing or dressing, repositioning or rolling in bed, and walking (Schoenfisch et al. 2019). Nursing staff, healthcare support workers, home carers, physiotherapists and occupational therapists are among the HCPs involved with manual assistance of patients within healthcare (Baptiste 2011; Schoenfisch et al. 2019; Smith et al. 2014). Work-related musculoskeletal disorders are multifactorial; however, patient handling is frequently documented as the largest risk factor for patient-facing HCPs (Anderson and Oakman 2016; Davis and Kotowski 2015; Health and Safety Executive (HSE) 2021). Low back pain is one of the most commonly reported complaints in working populations (HSE 2021). Effective and safe manual handling is therefore an important aspect for HCPs to reduce risk of WRMSD during manual patient handling tasks.

1.2.1 Moving and Handling Legislation and Guidance

Legislation on manual patient handling and associated training varies across geographical locations. Within the United Kingdom (UK), the legislation and regulations followed are the: Health and Safety at Work Act (1974); Management of Health and Safety at Work Regulations (1999); Manual Handling Operations Regulations 1992 (MHOR) (as amended 2002); provision of Use of Work Equipment Regulations 1998; and Lifting Operations and Lifting Equipment Regulations 1998 (HSE 2014). The MHOR provides guidance on individual capability, risks associated with manual handling, good handling technique, and risk assessments (HSE 2016). By complying with moving and handling legislation and regulations, safety during patient handling can be managed through use of risk assessments, training, and maintaining equipment so it is safe for use.

Staff involved in manual patient handling within the National Health Service (NHS) are required to complete both online theory and in-person training sessions. The sessions aim to allow staff to practice correct moving and handling principles to reduce their risk of injury (Smith et al. 2014). The in-person aspect of this training is required to be updated every 12-months (Smith et al. 2014). Training sessions include the underpinning knowledge of moving and handling, practical instruction, and practicing safe handling principles. Principles for good handling and lifting include: adopting a stable position, with your feet offset; avoiding flexing at the back; keeping the load close to the body; avoiding twisting or flexing sideways at the trunk; bending your knees; and moving smoothly (Graveling et al. 2003; HSE 2021; NHS 2021). These principles of safe handling are then applied to specific patient handling tasks such as sit-to-stand, bed manoeuvres, use of hoists and lateral transfers (HSE 2014). The aim of the training is to increase awareness of repetitive, stooped or twisting movements and the risks of working near or at physical limits, as these are recognised to increase risk of injury to the handler (HSE 2021; Smith et al. 2014).

The HSE state that employers are required to provide training, with instruction on how to use mechanical lifting aids (HSE 2016). However, the HSE do not have specific guidance on what content these training courses should include. Some NHS Scotland health boards have implemented the Scottish Manual Handling Passport Scheme (SMHPS) (Scottish Manual Handling Forum 2014). This scheme aims to improve the consistency of training and reduce the risk of developing WRMSD associated with manual handling in healthcare (HSE 2014). However, this SMHPS is not mandated within NHS health boards, with some boards implementing individual local training courses.

Within the United States (US), safe patient handling and mobility (SPHM) programmes have been implemented in 11 states (National Institute for Occupational Safety and Health (NIOSH) 2013) aiming to improve patient handling safety within HCPs. Safe patient handling programs are not federal law, with each state enacting SPHM programmes individually (NIOSH 2013). A recent nurse and healthcare worker protection act has been published in the United States (US), promoting the use of SPHM programmes within healthcare (Conyers 2015). These programmes strongly encourage the use of lifting aids during patient transfers. However, most states have not implemented SPHM programmes (NIOSH 2013). Barriers to SPHM programmes include resistance from politicians and poor enforcement power due to lack of staff and funding (Weinmeyer 2016).

Lifting aids, which are designed to assist with patient movement and transferring, thereby reducing loads on healthcare staff, can improve safety during manual patient handling (NIOSH 2013). Whilst lifting aids are appropriate in certain circumstances; frequently, situations are encountered that require nurses and AHPs to manually facilitate patient movement (Schoenfisch et al. 2019). Many patient transferring aids require the use of a sling, and the placement and removal of these slings is a physically demanding task. Healthcare practitioners are also often involved in rolling the patient, lifting the lower limbs or pulling the sling under the hips and lower limbs. There are no lifting aids for these steps and therefore these are completed manually (Baptiste 2011).

1.3 Work-related Musculoskeletal Disorders

1.3.1 Work-related Musculoskeletal Disorders in Healthcare

Patient handling can be manually intensive; therefore, it is not surprising that WRMSD are an issue in healthcare professions. Work-related musculoskeletal disorders are defined as “injuries or dysfunctions affecting muscles, bones, nerves, tendons, ligaments, joints, cartilages, and spinal discs” (Centers for Disease Control and Prevention 2020). Injury and pain can negatively affect the health and wellbeing of individuals in the workplace and the overall staffing levels of departments (HSE 2021). The incidence and aetiology of WRMSD have been investigated extensively in healthcare populations (Gaowgzeh 2019; Muaidi and Shanb 2016; Darragh et al. 2009; Menzel et al. 2016; Gilchrist and Pokorná 2021). Injuries in health and social work settings have been estimated at 1,500 injuries per 100,000 workers (HSE 2021). The low back is frequently documented as the most common anatomical region of WRMSD within healthcare populations (Gaowgzeh 2019; Muaidi and Shanb 2016; Darragh et al. 2009; Menzel et al. 2016; Gilchrist and Pokorná 2021). Multiple factors are involved in developing WRMSD within healthcare such as, patient handling, age, education level, gender, mental health, and psychosocial factors (del Campo et al. 2017; Krishnan et al. 2021). Within patient handling tasks, transferring patients out of chairs or beds, and repositioning patients are often reported as tasks that increase risk of WRMSD (Campo et al. 2008).

A large variation in statistics surrounding WRMSD within healthcare settings has been reported. International incidence rates and epidemiology surrounding WRMSD range from 28-96% in nursing and allied health populations (Anderson et al. 2019; Anderson and Oakman 2016; Ngan et al. 2010; Ribeiro et al. 2017). In addition to affecting physical and mental wellbeing, there is a significant financial cost associated with WRMSD. In the UK, it is reported that 9.5 million working days are lost to WRMSD each year with a financial burden of £400 million GBP per annum to the UK NHS (Chartered Society of Physiotherapy 2016). The US reported the cost of healthcare workers' related compensation losses as $2 billion USD per annum (OSHA 2013), with Australia reporting the cost of serious workplace injuries (1-week or more off work) as A$14 million AUD within healthcare settings (Anderson et al. 2019). Therefore, it is important to reduce the high incidence of WRMSD and the high financial costs associated.

1.3.2 Work-related Musculoskeletal Disorders in Physiotherapy

Physiotherapists are one of the 15 allied health professions (Health Careers 2022). It has been suggested that physiotherapists may experience fewer WRMSD due to their understanding of biomechanics and mechanism of injury; this assumption has however been refuted (Hignett 1995). Indeed, one-year prevalence rates among physiotherapists range from 56-80% internationally (Darragh et al. 2012; Glover et al. 2005; McCrory et al. 2014; Passier and McPhail 2011). Prevalence has previously been reported as 80% in prosthetists and orthotists (Anderson et al. 2021), 85.9% in occupational therapists (Park and Park 2017), 96% in sonographers (Hill et al. 2009) and 56.53% in podiatrists (Losa Iglesias et al. 2011). Therefore, the statistics suggest that physiotherapists experience similar rates of WRMSD as other health professions. Additionally, the low back is often documented as an area of injury within physiotherapy populations (Darragh et al. 2009; Muaidi and Shanb 2016; Glover et al. 2005; Anderson and Oakman 2016). However, there is uncertainty around the accuracy of physiotherapists reporting WRMSD.

Therapeutic activities are mentioned as an associated risk factor for physiotherapists (Darragh et al. 2012; McCrory et al. 2014). It has also been suggested that an increased workload can contribute to the increased risk of developing WRMSD (Karanikas and Jani 2022). Methods to reduce WRMSD include: modification of work practices; increased use of lifting aids; physical capacity assessments; manual handling training; and risk assessments (Garzillo et al. 2020; Passier and McPhail 2011). Physiotherapists can reduce their risk of injury by adopting comfortable positions, modifying their work, and adjusting the height of beds or plinths (Karanikas and Jani 2022; Faizan et al. 2019). Interventions to reduce risk of injury should be adopted at the management level in addition to the individual performing the patient handling. Work-related musculoskeletal disorders remain an issue within the physiotherapy field, despite the variety of strategies investigated.

1.4 Patient Handling in Physiotherapy

Physiotherapists use therapeutic handling in all specialties of physiotherapy to aid patient treatment and rehabilitation. Physiotherapists in many specialties will often aid in-patients with sit-to-stand, lie-to-sit and sit-to-lie (Ruszala and Musa 2005; Smith et al. 2014). Physiotherapists may also aid patients by manually facilitating stretches or strengthening exercises (Ainslie 2012). In outpatient settings, physiotherapists perform manual therapies such as joint mobilisations or soft tissue massage (Shah et al. 2021). The focus of this research was neurological physiotherapy, this speciality can require frequent therapeutic handling due to the nature and presentation of patients following stroke or brain injury (Smith et al. 2014).

Neurological physiotherapists aim to improve patient movement and function through aerobic exercise, strengthening exercise, problem solving, and specific task practice (Lennon et al. 2018). There are many principles to consider within neurological rehabilitation, ten of which are proposed in Figure 1.1. Relevant, functional, and challenging goals are set within rehabilitation settings (Duncan et al. 2013; Lennon et al. 2018). Goals provide direction for the multidisciplinary rehabilitation team to work towards. Physiotherapists use clinical reasoning and constant assessment of the patient’s abilities to ensure the goals and treatment remain relevant (Lennon et al. 2018). Guidance states that patients should initially be offered at least 45-minutes of rehabilitation treatment for a minimum of five days a week (Duncan et al. 2013), and that physiotherapists should rehabilitate patient movement, strength, fitness, upper limb function and walking (Duncan et al. 2013).

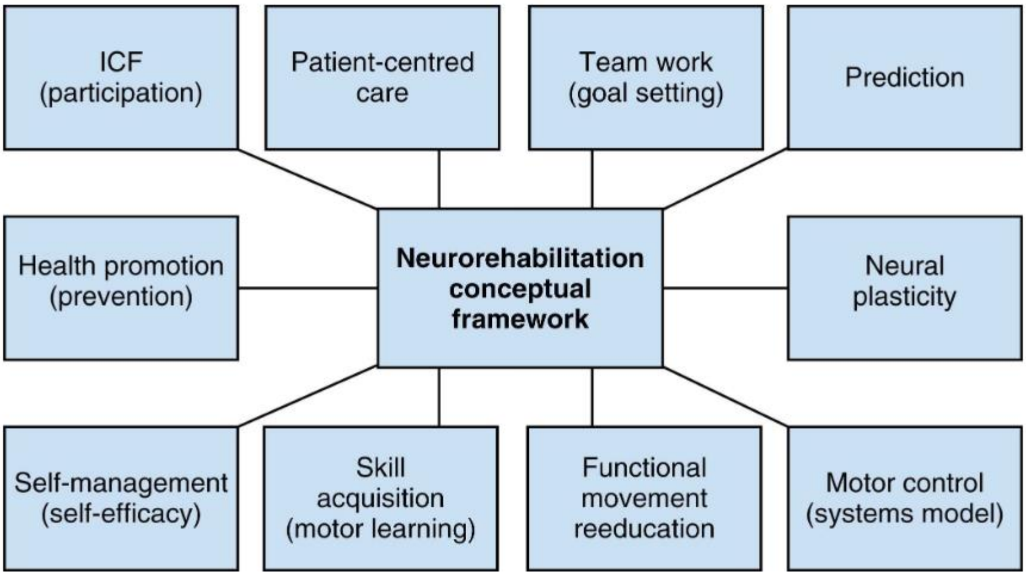


Figure 1.1: Conceptual framework for neurological rehabilitation (Lennon et al. 2018) Key: ICF – International Classification of Functioning, Disability and Health

The Scottish Government have recently published six principles of good rehabilitation. The six principles are illustrated in Figure 1.2. Compliance with the Scottish government principles, and the previously proposed ten principles of neurological rehabilitation (Figure 1.1) could improve the specificity and effectiveness of patient rehabilitation.

General exercise considerations when rehabilitating patients involve active or passive exercises, exercise against physiotherapist resistance, body-weight exercises, exercise to encourage normal movements (e.g., sit-to-stand), stretches, and balance (Ainslie 2012). These exercises aim to increase muscle strength, control, length and patterns of muscle activity which can improve the overall function and independence of the patient (Ainslie 2012). Additionally, there are multiple methods of treatment within neurological physiotherapy, including: the Bobath approach; proprioceptive neuromuscular facilitation (PNF); the Rood's approach; and Constraint-Induced Movement Therapy (CIMT). The Bobath approach, PNF and CIMT are popular approaches within physiotherapy and are described in detail elsewhere (Bhalerao Gajanan et al. 2016). Among these multiple approaches, there is little evidence to suggest one approach is more effective than another (Stokes 2013). Neural plasticity is defined as 'the capacity of the nervous system to modify itself, functionally and structurally, in response to experience and injury' (von Bernhardi et al. 2015). Physiotherapists can improve patient function through repeated task-specific training, functional movement training, and motor control training (Lennon et al. 2018).

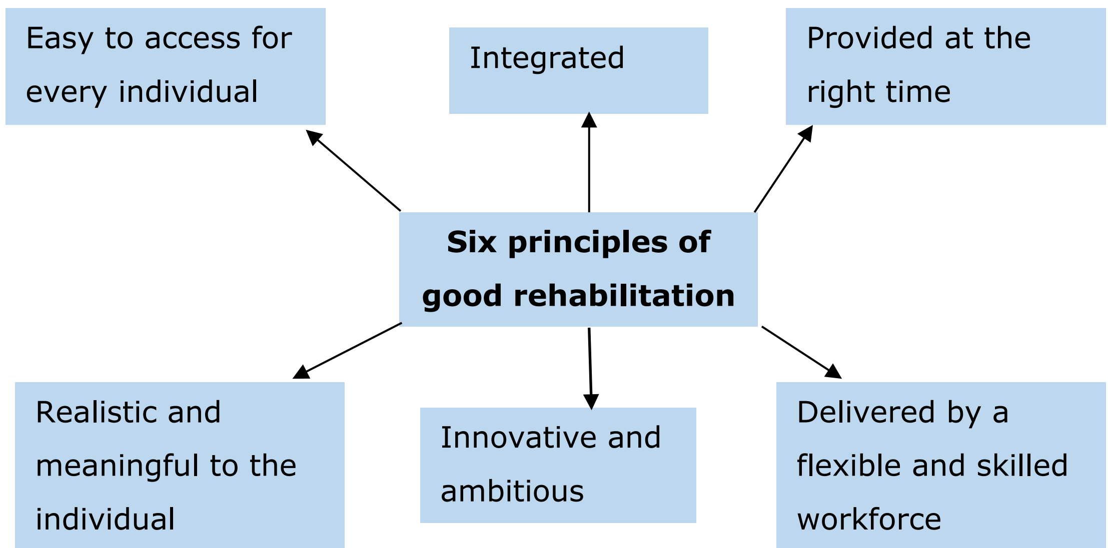


Figure 1.2: Six principles of good rehabilitation (Adapted from Scot Gov 2022)

Improving patient function often requires physiotherapists to go beyond manual patient handling, and to employ therapeutic handling to aid rehabilitation (Smith et al. 2014). Therapeutic handling is distinct from the previously described manual patient handling by using their own body in "guiding, facilitating, manipulating or providing resistance" to the patient (Smith et al. 2014 p18). Therapists will manually move and handle the patient to achieve therapeutic benefit (Smith et al. 2014). Therapeutic handling is different to 'traditional' patient handling as the goal of therapeutic handling is to help the patient improve functionally and gain further independence (Smith et al. 2014). An example of therapeutic handling is the physiotherapist resisting the patient during exercise (Ainslie 2012). The patients' neuromuscular memory and strength can be improved when providing resistance (Ainslie 2012). However, depending on the muscle group, movement or patient strength, this task could be manually intensive for the physiotherapist. Therapeutic handling actively requires the patient to be involved in the task. Depending on the patient's strength and balance this could require the physiotherapist to be exposed to high trunk loading during the time taken to perform the task (Waters and Rockefeller 2010). This could increase their risk of developing a WRMSD due to loading placed on the spinal tissues (Waters and Rockefeller 2010).

1.5 Ergonomics in Healthcare

Ergonomics can be defined as "an applied science concerned with and arranging things people use so that the people and things interact most efficiently and safely" (Merriam-Webster 2022). Ergonomics aims to reduce the risk of injury to the worker (Waters 2010). The National Research Council (NRC) and Institute of Medicine (IOM) produced a model of influencing factors involved in WRMSD; this is illustrated in Figure 1.3 (Waters 2010). The model illustrates that physical factors can contribute to the development of WRMSD by affecting loading placed on structures such as the low back. However, organisational and social factors are involved, and can increase the risk of developing WRMSD.

Ergonomic assessments have been used previously to observe and quantify the risk of developing WRMSD in industrial, healthcare, forestry, and agricultural settings (Joshi and Deshpande 2019). Ergonomic assessment tools include the NIOSH lifting equation, Rapid Upper Limb Assessment (RULA), the Rapid Entire Body Assessment (REBA), and Ovako Working posture Assessment System (OWAS) (Joshi and Deshpande 2019; Tang 2020). The RULA, REBA, and OWAS were found to be the most commonly used ergonomic tools in the literature by Joshi and Deshpande (2019). The RULA, REBA, and OWAS assess and score the risk at the arms, legs, neck and trunk during working tasks (Kee 2022). The individual's working posture is assessed and given a score which equates to the level of risk of injury. This score indicates if changes need to be made to improve the posture of the worker during the task (Kee 2022).

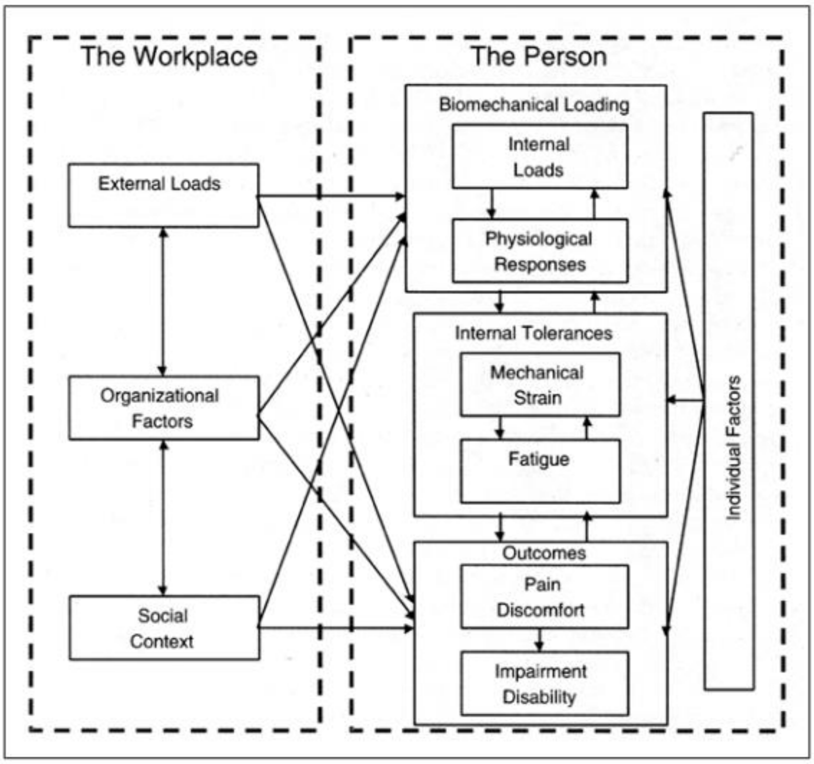


Figure 1.3: National Research Council and Intsitute of Medicine model of factors involved in developing a WRMSD (From Waters 2010)

No ergonomic tool has been used widely in physiotherapy. The Rapid Entire Body Assessment (REBA) was used to assess physiotherapist positioning during development of the tool (Hignett and McAtamney 2000). The REBA is similar to the RULA; however, the REBA has been found to be less sensitive and to demonstrate less robust inter and intra-rater reliability (Kee 2022). It is more common to investigate how physiotherapists assess the posture of others rather than assessing their own postures (Dockrell et al. 2012; Pereira et al. 2016).

In addition to observational methods, ergonomics can also be directly measured and assessed through use of devices such as optical motion capture systems, Lumbar Motion Monitors (LMM), Electromyography (EMG), force sensors, and electrogoniometers (Kee 2022; Tang 2020). Direct measurement allows for more detailed investigations into trunk postures and loading; however, they can be more costly and complex (Kee 2022; Tang 2020). Observational ergonomic assessments are also often less of an impact to the task being performed than optical motion capture methods (Kee 2022).

1.5.1 Motion Analysis Research and Ergonomics

Recent advances in motion analysis have progressed from 2-dimentional video analysis to portable 3-dimensional (3D) full-body recording. Motion analysis systems have become increasingly accurate and allow for joint measurement and calculation of trunk forces experienced through biomechanical modelling (Kim and Zhang 2017). Laboratory based optoelectronic systems, such as Vicon (Vicon Motion Systems Ltd) or Optotrak (Northern Digital Inc.) are stated as the gold-standard for motion analysis (Al-Amri et al. 2018; Cuesta-Vargas et al. 2010). However, inertial measurement units (IMU) have become increasingly used in recent years with success in sporting and ergonomic settings (van der Kruk and Reijne 2018). Tracker based systems allow for flexible recording of human movement out of the laboratory environment with minimal set up (Schepers et al. 2018; Roetenberg et al. 2013).

Motion analysis allows for real time recording of human movement during dynamic tasks to assess posture and provide further understanding of the mechanics of human movement (Roetenberg et al. 2013; Merino et al. 2019). Motion analysis is beneficial to gain further understanding in clinical, industrial, and sporting settings. In industrial settings, handler movement can be measured to aid with ergonomic assessment (Robert-Lachaine et al. 2016). Clinically, patients' movement can be investigated and aid with diagnosing and treating the patient (Menolotto et al. 2020). A greater understanding of human motion can allow for identification of movement disorders and improve injury prevention (Lopez-Nava and Munoz-Melendez 2016). Motion analysis systems are more often used to investigate the patients' movement rather than the physiotherapists. Motion analysis systems could be used to provide useful information regarding physiotherapist movement during therapeutic handling tasks. Understanding how physiotherapists move during therapeutic handling could aid development of training programs or interventions to reduce the risks involved.

One anatomical region that is focused on in the literature is the low back. As discussed previously in section 1.3, the low back is a frequently documented area of injury for physiotherapists and other healthcare populations (Gaowgzeh 2019; Muaidi and Shanb 2016; Darragh et al. 2009; Menzel et al. 2016; Gilchrist and Pokorná 2021). Investigations have been conducted into injury prevention, loading and movements involved with patient handling by HCPs (Callison and Nussbaum 2012; Glover et al. 2005; Hegewald et al. 2018; Schoenfisch et al. 2019; Weinmeyer 2016). However, the body of literature surrounding manual patient handling in healthcare needs to be reviewed to investigate the area and identify potential gaps in the literature. The following chapter of this thesis will describe and discuss the scoping review conducted to investigate manual patient handling in healthcare.

1.6 Impact of COVID-19 on Research

This research originated as a laboratory-based project investigating movement of healthcare practitioners during facilitation of sit-to-stand. Ethical and management approvals had been obtained and data collection was scheduled to commence in summer 2020. The COVID-19 pandemic resulted in closure of the university and the human performance laboratory and there was uncertainty about when access to the university and laboratory would return. The research originally aimed to investigate physiotherapists and nurses' movement; however, participant recruitment was suspended within the NHS due to the pandemic. There were also ongoing increased pressures placed on the NHS throughout 2020 and into 2021, and it was not feasible to ask staff to take three hours out of their working day to attend Robert Gordon University (RGU) in order to take part in the research.

After discussion with the supervisory team and NHS physiotherapy staff, the project was adapted to explore physiotherapist movement in the clinical setting using the Xsens MTW Awinda system (Movella, Henderson, NV). It was felt that this would allow for less invasive measurement of physiotherapist movement with minimal impact on the clinician's usual day-to-day activities. The new research proposal was developed, and ethical and management approvals applied for. This adaption of the research, re-application for ethics and training with Xsens resulted in a significant delay to starting data collection. However, the new project was designed, implemented and the thesis written within the standard 6-months of additional time granted to all post-graduate research students as a result of the impact of the COVID-19 pandemic.

1.7 Summary

This chapter has introduced the legislation and guidance surrounding moving and handling in healthcare and how the UK implements and follows these. Moving and handling within healthcare and more specifically therapeutic handling within physiotherapy has been described. The associated incidence and impact of WRMSD in healthcare, relation to patient handling practices and resulting methods to reduce the risk of injury have also been introduced. The following chapter will further explore the literature surrounding manual handling in healthcare as identified through a scoping review.

2. SCOPING REVIEW

The previous chapter has introduced moving and handling within healthcare, WRMSD and the associated individual and wider workplace impact. Frequently performed patient handling and specific treatment approaches within physiotherapy has also been introduced. This chapter presents a scoping review on moving and handling of patients without the use of equipment in healthcare. Initially, the literature review methodology is discussed, and the approach taken in this thesis justified. Finally, the findings of this scoping review are presented and their implications discussed.

2.1 Introduction

Many studies and reviews have been conducted to investigate the epidemiology and prevalence of WRMSD (Campo et al. 2008; Darragh et al. 2009; Glover et al. 2005; Krishnan et al. 2021). These studies and reviews have identified the high prevalence of WRMSD in healthcare populations. Lifting equipment in healthcare and the potential reduction in WRMSD risk has also been comprehensively explored previously (Dennerlein et al. 2016; Li et al. 2004; Lipscomb et al. 2011). To investigate the impact of lifting aids, changes in compensation costs and injury rates within healthcare populations was investigated (Dennerlein et al. 2016; Li et al. 2004; Lipscomb et al. 2011). Additionally, research has investigated HCPs use and perceptions of equipment for transferring and rehabilitation of patients (Campo et al. 2013; Olkowski and Stolfi 2014; Schoenfisch et al. 2019). Lifting aid use for rehabilitation has been investigated through exploring patient outcomes and a survey of HCPs perceptions (Campo et al. 2013; Olkowski and Stolfi 2014; Schoenfisch et al. 2019). Lifting aids are a key component of SPHM programmes, with use of equipment encouraged to improve HCP safety at work (Hegewald et al. 2018; Mayeda-Letourneau 2014; Nelson and Baptiste 2004; Weinmeyer 2016). Motion analysis technologies have been used previously to investigate patient movement and mechanics during standing and transferring with lifting aids (Fray et al. 2018; Burnfield et al. 2013). Motion analysis methods have also been used to investigate handler movement and posture when moving and handling patients with lifting aids (Dutta et al. 2012; Marras et al. 2009; Owlia et al. 2020). Manual patient handling with equipment in healthcare has been investigated extensively. However, there is also a body of literature investigating manual patient handling undertaken without the use of assistive devices (Callison and Nussbaum 2012; Daynard et al. 2001; Doss et al. 2018).

As highlighted previously in Chapter 1, manual and therapeutic handling is often performed in physiotherapy to aid patient rehabilitation and is associated with an increased risk of WRMSD. However, to guide the research presented in Chapter 4, the body of literature surrounding manual patient handling in healthcare first needed to be reviewed. A preliminary search of MEDLINE, CINAHL, JBI Evidence Synthesis, Open Science Framework, Cochrane library and PROSPERO was conducted and no published or in-progress scoping or systematic reviews on the topic were identified.

2.2 Review Questions

The objective of this scoping review was to explore the literature surrounding manual patient handling in healthcare without the use of assistive devices. The specific review questions were:

1. What is the current evidence-base on moving and handling of patients by healthcare practitioners?

2. What primary research has been conducted on moving and handling of patients by healthcare practitioners?

a. What questions has the research addressed?

b. Which populations has the research been conducted on?

c. Which settings has the research been conducted in?

d. Which aspects of patient moving and handling have been explored?

e. Which outcome measures/techniques/technologies have been used?

2.3 Methodology

2.4.1 Literature Review Types

Literature reviews are found in all areas of research and aim to summarise and synthesise data and information (Snyder 2019). There has been an increase in literature reviews conducted in recent years due to the growing body of research and literature following a push for evidence-based practice (Bastian et al. 2010; Egger et al. 2022; Grant and Booth 2009). Literature reviews aim to gather, summarise, and map available literature to provide guidance for further research or reviews and identify gaps within the evidence base (Snyder 2019). If appropriate, the review may also critically appraise the literature and provide suggestions for future clinical guidelines and practice (Snyder 2019). There are many types of literature review; some of which are summarised in Table 2.1. The type of review chosen depends on the research question, volume of literature in the area, and the depth of analysis intended (Snyder 2019). Prior to conducting a literature review, the body of literature needs to be considered and the research team needs to ensure the review has not been conducted previously (Peters et al. 2020).

Narrative literature reviews allow for an overview and summary of literature on a particular topic. They can provide a broad overview of an area, identify gaps, and can suggest areas for further reviews or research (Aromataris and Pearson 2014). However, narrative reviews do not necessarily follow a clear methodology and may not include all potential literature due to the method of searching and selecting literature (Aromataris and Pearson 2014). The methods used to search and select literature for narrative reviews are not reproducible compared to systematic review methods (Franco et al. 2018). It is not required for narrative reviews to state inclusion or exclusion criteria, with literature often being hand-selected (Franco et al. 2018). Due to the nature of hand-selecting literature there is a risk of bias in narrative reviews (Franco et al. 2018; Kühberger et al. 2016). In healthcare settings, a more robust method of literature reviewing can provide more balanced and reliable information and allow for improvement in clinical practice and guidance (Aromataris and Pearson 2014).

Table 2.1: Summary of literature review types and key characteristics

Literature review type	Characteristics of review
Narrative/literature review	Can include broad selection of recent literature, can have more than one research question, methods of study selection may not be described, risk of bias with study selection (Ferrari 2015)
Systematic review	Question clearly defined, selection criteria clearly defined, studies critically appraised, literature findings synthesised (Ferrari 2015; Munn et al. 2018; Snyder 2019)
Integrative review	Aims to create theoretical frameworks and perspectives, includes both experimental and non-experimental research, collates different perspectives (Snyder 2019)
Semi-systematic review	Systematic methods used for literature searching with narrative summary of the literature (Snyder 2019)
Critical review	Critically evaluates quality of research, identifies and reviews most relevant research (Saunders and Rojon 2011)
Scoping review	Maps the range and nature of research, broad range included, all study types included (Munn et al. 2018; Sucharew et al. 2019)
Umbrella review	Summarises systematic review findings, compares systematic review findings (Booth et al. 2019; Aromataris and Pearson 2014)

One method of reviewing literature in a repeatable and robust manner is a systematic review. Systematic reviews have been conducted since the 1970s and are defined as the gold standard of literature reviews (Mulimani 2017; Munn et al. 2018). They are a robust and critical method of reviewing literature and are included within higher levels of evidence (Mulimani 2017). Systematic review methods are systematic and clear (Snyder 2019). The transparent and robust methods reduce bias and ensure the quality of literature searching and selection is to a high standard (Munn et al. 2018; Snyder 2019). In addition to the robust methodology, systematic reviews critically appraise the research and synthesise the findings. However, there needs to be an adequate number of studies and homogeneity to address the specific review question for inclusion in the systematic review (Munn et al. 2018). Additionally, if there is an adequate number of studies, the review can provide meaningful and useful results (Munn et al. 2018).

Scoping reviews can be conducted to provide a map, identify the scope and nature, and also any gaps within the evidence base (Munn et al. 2018). In addition, scoping reviews can be conducted as a precursor to systematic reviews to identify which specific areas contain sufficient literature to conduct a review (Munn et al. 2018). Scoping reviews have increased in popularity over recent years and are a valid method of reviewing the literature when indicated (Khalil et al. 2021; Munn et al. 2018; Pollock et al. 2021). Scoping reviews investigate a broad research area and include a wide range of study designs (Munn et al. 2018; Sucharew et al. 2019). The aim of a scoping review is to map the scope and volume of research on a topic, and provide summaries on the characteristics of that research (Munn et al. 2018; Sucharew et al. 2019). It is not the objective of scoping reviews to synthesise the findings from the literature or to assess the quality of the available literature (Khalil et al. 2021). As scoping reviews do not assess and synthesise findings, they are unable to inform practice or policy (Munn et al. 2018). Scoping reviews can however use transparent methods to identify gaps in the literature, provide guidance for further primary research and evidence synthesis, and can be completed relatively quickly (Arksey and Malley 2005; Munn et al. 2018; Pollock et al. 2021; Sucharew et al. 2019; Tricco et al. 2016).

An initial search of the literature was undertaken to inform the type of review that should be completed for this thesis. The area of research was manual patient handling in healthcare. This is a broad area encompassing many research questions, staffing populations, techniques of data collection and methods used. The key review characteristics outlined in Table 2.1 helped identify the review type that would best address the review objectives. A specific review question had not been identified, which excluded choosing a systematic review. Umbrella reviews require multiple systematic reviews to be conducted within the area. Few systematic reviews have been conducted in this area; therefore, an umbrella review was not chosen. Integrative reviews use a less rigorous methodology, and the aim of these reviews did not fit with the broad evidence base. Narrative reviews would allow a broad overview of the area. However, the methods are not robust or reproducible and there is a risk of bias. Due to the broad evidence base, lack of specific question and rigorous methodology, a scoping review was chosen for this thesis.

A scoping review allowed for mapping and identification of gaps within the evidence base. The scoping review then identified areas for future research and/or systematic reviews. Importantly, this scoping review informed the primary research phase of this programme of doctoral research.

This scoping review aimed to explore literature investigating manual patient handling by HCPs, map the available literature and identify gaps for future research. Further research in this area could allow for a more comprehensive understanding of manual patient handling in healthcare which could allow for the investigation of methods of reducing HCPs risk of WRMSD.

Manual patient handling in this scoping review was defined as any patient handling task that was completed without the use of a mechanical device or assistive aid, such as: assisting with transfers, moving patients for care tasks or dressing, and placing of slings or sheets under patients.

2.4.2 Scoping Review Methodology

This scoping review was conducted in accordance with JBI guidance for scoping reviews, followed an *a priori* registered open access protocol (Johnson et al. 2022) and is reported in accordance with PRISMA reporting guidance (Peters et al. 2020). The JBI methodology was chosen for this scoping review as it is widely used and provides comprehensive and robust guidance for researchers to follow (Khalil et al. 2021); the supervisory team were also experienced in conducting JBI scoping reviews. Recently, JBI published updated scoping review methodological guidance (Peters et al. 2020). These updates aim to improve clarity of when scoping reviews are indicated, methods of analysis, and data presentation and were used to guide this scoping review.

2.4 Inclusion Criteria

2.4.1 Participants

This scoping review considered literature that included or concerned qualified or unqualified HCPs engaging in manual patient handling tasks (e.g., nurses, AHPs and support workers within nursing and allied health). Legislation and policy vary, but in some countries (e.g., UK) qualified and unqualified staff (e.g., support workers) are required to undertake manual handling training and perform manual patient handling tasks. Therefore, qualified, and unqualified staff were included. If literature included healthcare students, or healthy volunteers performing patient handling, it was considered for inclusion where these populations formed less than 50% of the sample or where the results on staff were reported separately.

2.4.2 Concept

This scoping review considered literature that explored manual patient handling by HCPs within healthcare settings, or research on manual patient handling by HCPs conducted in laboratory settings. Literature was included if it involved HCPs manually assisting patients for tasks or transfers, or if it investigated guidelines or legislation for correct manual patient handling skills. Literature that solely focused on patient handling with mechanical devices such as hoists or stand aids was not included because this body of work has been extensively reviewed previously, as discussed above in Section 2.1. This scoping review focused on manual patient handling where the HCPs were involved with manual movement of patients for self-care, manually aided transfers or therapeutic handling, as these tasks cannot be completed with mechanical devices. Literature was excluded if it solely investigated epidemiology or prevalence of WRMSD within HCPs as this has also been extensively reported and was therefore considered out with the scope of this scoping review.

2.4.3 Context

This scoping review considered literature that focused on any healthcare setting where manual patient handling is performed. Literature that concerned HCPs performing patient handling out with a healthcare setting, such as a laboratory, was also considered where it could address the review objectives. Guidelines for moving and handling differ across geographical locations. This review was the first step in a programme of research on manual patient handling in the UK. Therefore, any of the 62 very highly developed nations, as defined at the time of the review, were included to ensure the findings would be relevant to the UK context. The very highly developed nations were defined by the Human Development Index (HDI) (United Nations Development Programme 2020).

2.4.4 Types of Sources

This scoping review considered: primary research of any type (e.g., quantitative, qualitative, mixed methods); literature reviews of any type (e.g., narrative, systematic, scoping); guidelines; narrative summaries (written summaries of research), text and opinion (e.g., editorials, opinion pieces); and educational resources for HCPs.

2.5 Methods

2.5.1 Search Strategy and Information Sources

The search strategy aimed to locate both published and unpublished literature. An initial limited search of AMED (EBSCOhost), CINAHL (EBSCOhost) and MEDLINE (PubMed) was undertaken using the keywords "(TX moving and handling OR TX manual handling)" AND "(MH nurse OR TX nurs* OR TX physiotherap* OR TX allied health*)" to identify articles on the topic. The text words contained in the titles and abstracts of relevant articles, and the index terms used to describe the articles which were identified in this search were used to develop a full search strategy. The search strategy, including all identified keywords and index terms, was adapted for each included information source and a second comprehensive search was undertaken on 12th August 2020, and updated on 10th November 2021. Literature published in English from 2002 to November 2021 was included, as the influential Manual Handling Operations regulations 1992 was amended in 2002 (HSE, 2016).

The databases that were searched were: AMED, CINAHL, MEDLINE, SPORTDiscus (all via EBSCOhost); EMBASE (via Ovid). Sources of unpublished and grey literature included: Google Scholar, EThOS, Open Grey, HSE, NIOSH, Safe Work Australia, Canadian Centre for Occupational Health and Safety, and Worksafe New Zealand. These databases and grey literature sites were chosen to allow for a broad and comprehensive search of the literature. The full search strategy including the search terms and returns from each database and grey literature site are provided in Appendix 1.

2.5.2 Source of Evidence Selection

Following the searches, all identified records were collated and uploaded into RefWorks ProQuest (Ex Libris, Jerusalem, Israel) before removing duplicates. The records were then exported into Covidence (v2477; Veritas Health Innovation, Melbourne, Australia), a bespoke systematic review software, and any remaining duplicates were removed. Titles and abstracts were initially screened independently by three reviewers (KJ, KC, AP) against the inclusion criteria for the scoping review. Excellent agreement (average 96%) was found after 39% title and abstract screening. As this scoping review formed part of a doctoral research programme, after establishing good agreement one reviewer (KJ) conducted the remainder of the title and abstract screening, with regular review and discussion with the review team. Three reviewers (KJ, KC, AP) independently conducted an initial full text screen on 30% of the records and an average of 70% agreement was found. Many of the conflicts were due to different reasons for exclusion used by each of the independent reviewers. Inclusion criteria regarding exclusion reasons and study types was clarified. One reviewer (KJ) then completed the remaining full-text screening with regular review and discussion with the review team. Full-text records that did not meet the inclusion criteria were excluded, and reasons for exclusion are provided in Appendix 2.

Double screening of the records is the recommended method for literature reviews as it reduces bias during screening (Waffenschmidt et al. 2019). However, recently published scoping reviews have used methods similar to those used in this scoping review, where a percentage of the records were double screened, and similarity assessed between the reviewers (Sheringham et al. 2021; Nowland et al. 2021). After agreement was found to be sufficient in these reviews, one reviewer then continued and completed screening with regular review and discussion with the review team (Sheringham et al. 2021; Nowland et al. 2021). Therefore, although deviating from recommended methodology, this can be considered a pragmatic solution to completing the review in a timely manner within the available resources.

2.5.3 Data Extraction

Following JBI methodological guidance, a charting table was created to record key information from the included records. The table was created using Microsoft Excel and the information extracted was presented in a table format. Data were initially extracted independently from 10% of the included articles by two reviewers (KJ, KC). Findings were discussed to assess similarity, and it was concluded the two reviewers were highly similar; therefore, one reviewer (KJ) completed the remaining data extraction, consulting the wider review team regularly. Similar to screening of the literature, double extraction is the recommended method in literature reviews to reduce bias and errors with data extraction (Büchter et al. 2020; Buscemi et al. 2006). However, scoping reviews have demonstrated methods similar to those used in this scoping review (Sheringham, Kuhn and Burt 2021; Nowland et al. 2021). A percentage of the data was extracted and assessed for similarity before one reviewer completed data extraction of all included studies. Therefore, similar to screening of the records, this methodology was considered a pragmatic solution for completing the review.

Eight authors of articles were contacted to request missing or additional data where required; at the time of writing no authors had responded. The data extracted included: authors, title, year, country of origin, aims/purpose, study type, setting, participant profession, participant age, participant gender, participant years of experience, sample size, patient population, outcome measure domain, and measurement tools.

2.5.4 Data Analysis and Presentation

Search results and included records are summarised in a PRISMA flow diagram (Page et al. 2021) in Figure 2.1. Summary data from all the included literature is presented in tabular form and displayed in Table 2.2. Previously reported research and populations investigated are grouped into umbrella terms and displayed in tables. Research questions, settings and outcome measures are displayed graphically. A narrative summary accompanies each of the displayed results. The findings are reported aligned to the two review questions. The first review question (what is the current evidence-base) includes all the literature (n

= 49), the second review question (what primary research has been conducted) includes the primary research only (n = 36).

2.6 Results

2.6.1 Study Inclusion

Initial screening of databases retrieved 8,638 records, with an additional 31 records identified from grey literature sources. Following removal of duplicates, 6,956 records remained for title and abstract screening. Of these, 430 records proceeded to full text screening. Forty-nine records met the inclusion criteria and were included in the review. The PRISMA flow diagram (Figure 2.1) illustrates the number of articles at each of these stages and distribution of reasons for exclusion. Due to the large number of studies included in this scoping review, only example references will be included in-text. Table 2.2 provides a detailed summary of all the characteristics of the included articles in this scoping review organised by study design.

2.6.2 Characteristics of Included Studies

This scoping review included 49 reports which consisted of one systematic review, 36 primary research and 12 other evidence types. Most of the reports were published between 2007-2016 for both research (n = 25) and other (n = 8) evidence types. Most reports originated from the US for both research (n = 8) and other evidence (n = 7) types.

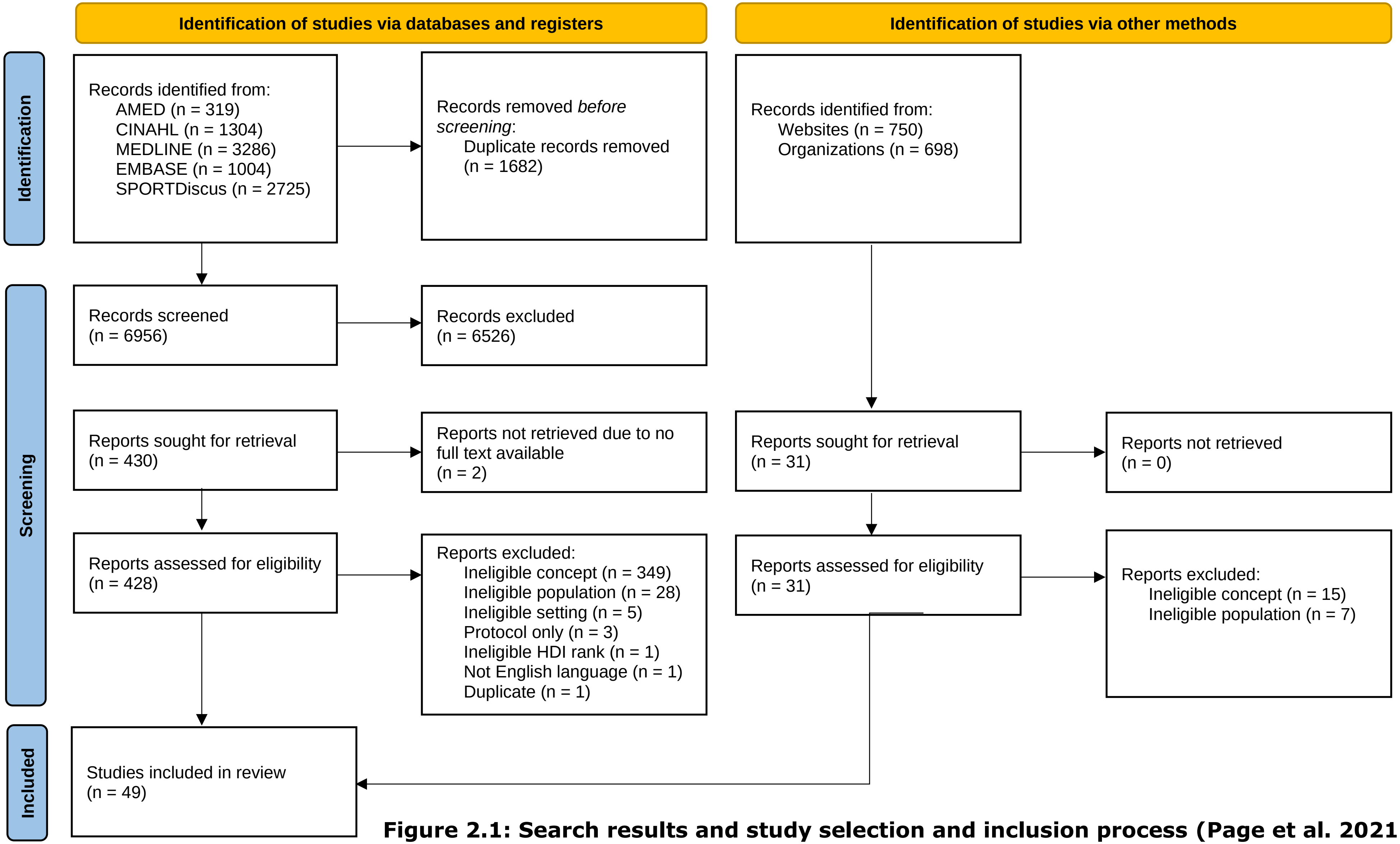


Figure 2.1: Search results and study selection and inclusion process (Page et al. 2021)

Table 2.2: Summary of literature included in scoping review

Author, Year, Country of origin	Aims/purpose	Study type	Setting	Participant profession	Participant age, gender, years of experience, description, and sample size	Patient population	Outcomes: Domain. Measurement tool
Systematic reviews							
Tullar, 2010, US	Do occupational safety and health interventions in health care settings have an effect on musculoskeletal health status?	Systematic review	NA	NA	NA, 19 studies included	NA	Effects of interventions in healthcare settings on musculoskeletal health. Evidence of quality appraisal and data extraction and synthesis
Observational							
Baptiste, 2011, US	To objectively determine the physical demands of patient	Observational cross-sectional	Laboratory	Caregiver	age NR, all male, years of experience NR, caregiver	3 mannequins	Peak force and total impulse. tri-axial load cells

	transfer tasks performed by nurses				represented by 1 male (approx. 6 feet tall and 200lbs), sample size 1	of 3 different weights	
Brusco, 2007, Australia	To develop and implement an allied health occupational health and safety package, based on a risk assessment model, which incorporated clinicians' clinical judgement to minimize manual handling risks, while maximising the therapeutic	Observational - cohort	Hospital	5 Physiotherapists, 5 Occupational therapists, manual handling coordinator, allied health assistant	age NR, gender NR, years of experience NR, description NA, sample size 200	All health/social care patients	Training completion, musculoskeletal injury incidence rate. Staff attendance rates, staff evaluation, incidence rate of injury

	benefits for the patient						
Cantarella, 2020, Italy	To validate the effectiveness of MAPO method (Movement and Assistance of Hospital Patient) after the introduction of some changes to improve assessment objectivity	Observational cohort, multi-centre study	Hospital	Health and safety professionals, caregivers	age <35 = 141, 35-44 = 593, 44-54 = 801, >55 = 463, gender majority female, years of experience 0-9 = 287, 10-19 = 697, 20-29 = 642, >30 = 372, sample size 1998 participants	Various inpatient	Incidence of back pain, risk exposure. BORG scale, staff training. MAPO risk assessment

Carneiro, 2015, Portugal	To identify the main risk factors of WRMSD for home care nurses and to perform an objective assessment of the risk for these professionals	Observational cross-sectional	Community	Home care nurses	age NR, gender NR, years of experience NR, description NA, sample size 5	Community	Risk of WRMSD. Video footage, photographs
Chen, 2014, US	How are nursing work activities distributed over a 12h day shift? And how does heart rate level differ across nursing work activities?	Observational cross-sectional	Hospital	Nurses	Age 43.4 (SD 8.8), gender NR, years of experience 10.6 (SD 6.1), sample size 8	Telemetry unit patients	Heart rate, nursing activities. Heart rate monitor, observation
Hodder, 2010a, Canada	To chronicle trunk posture and work tasks of long-term	Observational cross-sectional	Care home	Personal support workers	Age 46.7 (SD 8.6), gender all female, years of	Long term care residents	Trunk kinematics and tasks performed. Inclinometer and observation

	healthcare professionals				experience of all participants 19.5 (SD 9.3) and observed 13.3 (SD 8.6), description NA, sample size 27		
Hodder, 2010b, Canada	To quantify the postural changes that occur with Back Injury Prevention Programme (BIPP)	Observational cross-sectional	Laboratory	Nurses, untrained volunteers	Age 41.6 (SD 10.2), gender all female, years of experience 11.3 (SD 9.5), Completed BIPP training in last 2 years, sample size 12 untrained 10 nurses	Healthy volunteer patient (175cm 81kg, varying levels of passiveness, weight bearing and following verbal cues	Muscle activity, 3D thoracolumbar kinematics. EMG, lumbar motion monitor
Holmes, 2010, Canada	To evaluate peak and cumulative lumbar spine loads	Observational cross-sectional	Care home	Personal support workers	Age 47.2 (SD 9.4), gender all female, years of	Long term care patients	Trunk posture, activities completed by each personal support worker.

	experienced by personal support workers				experience 19.6 (SD 9.3), description NA, sample size 20		Observation, inclinometer
Howard, 2013, US	1. To compare the muscle activity of 5 muscle groups of the back, shoulder, and upper extremity between 4 bed-to-wheelchair transfer types. Comparisons are made across the transfer as a whole and between the common components of the transfers. 2. To compare the duration of the	Observational cross-sectional	Laboratory	1 Occupational therapist, 1 physiotherapist	Age 55 (SD1), gender all female, years of experience 19.5 (SD 13.5), description NA, sample size 2	Volunteer patients simulating varied levels of physical ability	Bilateral muscular effort, duration of task. EMG, video recording

	components (tasks) of each transfer type						
Hye-Knudsen, 2004, Denmark	To investigate the kinematics of the thoracolumbar spine during commonly used patient handling tasks	Observational cross-sectional	Laboratory	Health care workers	Age 43, gender all female, years of experience 19, description NA, sample size 10	Stroke patient, left sided paralysis	Kinematic data, muscle activity. Lumbar motion monitor, EMG, triaxial electro-goniometer
Jordan, 2011, Germany	To perform a detailed investigation on the load of the lumbar spine during manual patient handling	Observational cross-sectional	Laboratory	Health care workers	age NR, gender all female, years of experience NR, professionally experienced healthcare workers, sample size 2	Two healthcare workers alternating as simulated partially cooperating patient	Load at IVD L5-S1, considering for posture and action force data. OPTOTRAK

Kang, 2013, Republic of Korea	To investigate the effects of the application of postural taping on the kinematics of the lumbar spine, pelvis, and hips, EMG activity of the erector spinae, and RPE in the low back during patient transfer in physical therapists with chronic LBP	Observational cross-sectional	Laboratory	Physiotherapists	Age 30.68 (SD 4.23), gender all male, years of experience NR, chronic LBP, sample size 19	Healthy volunteer simulated patients	Peak angle and ROM of lumbo-pelvic-hip complex, muscle activity, RPE. VICON motion capture system, EMG, BORG scale
Kim, 2014, Republic of Korea	To analyse, through ergonomic analyses, those motions most used by radiological technologists that	Observational cross-sectional	Hospital	Radiological technologist	age NR, gender NR,>5 years of experience, description NA, sample size 7	NR	Working postures. Video footage, REBA, RULA, NIOSH lifting equation, Strain index

	cause musculoskeletal disorders						
Kjellberg, 2003, Sweden	To explore the work technique applied by nursing personnel in patient transfer tasks and to determine whether different personal factors were associated with work technique	Observational cross-sectional	Hospital	Nurses, enrolled nurses	Age 35 (SD 10), gender majority female, years of experience 11 (SD 8.7), mix of participants with and without low-back, neck, shoulder pain, sample size 102	Three healthy women simulated patients	Work technique score, personal factors. Video recordings, observation, questionnaire
Kurowski, 2014, US	To obtain a comprehensive analysis of the physical workload of clinical staff in	Observational cohort	Care home	Nurse, nursing assistants	age NR, gender majority female, years of experience	Nursing home residents	Average compressive forces on the spine, body postures, manual handling frequencies,

	long-term care facilities, before and after a safe resident handling programme (SRHP)				3.03-6.44, description NA, sample size 58-123		biomechanical index. Observation, physical workload index
Kyriakidis, 2021, Denmark	To investigate which organisational levels and factors determine the number of resident handlings in eldercare	Observational cross-sectional	Care home	Eldercare workers	Age day shift = 44.4 (SD 10.8), night shift = 47.3 (SD 11), gender majority female, years of experience 15.1 (SD 11.1), sample size 619	Nursing home residents	Factors affecting number of patient handling. Staff seniority level, personal factors, number of patient handling incidences per shift
Larouche, 2019a, Canada	To create an overall risk index that takes account of several aspects	Observational cross-sectional	Community	Paramedics	Age 35 (SD 10), gender majority male, years of experience 11	Community	3D angular movements of their back, lifting index, overall risk index. Camcorder,

	of risk, such as awkward postures recorded by a dosimeter, a lifting index, perceived exertion and duration of the task, and to compare the risk associated with patient transfers in total assistance mode observed in real work situations and assigned to three families of transfers				(SD 11), description NA, sample size 45		observation, posture dosimeter
Larouche, 2019b, Canada	To identify factors that may favour or inhibit the application of	Observational cross-sectional	Community	Paramedics	Age 31 (SD 9), gender majority male, years of	Community	Work activity analysis, difficulty of various tasks in the intervention, patient

	safe patient handling principles by paramedics performing full-body transfers of patients from a chair to a stretcher				experience 8 (SD 9), description NA, sample size 32		handling methods. Observation, video footage, semi-structured interview
Maekawa, 2009, Japan	To quantify the load on the lumbar region, predict the risk, prevent LBP, and use information in education, based on nursing techniques learned in nursing basic education and nursing modality carried out in	Observational cross-sectional	Laboratory	Nurses	Age 30s, gender all female, years of experience NR, description NA, sample size 2	Nursing staff volunteers	Twist angle of lumbar spine, muscle activity. Goniometer, EMG

	clinical experience						
Skotte, 2008, Denmark	To investigate the low back load during repositioning of patients in bed and to assess the influence of patient's weight and disability	Observational cross-sectional	Laboratory	Health care workers	Age 46 (SD 9), gender all female, years of experience 5-30 years, description NA, sample size 9	Volunteer patients, 1 paraplegic with the rest otherwise healthy volunteers simulating hemiplegia, paraplegia and near paralysis	Net torque, compression and shear forces at L4/5, ground reaction forces, reaction force of thighs on the bed. Digitized video, force platforms, force transducers
Skotte, 2002, Denmark	To investigate the low back-loading during common patient-handling tasks	Observational cross-sectional	Laboratory	Health care workers	Age 43 (SD 8.7), gender all female, years of experience 19 (range 6-26),	Stroke patient, male, 53 years old, 88kg, left	L4/L5 net moment, compression, shear forces, muscle activity, RPE, ground and bed reaction forces. EMG, Borg

					no special education of training on patient handling technique, sample size 10	sided weakness	scale, video recording, force platforms, force transducers
Stringer, 2014, US	To investigate the influence that experience in performing manual patient transfers has on the ability to rate the assistance level required during a patient transfer	Observational cross-sectional	Laboratory	Occupational therapist, physical therapist, occupational therapy students, physiotherapy students	Age 50.5 (range 40-56), gender majority female, years of experience 26.1 (range 15-32), description NA, sample size 23	Volunteer patients	Ground reaction forces of participant and patient, perceived level of assistance the patient required after each picot transfer. Force plates, Visual Analogue Scale (VAS)
Theis, 2014, US	To evaluate the effectiveness of a safe patient handling programme	Observational cohort	Hospital	Nurses, therapy staff	Age 62.7 (SD 16.4), gender equal split, years of experience NR,	Inpatient rehabilitation patients	Injury rates pre and post training. Assessment forms

	(STEPS) at an impatient rehabilitation unit in reducing injury due to patient transfers				description NA, sample size 55		
Vieira, 2009, Canada	To quantify physical demands of frequent nursing tasks and provide evidence-based recommendations to increase low back safety	Observational cross-sectional	Laboratory	Nurses	Age orthopaedic 35 (SD 7) Intensive care 34 (SD 9), gender all female, years of experience NR, description NA, sample size 36	Same nursing participants simulating patients	Lumbar ROM, motion during nursing tasks, L5/S1 compression and shear forces estimated, sufficient torso strength estimated. Electro-goniometer, perpendicular marker photogrammetry
Pilot studies							
Arias, 2017, US	To characterize the physical load of trunk flexion and physical	Pilot - undefined	Hospital	Nurses, patient care assistants	Age 42 (SD 13), gender majority female, years of experience	Thoracic intensive care, orthopaedic, burn and	Physical activity, trunk flexion. Accelerometer, tri-axial accelerometer

	activity of patient care unit workers				NA, description NA, sample size 50	trauma, cardiac and cardiac step-down patients	
Fiedler, 2012, Canada	To determine the feasibility of documenting all job-related nursing tasks performed during a typical shift in a hospital setting using video	Pilot - feasibility	Hospital	Nurses	Age 40.6 (SD 13.3), gender all female, years of experience 13.6 (SD 11.2), description NA, sample size 10	Intensive care unit, inpatient rehabilitation, complex continuing care unit, acute care unit, outpatient surgery, ambulatory care	Patient handling tasks. Camcorder, observation
Fragala, 2011, US	To quantify and objectively measure the risk reduction achieved with the	Pilot - undefined	Laboratory	Caregivers	age NR, gender NR, years of experience NR,	200lb mannequin	Total force, peak force, total work, slope of the force curve. Force transducer

	gravity assist feature				description NR, sample NR		
Garzillo, 2020, Italy	To propose an MPH training model involving interdisciplinary aspects	Pilot - undefined	Hospital	Healthcare workers	Age men 49.4 (SD 7.2) women 45.9 (SD 8.8), equal split of gender, years of experience 24.6 (SD 8.1), sample size 52	Various inpatient	Risk assessing tasks, staff training, effort required for tasks. Questionnaire, multidisciplinary training programme, BORG scale
Newton, 2020, Australia	To ascertain the incidence of Australian private practice sonographers moving patients unassisted and determine what training these sonographers have in order to	Pilot - undefined	Sonography clinics	Sonographers	age NR, gender NR, years of experience <5 = 24, 6-10 = 6, 11-20 = 4, >21 = 1, sample size 35	Outpatient	Incidences of manual assistance of patients, level of training. Survey

	appropriately perform these procedures						
Qualitative							
de Ruiter, 2011 US	To identify patient-handling practices in clinical practice	Qualitative	Hospital	Registered nurse, nursing assistant	Age <24=7, 24-36=13, 40-59=9, 60+=3, gender majority female, years of experience <1=3, 1-3=9, 4-10=10, 11-20=7, 21+=3, sample size 32	Neurology and rehabilitation patients	Patient handling practices and nurses' judgment of these practices, observation of caregivers and interviews
Osborne, 2021, Australia	To investigate emergency nurses' beliefs and experiences with patient handling in the	Qualitative - phenomenological	Hospital	Nurses	age NR, gender majority female, years of experience mean 3.9 years (range	Emergency department patients	Experiences of patient handling. Focus group interviews

	emergency department				1-27), sample size 40		
Wangbad, 2009, Sweden	To describe nurses aids' experiences of physical strain during person transfer tasks as dementia care units	Qualitative	Hospital	Nurses aids	Age 43 (range 26-64), gender all female, years of experience 15 (range 2-31), description NA, sample size 16	Dementia patients	Experiences, apprehensions, person transfer tasks. Focus groups
Survey							
McKoskey, 2007, US	To describe patient-handling demands in inpatient units during a 24-hour period at a military health care facility	Survey	Hospital	Nurses, licensed practical nurses, nursing assistants, and nursing students	Age 35 (SD 10.7), gender majority female, years of experience median 6 (range 0.5-38), description NA,	Military inpatients	Nature and impact of patient-handling tasks relative to a variety of nursing care units, patient characteristics, and transfer equipment. 24-hour population survey

					sample size 283		
Conference abstract							
Lavender, 2016, US	To measure the compression and shear loads on the spine that are experienced as slings are (1) placed under patients prior to lifting, and (2) removed at the completion of the transfer	Conference abstract - repeated measures study	Laboratory	Nurses	age NR, gender NR, years of experience NR, description NA, sample size 12	simulated patients, 54kg and 100kg	Muscle activity, lumbar spine compression, shear forces. EMG, digitized video
Nikolajsen, 2015, Denmark	To document and describe how manual patient handling may be carried out as	Conference abstract - Mixed methods	Various – nursing home, community and hospitals	Health care providers	age NR, gender NR, years of experience NR, description NA, sample size 56	Various	Manual patient handling activities. Field notes and observation.

	part of everyday practice						
Wade, 2017, UK	To investigate healthcare staff perceptions surrounding manual handling and patient handling related injuries	Conference abstract - ethnographic study	Community	Physiotherapists, occupational therapists	age NR, gender NR, years of experience NR, sample size 8 participants for observation, 6 for interviews	Community	Manual patient handling factors, challenges/benefits, perceptions of training. Observation, focus groups
Other literature							
Apple, 2021, US	To review published research and describe the ergonomic challenges of working in the operating room	Other, narrative review	NA	NA	all NA	Peri-operative patients	Ergonomic challenges, safety recommendations. Data from literature

Haney, 2003, US	To review various physical stressors as they relate to the capacity of the human body during handling (lifting, transferring, moving, and walking) of residents	Other, narrative review	NA	NA	all NA	NA	Force and repetition, dynamic lifting, posture, risk management, push/pull forces, philosophy of care. Data from literature
Hignett, 2007, UK	To review the implementation of EU Health and Safety Directive on Manual Handling (90/269/EEC) for patient handling in 9 European countries and gather expert opinion on the residual problems	Other, Narrative summary of government statistics and expert opinion from a panel of manual handling experts	NA	NA	all NA	All health/social care patients	Implementation of the EU manual handling directive, expert opinions. European National Government statistics, expert opinion.

	(barriers) to safer patient handling						
Johnstone, 2020, UK	To discuss WRMSD within Nursing focusing on legislation, regulations and risk-assessment	Other, narrative review	NA	NA	all NA	All health/social care patients	WRMSD in nursing related to moving and handling. Information from legislation and guidance materials
Rinds, 2008, UK	To consider the importance of safe manual handling, risk assessment, the law and useful equipment designed to aid the care worker	Other, Narrative summary of law and guidance in manual handling in healthcare	NA	NA	all NA	All health/social care patients	Safety during manual patient handling. Information and evidence from laws and guidance.
Tofts, 2012, UK	To explain the legislation related to moving and handling, with	Other, Narrative summary of legislation surrounding	NA	NA	all NA	All community patients	Legislation surrounding moving and handling. Information from

	particular application to community nurses	moving and handling in the community					health and safety publications
Vatwani, 2017, US	To provide practical information and instruction for caregivers assisting individuals experiencing difficulty performing bed mobility tasks	Other, Educational short article	NA	NA	all NA	All health/social care patients	Educational resources.
Waters, 2007, US	To describe high-risk patient handling tasks performed frequently in critical care units, delineate the physical demands	Other, Ergonomic task force identified tasks with high risk for musculoskeletal disorders	Hospital	Nurses, nurse managers	all NR	NR	Critical care tasks that are high force, awkward posture, repetitive loading. Observation.

	associated with each task, identify technologic solutions, and outline useful tips for making each task safer						
Waters, 2011, US	To determine the best practices for safe lateral patient transfers	Other, Ergonomic tool for positioning	NA	NA	all NA	All health/social care patients	Ergonomic tool development. Risk assessment tools.
Waters, 2011, US	To determine the best practices for safe positioning and repositioning of the supine patient	Other, Ergonomic tool for positioning	NA	NA	all NA	All health/social care patients	Safety during supine patient handling. Risk assessment tools.
Weiner, 2015, Israel	To present current research about the risk factors, prevention	Other, Narrative summary	NA	NA	all NA	All health/social care patients	Association between WRMSD and repositioning patients in bed, risk factors for WRMSD during patient

	strategies, and assistive devices that could reduce work-related musculoskeletal disorders caused by repositioning patients in bed						repositioning in bed. Published literature and data.
Weinmeyer, 2016, US	Laws and programmes to address the problem of nursing-specific musculoskeletal injuries.	Other, Narrative summary of laws and programmes for safe patient handling for health care workers	NA	NA	all NA	All health/social care patients	Working conditions leading to injuries, patient handling related injuries, barriers to safe patient handling. Published laws and programmes.

Key – MAPO –Movement and Assistance of hospital Patient; BIPP – Back Injury Prevention Programme; EMG - Electromyography; PSW – Personal Support Worker; IVD – intervertebral disc; LBP – low back pain; REBA – Rapid Entire Body Assessment; RULA – Rapid Upper Limb Assessment; SRHP – Safe Resident Handling Programme; VAS – Visual Analogue Scale; ED – Emergency Department; OR – Operating Room.

2.6.3 Secondary Research Characteristics

One systematic review was included in this scoping review which was published in 2010 in the United States (Tullar et al. 2010). Nineteen articles were included in the systematic review, which aimed to investigate the effect of health and safety interventions on WRMSD and to evaluate the effectiveness of interventions. Articles included in that systematic review were not included in this scoping review as 12 were published before 2002 and four focused on the use of equipment, with the remaining three investigating injury rates in relation to training programmes.

2.6.4 Primary Research Characteristics

Most of the literature included in this scoping review comprised primary research studies (n = 36; 73%), with observational designs the most common type (n = 24; 65%). The characteristics of the primary research included in this scoping review are summarised in Table 2.3. Most primary research originated from the US (n = 12; 39%), followed by Canada (n = 7; 23%). There was a large range in sample size (n = 1 to n = 1998) with a median sample size of 23 and interquartile range of 9 – 41.5 participants. The large range in sample size could be due to the different types of study included in this scoping review. The largest sample size is from an observational study completed over three years (Cantarella et al. 2020). The smallest sample is from a laboratory based kinetic study (Baptiste 2011).

2.6.5 Narrative, Text, and Opinion Characteristics

Other evidence types (n = 12; 27%) included in this scoping review consisted of narrative summaries of statistics or legislation (n = 8; 67%), ergonomic assessment tools (n = 2; 5%) (Waters et al. 2011; Waters et al. 2011), a healthcare task force (n = 1; 2%) (Waters and Thomas 2007), and an educational short article (n = 1; 2%) (Vatwani 2017). The characteristics of the other literature types included in this scoping review is summarised in Table 2.4.

Table 2.3: Characteristics of primary and secondary research included in scoping review (n = 37)

Type of study included	
Observational cross-sectional	20 (54%)
Observational cohort	4 (11%)
Pilot – undefined	4 (11%)
Qualitative	4 (11%)
Pilot – feasibility	1 (3%)
Survey	1 (3%)
Systematic review	1 (3%)
Experimental – repeated measures	1 (3%)
Mixed methods	1 (3%)
Sample size	
<10	10 (26%)
10-19	9 (24%)
20-29	2 (5%)
30-39	4 (11%)
40-49	4 (11%)
>50	9 (24%)
Range	1-1998
Median	23
Interquartile range	41.5
Systematic review (no. of included studies)	19

Year of publication	
2017-2021	9 (24%)
2012-2016	11 (30%)
2007-2011	14 (38%)
2002-2006	3 (8%)
Country of origin	
United States	12 (32%)
Canada	7 (19%)
Denmark	5 (14%)
Australia	3 (8%)
Sweden	2 (5%)
Republic of Korea	2 (5%)
Italy	2 (5%)
Portugal	1 (3%)
Japan	1 (3%)
Germany	1 (3%)
United Kingdom	1 (3%)

The narrative summaries described current legislation, directives, or research on manual patient handling. These also provided summary information concerning the risk involved with certain patient handling tasks and potential methods of reducing risk of injury. Previously published research, legislation, and government statistics on number of hospital beds, nurses, and health and social care staff were used to provide information for the narratives. Legislation in moving and handling in health and social care was last updated in 2002 (*L23*

Manual Handling: Manual Handling Operations Regulations 1992 (Fourth edition) 2016). Three of the narratives were published in the UK in 2008 and 2012 and provide summaries of the legislation surrounding moving and handling (Apple and Letvak 2021; Rinds 2008; Tofts and Arnold 2012). They also detail the importance of frequent and accurate risk assessments.

Table 2.4: Characteristics of other literature included in scoping review (n = 12)

Type of literature included	
Narrative summaries of legislation or statistics	8 (67%)
Ergonomic tool for transferring and positioning patients in the operating theatre	2 (17%)
Task force identifying high risk tasks	1 (8%)
Educational short article	1 (8%)
Year of publication	
2017-2021	3 (25%)
2012-2016	3 (25%)
2007-2011	5 (42%)
2002-2006	1 (8%)
Country of origin	
United States	7 (58%)
United Kingdom	4 (33%)
Israel	1 (8%)

One narrative review summarised legislation in the US in 2016 (Weinmeyer 2016). Reviewing the implementation of a healthcare directive and expert opinion was reported in 2007 (Hignett et al. 2007). Expert opinion was also used within an ergonomic task force identifying and discussing high risk tasks within a critical care setting (Waters et al. 2007). The development of ergonomic tools to aid moving and repositioning of patients in the operating theatre was reported in two ergonomic assessment tools (Waters et al. 2011; Waters et al. 2011). The objective of these tools was to provide clear steps to ensure correct staffing numbers and ergonomics, accounting for certain patient factors.

There is therefore a body of narrative, opinion and text concerning various aspects of manual patient handling, with reference to legislation in the UK and US only. The “other” evidence provides educational materials and guidance for improving manual patient handling in various settings including the community and operating theatres.

2.6.6 Primary Research

The following sections (Sections 2.6.7 - 2.6.11) of the scoping review are focused on the included primary research studies (n = 36) to address the review questions 2a – 2e (Page 15).

2.6.7 Questions Addressed

The aims and objectives of the primary research studies included in the review (n = 36) were reviewed and seven core research topics identified by the author. Some studies included multiple topics. The topics included 1) Physical demands during manual patient handling; 2) Patient handling practices and tasks performed; 3) Improving safety of patient handling; 4) Risk assessment of patient handling tasks; 5) Investigation of kinetics (loading) experienced by the HCP; 6) Investigation of kinematics (joint motion); and 7) Personal factors affecting patient handling. The full table of each topic and the included research are summarised in Appendix 3.

Studies that investigated physical demands during manual patient handling (n = 13) investigated or identified physically demanding tasks. Two studies aimed to provide suggestions for reducing physical demand for HCPs (Baptiste 2011; Wångblad et al. 2009).

Patient handling practices and tasks performed (n = 13) explored and documented all the patient handling tasks performed during HCPs shifts. Improving safety of patient handling (n = 7) was investigated through reducing

WRMSD and risks to HCPs through staff training programmes, identifying high-risk patient handling tasks and recommendations to reduce risk of injury. Risk assessment of patient handling tasks (n = 8) investigated and assessed working postures with ergonomic assessment tools and predicted risks involved with manual patient handling.

Kinetics (loading) experienced by the HCP (n = 7) investigated spinal kinetics (e.g., compression, shear) during manual patient handling. Kinematics (joint motion) (n = 7) investigated movement or posture of HCPs during manual patient handling. The most investigated region of the body was the spine (e.g., flexion, range of motion).

Personal factors affecting patient handling (n = 9) investigated the impact of both HCPs and patient factors. These factors included measurement of forces during handling with consideration for patient weight or disability (Skotte and Fallentin 2008), and HCPs rating their perceived exertion or level of assistance required during patient handling (Kang et al. 2013; Stringer and Rice 2014). Interviews were conducted to investigate perceived difficulty of patient handling tasks and focus groups investigated physical strain, the effect of dementia on patient handling and methods adopted to reduce physical strain (Larouche et al. 2019; Wångblad et al. 2009).

2.6.8 Populations

The summary of populations included in the review is displayed in Table 2.5. Nursing staff comprised the largest population included in the primary studies (n = 13; 43%). Many studies investigated both qualified and unqualified staff (n = 9; 30%). In addition, there was substantial heterogeneity in terminology for each staff population, which was challenging to separate into staff groups for data extraction. Terms used to describe unqualified staff included: nursing assistant; personal support workers; health care workers; patient care assistant; caregivers; and nurses aids. The other staff populations included in the studies were physiotherapists, occupational therapists, paramedics, radiological technologists, and manual handling coordinators.

The age of the participants ranged from <24 to over 61 years old. Most of the studies included 31–50-year-olds (n = 19, 63%). Female HCPs formed most of the included participants, with 12 (40%) studies investigating an all-female population. Healthcare practitioners mean years’ experience was reported in 18 studies and ranged from less than 1 year to over 20 years. Staff with over 10 years of experience comprised 21 studies (73%) that reported this variable.

The most common patient population included within the primary research was volunteer simulated patients (n = 12; 40%), followed by various inpatient populations (n = 11; 30%). Care home, community, outpatient, mannequins, and unspecified patient populations were also included in the primary research.

2.6.9 Settings

The two most common settings were laboratories (n = 13; 36%) and hospitals (n = 13; 36%). Other settings included in the research were care homes (n = 4), community (n = 4), sonography clinics (n = 1) and a combination of nursing home, community and hospitals (n = 1).

Studies that investigated kinematics and kinetics of manual patient handling tasks were performed most frequently in laboratory (n = 9) settings, followed by care homes (n = 2), hospitals (n = 2) and community settings (n = 1). Studies that observed and documented manual patient handling tasks were conducted in hospital (n = 7), care home (n = 4), community (n = 1) and a combination of all three settings (n = 1). Risk assessments and risk reduction were investigated in hospital (n = 2), laboratory (n = 2) and community settings (n = 3). Personal factors were investigated in the laboratory (n = 3), hospital (n = 2) and community settings (n = 1).

Table 2.5: Healthcare population groups, age, gender, years of experience and patient populations included in research, reported as n (%) studies (n=36)

Populations		Demographics of HCP participants	
Nursing		**Age range**	
Registered nurses	14 (38%)	<20-30	1 (3%)
Healthcare workers	13 (35%)	31-40	9 (24%)
Nursing assistants	4 (11%)	41-50	14 (38%)
Allied Health		51-60	4 (11%)
Physiotherapists	5 (14%)	>61	2 (5%)
Occupational therapists	4 (11%)	**Gender**	
Paramedics	2 (5%)	All female	2 (5%)
Allied health assistants	1 (3%)	Majority female	15 (41%)
Therapy staff	1 (3%)	All male	2 (5%)
Radiological technologists	1 (3%)	Majority male	6 (16%)
Other		Equal split	2 (5%)
Manual handling coordinators	1 (3%)	**Years of experience**	
Health and safety professional	1 (3%)	<1	1 (3%)
Patient population		2-5	6 (16%)
Simulated by volunteers	12 (32%)	6-10	7 (19%)
Inpatient	11 (30%)	11-15	12 (32%)
Care home	4 (11%)	16-20	9 (24%)
Community	4 (11%)	>20	7 (19%)
Mannequins	2 (5%)		
Unspecified	2 (5%)		
Outpatient	1 (3%)		

2.6.10 Aspects of Manual Patient Handling

For each of the seven research topics identified and discussed in Section 2.6.7, specific aspects of moving and handling under investigation were identified. These aspects are illustrated in Figure 2.2, and each aspect and the associated primary research is described below. The aspects of the primary research with the associated included studies are summarised in Appendix 3.

Physical Demands

Aspects within physical demands included: physical activity and trunk flexion (Arias et al. 2017); tasks which cause fatigue/strain to the HCP (Baptiste 2011; Wångblad et al. 2009); potential solutions for physically demanding tasks (Baptiste 2011; Wångblad et al. 2009); muscular effort (Howard et al. 2013); the impact of taping on muscular effort (Kang et al. 2013); perceived exertion (Cantarella et al. 2020; Garzillo et al. 2020; Larouche et al. 2019; McCoskey 2007); level of assistance (Garzillo et al. 2020; Stringer and Rice 2014); heart rate (Chen et al. 2014); physical workload index (Kurowski et al. 2014); and estimation of loading dependent on torso strength (Vieira and Kumar 2009).

Patient Handling Practices

Studies in the patient handling practice topic mostly focused on exploring and documenting which patient handling tasks were performed by HCPs during their shifts. In addition to task documentation, the following aspects were also explored: the time taken to perform the task (de Ruiter and Liaschenko 2011; Fiedler et al. 2012; Kim and Roh 2014; McCoskey 2007); staff position (Chen et al. 2014; Kim and Roh 2014); number of staff used (Hodder et al. 2010; McCoskey 2007); use of written information and its impact on handling (such as care plans or policies) (de Ruiter and Liaschenko 2011); patient factors such as weight (Hodder et al. 2010; McCoskey 2007); ergonomic assessment of tasks (Kim and Roh 2014; Kurowski et al. 2014); and work technique assessment (Kjellberg et al. 2003).

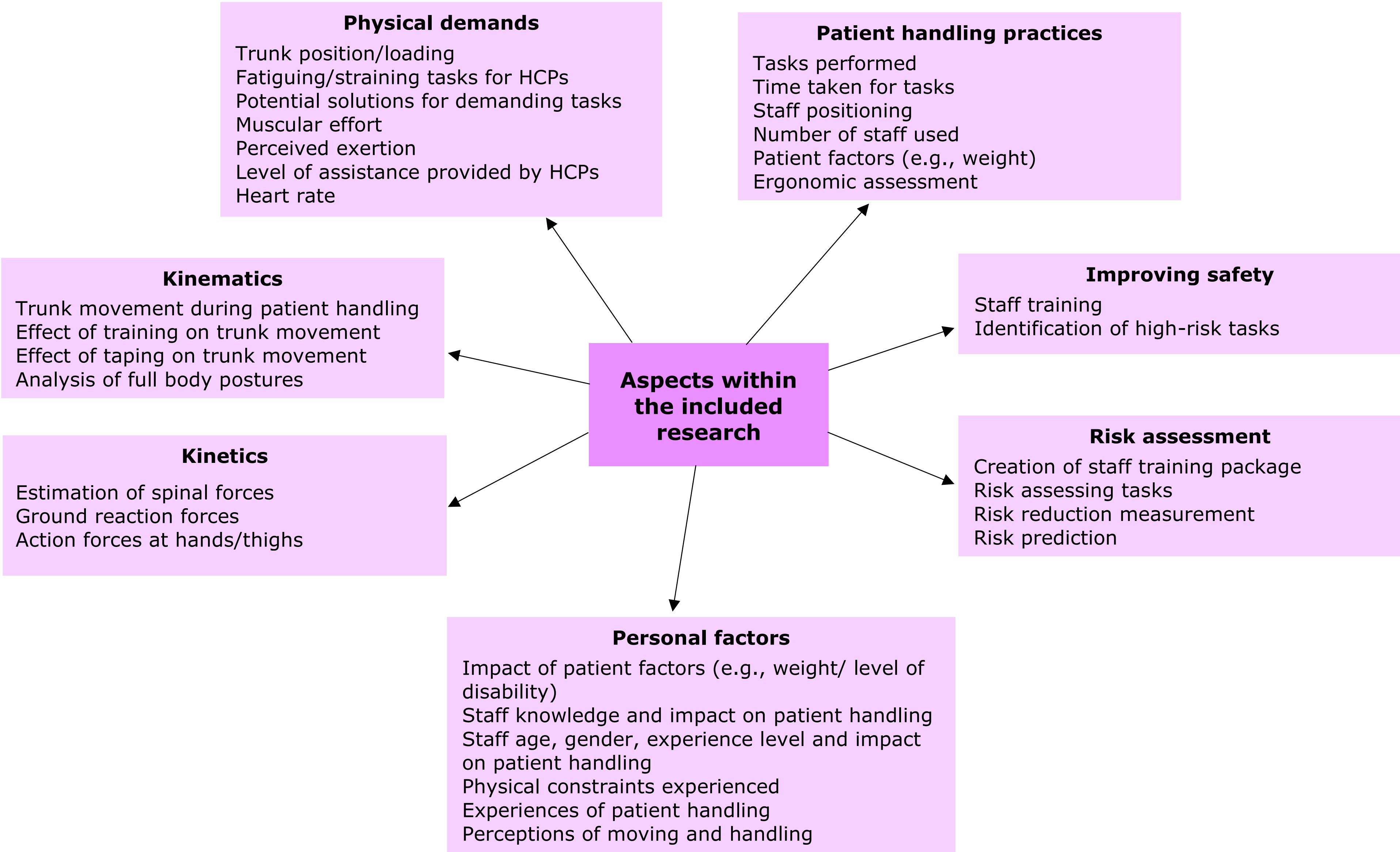


Figure 2.2: Aspects of manual patient handling investigated by the included primary research studies

Improving Safety

The aspects investigated within improving safety of patient handling were staff training (Brusco et al. 2007; Garzillo et al. 2020; Hodder et al. 2010; Theis and Finkelstein 2014), angle of the patient's bed (Kurowski et al. 2014) and identification of high-risk tasks to the HCP (Vieira and Kumar 2009). Risk assessments were used to: create a staff training package that maximises therapeutic benefit while minimising risk (Brusco et al. 2007); analyse the risk of tasks (Cantarella et al. 2020; Carneiro et al. 2015; Kim and Roh 2014; Larouche et al. 2019a; Larouche et al. 2019b); measure risk reduction (Fragala 2011); observe application of safety principles by paramedics (Larouche et al. 2019b); and predict the risk while transferring a patient from bed to wheelchair (Maekawa et al. 2009).

Kinetic (loading) Analyses

A common aspect investigated within kinetic analyses included estimation of forces experienced within the HCPs spine during manual patient handling (Baptiste 2011; Holmes et al. 2010; Jordan et al. 2011; Lavender et al. 2016; Maekawa et al. 2009; Skotte and Fallentin 2008; Skotte et al. 2002). Other aspects investigated were ground reaction force (Jordan et al. 2011; Skotte and Fallentin 2008); forces between the handler's thighs and the side of the bed (Jordan et al. 2011); and action forces at the hands (Jordan et al. 2011).

Kinematic (movement) Analyses

The main aspect investigated within kinematic analyses included trunk movement of HCPs during manual patient handling, specifically: describing trunk movement during patient handling tasks (Arias et al. 2017; Hodder et al. 2010; Hye-Knudsen et al. 2004; Larouche et al. 2019); the effect of training on the range of motion of the trunk (Hodder et al. 2010); and whether taping affects spinal movement (Kang et al. 2013). One study investigated full body postures of radiographic technologists (Kim and Roh 2014).

Personal Factors

Aspects within physical and personal factors included the impact of patient weight on spinal loading (Skotte and Fallentin 2008); patient disability and the load or physical strain experienced (Skotte and Fallentin 2008; Wångblad et al. 2009); staff knowledge of patient conditions and its impact on patient handling (Osborne et al. 2021; Wångblad et al. 2009); HCP age, gender, injury/pain, or experience level and its effect on patient handling practices (Cantarella et al. 2020; Kang et al. 2013; Kjellberg et al. 2003; Stringer and Rice 2014); communication with patients to assist with patient handling (Larouche et al. 2019b); physical constraints faced by paramedics while out with hospital settings (Larouche et al. 2019a); and perceptions of moving and handling (de Ruiter and Liaschenko 2011; Garzillo et al. 2020; Wade et al. 2017).

2.6.11 Outcome Measures

The outcome measures considered were measurement domains and measurement tools. The outcome measures found in the literature included in this scoping review are displayed in Figure 2.3. Appendix 4 summarises each outcome measure and the relevant included primary research studies. The domains were grouped into seven areas by the author based on the methods used to collect data. The domains included: *kinematics* (n = 12); *physical demands* (n = 12); *tasks performed* (n = 12); *kinetics* (n = 9); *staff perceptions/opinions* (n = 7); *safety* (n = 9); and *WRMSD* (n = 3).

As some of the research investigated multiple outcome measures, the total outcomes presented equals more than the number of included studies in the review (n = 36).

Kinematics (movement)

Kinematics showed the most variation in measurement tools used. The most frequent measurement tool used within kinematics was video. Standard video cameras were used for single plane analyses of movement (Kim and Roh 2014;

Kjellberg et al. 2003; Vieira and Kumar 2009), whereas opto-electronic cameras used alongside markers attached to the body were used for 3D analyses of motion with lab-based systems such as Vicon (Kang et al. 2013; Skotte and Fallentin 2008; Skotte et al. 2002) and OPTOTRAK (Jordan et al. 2011). Three-dimensional motional analysis studies mostly used volunteer patients (i.e., healthy adults) with a volunteer stroke patient used in one investigation (Hye-Knudsen et al. 2004). Within care homes, hospitals, and community settings, kinematics was investigated using inclinometers (Hodder et al 2010; Holmes et al 2010), accelerometers (Arias et al 2017), and posture dosimeters (two inertial sensors connected with a potentiometer) (Larouche et al 2019a) with real patients.

Physical Demands

Physical demands were mostly investigated using EMG to measure muscle activity during manual patient handling in laboratory settings (Hodder et al. 2010; Howard et al. 2013; Hye-Knudsen et al. 2004; Kang et al. 2013; Maekawa et al. 2009; Skotte et al. 2002). The erector spinae muscle group was investigated in all studies that used EMG. In hospital, care home and community settings, physical demands were measured by rating of perceived exertion scales, lifting indices, heart rate monitors or accelerometers (Arias et al. 2017; Chen et al. 2014; Larouche et al. 2019a; McCoskey 2007; Wångblad et al. 2009).

Tasks Performed

Visual observation was the most common measurement tool used to document patient handling tasks (Cantarella et al. 2020; Chen et al. 2014; de Ruiter and Liaschenko, 2011; Fiedler et al. 2012; Hodder et al. 2010; Holmes et al. 2010; Kyriakidis et al. 2021; Larouche et al. 2019a; Nikolajsen and Nielsen 2015). Observation was completed by researchers shadowing HCPs during their shift and noting tasks in real time or by photographing or video recording HCPs and retrospectively documenting the tasks performed. Observations were completed in hospitals, care homes or in the case of paramedics, in the field, and consisted of listing the tasks performed and length of time taken to perform them.

Figure 2.3: Outcome measures from the primary research (n = 36) separated into domain (inner ring) and measurement tool (outer ring) (size of sections based on relative count for each measurement tool).

Key: LMM – Lumbar motion monitor; Posture D – Posture dosimeter; TG – Tri=axial goniometer; TA – Tri-axial accelerometer; PWI – Physical workload index; TLC – Tri-axial load cells; Erg Ax – Ergonomic assessment; 24-h – 24-h Survey.

Kinetics (loading)

Digitized video recording was the most common measurement tool within kinetics (Jordan et al. 2011; Skotte and Fallentin 2008; Skotte et al. 2002; Vieira and Kumar 2009). These video systems were used in combination with another measurement system to allow for estimation of forces experienced by HCPs using 3D biomechanical models. The other systems used were: force transducers (Fragala 2011; Skotte et al. 2002; Skotte and Fallentin 2008) and force platforms (Skotte et al. 2002; Skotte and Fallentin 2008; Stringer and Rice 2014) to investigate ground reaction forces, and loading experienced by the HCPs.

Staff Perceptions or Opinions

Staff perceptions and opinions regarding manual patient handling were investigated using interviews (de Ruiter and Liaschenko 2011; Larouche et al. 2019b), focus groups (Osborne et al. 2021; Wade et al. 2017; Wångblad et al. 2009), and questionnaires (Kjellberg et al. 2003; McCoskey 2007). These measurement tools investigated HCPs experiences with patient handling and opinions surrounding patient handling practices, impact of patient disability levels and communication during patient handling.

Safety during Manual Patient Handling

Measurement tools used to investigate safety during manual patient handling included video (Carneiro et al. 2015; Kjellberg et al. 2003), observation (Cantarella et al. 2020; Kjellberg et al. 2003; Larouche et al. 2019b; Wade et al. 2017), photographs (Carneiro et al. 2015) staff training attendance (Brusco et al. 2007) and surveys (Newton et al. 2020). These tools were used to measure and assess risk during patient handling tasks or to implement a training programme aiming to reduce the risk to HCPs during patient handling tasks.

WRMSD

Incidence rates and risk factors of WRMSD were used to investigate the impact of staff training on injury rates (Brusco et al. 2007; Theis and Finkelstein 2014) and identify high risk tasks (Carneiro et al. 2015).

2.7 Discussion

In this scoping review, the literature on manual patient handling in healthcare was identified and examined, providing a comprehensive map. This scoping review included literature related to, and research that investigated, manual patient handling without the use of assistive devices or equipment. This allowed for a focus on manual patient handling tasks that require manual assistance from HCPs or involve therapeutic handling. The primary research included a large range of investigations on patient handling techniques and safety, using a variety of outcome measurement tools.

2.7.1 Research

This scoping review included 49 results, of which only one was a systematic review published in 2010. A wide range of research questions, and outcome measures were found in this scoping review. A lack of homogeneity in the area could make identification of specific review questions challenging. However, there may be adequate evidence to conduct a future systematic review on HCPs movement during manual patient handling tasks. The aim of this review was to map the evidence base surrounding manual patient handling to guide the primary research reported in Chapter 4. A scoping review was conducted as it could provide a broader investigation into manual patient handling in healthcare than a systematic review could provide.

There has been a shift towards using evidence-based practices and treatments within medicine and healthcare professions (Burns et al. 2011). Therefore evidence-based practice, combined with the rate of publications, makes it essential for up-to-date syntheses to inform practice. However, as found in this scoping review the evidence base in this area is relatively small and the outcomes are highly disparate.

The most common study design was observational cross-sectional, which allows for practical investigations of manual patient handling practices. Observational studies are relatively quick and inexpensive to complete and allow for investigation of multiple outcomes (Mann 2003). However, these study types are limited in terms of drawing conclusions on cause and/or effect (Mann 2003), suggesting the need for further well-designed research on therapeutic handling and handler movement and forces experienced during manual patient handling. To effectively investigate cause and effect, a longitudinal study would be recommended (Ployhart and Vandenberg 2010). However, longitudinal studies can be expensive to conduct and there is potential for participant drop out (Ployhart and Vandenberg 2010; Wang et al. 2017; Plano Clark et al. 2015). Physiotherapists often rotate through clinical areas which could also affect dropout rates.

The evidence base regarding AHPs, especially physiotherapists, in comparison to nurses is small. Nursing forms the largest occupational group within healthcare globally (Corazza et al. 2009) and therefore it is not surprising that a high rate of WRMSD is found within the profession (Serranheira et al. 2015), and likewise that research has been conducted in this population. However, physiotherapists perform many of the same manual patient handling tasks as nurses (Anderson and Oakman 2016), in addition to therapeutic handling for rehabilitation purposes. Therapeutic handling can be manually intensive but there has been little research to explore how these tasks are performed, how manually intensive they are, and the risks associated with performing them regularly. This scoping review identified two reports that discussed therapeutic handling (Brusco et al. 2007; Wade et al. 2017). Manual handling training and guidance does not appear to include therapeutic patient handling (personal communication with local NHS manual handling facilitator), with the focus being on safe methods of placing and removing slings for hoisting and assisting patients from sitting to standing.

Within the five included reports that included physiotherapists (Brusco et al. 2007; Howard et al. 2013; Kang et al. 2013; Stringer and Rice 2014; Wade et al. 2017), three investigated patient transfers (Howard et al. 2013; Kang et al. 2013; Stringer and Rice 2014) with only one each investigating perceptions surrounding patient handling and injuries related to patient handling (Wade et al. 2017) and therapeutic handling (Brusco et al. 2007). Brusco et al. (2007) developed a training package for allied health staff to minimise patient handling risk while maintaining therapeutic benefits for patients. The training package included recommendations for clinicians depending on the level of assistance required by the patient. Fifteen tasks were considered in the training package, including transfers, repositioning in bed, and stairs. The training package was implemented with the clinicians, and an improvement in knowledge surrounding safe patient handling was demonstrated. Additionally, reduction in incidence of WRMSD was observed. However, the effect on WRMSD needs to be investigated over a longer time period.

Howard et al. (2013) investigated two healthcare providers (physiotherapist aide and occupational therapist) while performing four methods of transferring a simulated patient from a bed to a wheelchair. The transfers included: 1. Ceiling lift with hoist; 2. Manual with no equipment; 3. Manual scoot with a sheet; and 4. Modified scoot. Within each transfer method individual tasks, such as placing the sling or rolling the patient, were identified and included in the analysis. The time taken to perform the transfer and the muscle activity at the back, shoulders and upper limbs were measured during each of the four transfers. The hoist was found to take nearly four times longer than the manual transfer, due to attaching the sling and lifting/lowering of the patient. However, the ceiling lift demonstrated the lowest mean EMG of all transfer methods. Further investigation with a larger sample size and with real patients is needed to further investigate muscle activity during patient handling.

Kang et al. (2013) investigated physiotherapists’ lumbar movement, muscle activity and perceived exertion with and without postural tape during a patient transfer from wheelchair to chair. Nineteen physiotherapists with chronic back pain performed the manual transfer with a simulated patient. Lumbar flexion, erector spinae activity and perceived exertion were reduced following application of tape. However, the physiotherapist in Kang et al's. (2013) research performs the patient transfer by standing in front of the patient, with straight legs and bending forward at the trunk. This posture differs to the safe handling principles taught in the NHS which encourages bending your knees and avoiding trunk flexion (Graveling et al. 2003; HSE 2021; NHS 2021).

Stringer and Rice (2014) investigated ground reaction forces during patient transfers and if the handlers experience influenced the accuracy of grading the level of assistance required to complete the transfer. Nine experienced occupational therapists and physiotherapists and 14 occupational therapy and physiotherapy students performed 12 pivot transfers with a simulated patient. The experienced therapists demonstrated reduced ground reaction forces to the student cohort. Additionally, the rating of effort during the transfer could be predicted by the ground reaction force. Further research into experienced handlers and how they reduce their ground reaction forces could allow for identification of potential methods to reduce loading placed on the handler.

Wade et al. (2017) investigated physiotherapist and occupational therapists' perceptions of applying safe handling principles in the community setting. Eight participants were observed, followed by six semi-structured interviews. The participants reported that the manual handling training was basic and was not always applicable to the community setting. The participants also stated that therapeutic handling was involved in manual handling.

The five included reports including physiotherapists have investigated kinematics, loading, perceived exertion and perceptions. However, further well-designed research including therapeutic handling, handler movement and handler perceptions is required to better establish the factors that increase risk of injury. Additionally, more needs to be known about other therapeutic handling tasks and treatments performed in physiotherapy. Transfers are heavily focused upon in research and have been identified as a task of potential risk for developing WRMSDs (Campo et al. 2008). However, physiotherapy treatments often consist of more patient handling tasks than just patient transfers. To effectively develop and implement interventions to improve safety during patient handling and training, more needs to be known about the manual tasks involved in physiotherapy.

This scoping review found that it was more common to explore the tasks performed during manual patient handling than to investigate the biomechanics involved. In addition, there were only four qualitative studies on the opinions, perceptions and experiences surrounding manual patient handling (de Ruiter and Liaschenko 2011; Osborne et al. 2021; Wade et al. 2017; Wångblad et al. 2009). A greater focus was placed on the identification of patient handling tasks and the physical risks involved during these tasks. It has been demonstrated that changes in practice are aided by qualitative input (Rolfe et al. 2018). Gaining perceptions, opinions and experiences could allow for more effective implementation and engagement with staff. Increasing the amount of qualitative research is imperative for improving the health and safety of staff involved in manual and therapeutic handling.

Within this scoping review, laboratory-based research was the most common setting. Laboratories allow for research to be controlled, as external confounding factors can be limited. There is also access to optoelectronic motion analysis systems (e.g., Vicon, OPTOTRAK) which are deemed the gold standard within motion analysis (Corazza et al. 2009). These systems use fixed cameras and allow for accurate full-body 3D measurement during manual patient handling tasks. Laboratory based systems provide valuable and robust data. However, the findings may not be applicable to 'real-world' settings (Moriguchi et al. 2012; Scott and Renz 2006). Research conducted out with laboratory settings allows for investigation into the real-world tasks and challenges faced by HCPs in clinical settings. Twenty-three studies were conducted in the real-world setting, comprising hospitals, community, care homes and sonography clinics. A range of investigations were conducted in these settings such as, observation of patient handling tasks, assessment of risk, movement measurement with inclinometers/ accelerometers or posture dosimeters, and interviews.

Staff may move in a different manner in their normal clinical environment when compared to a laboratory set-up due increased awareness of being observed, wearing trackers or markers, and performing patient handling in a non-clinical environment. Research participants have been found to change their behaviour when being observed (Oswald et al. 2014; Sedgwick and Greenwood 2015). Some of this observer-bias is likely to remain in the clinical setting. However, working in their normal work area and with patients may reduce the effects of observer bias.

Technology and methods used to collect data out of the laboratory (e.g., Xsens, Kinect) are less accurate (Cuesta-Vargas et al. 2010) than the optoelectronic systems. Despite this, these systems can provide clinically relevant information and improve the knowledge base. On balance, the findings from this scoping review suggest that there is a need for both research with the tools and control of the laboratory as well as the naturalistic setting of hospitals and the community.

Most studies used healthy volunteers simulating a disability or altered cognitive levels as the ‘patient’ population during data collection. These volunteers allowed for research to take place in laboratory settings where the involvement of real patients may be challenging. In some research, the study volunteers alternated as handler and patient and whilst this improved efficiency of data collection, it raises concerns over volunteer bias (Simundic 2013). Some volunteers were HCPs who, despite understanding the disabilities involved, are not a true representation of patients with true weakness or disabilities. As the focus of the research was on the HCPs during manual patient handling, the forces and movement involved while moving and assisting these simulated patients may not be an accurate reflection as the volunteers may subconsciously help the HCP where a real patient would not be able to do so. Patients in neurological settings or volunteers simulating neurological patients were included in four of the included studies. These studies investigated lumbar movement or loading during patient handling tasks (Hye-Knudsen et al. 2004; Skotte and Fallentin 2008; Skotte et al. 2002), and qualitatively investigated handler perceptions and experiences in a neurological setting (de Ruiter and Liaschenko 2011). As stated previously in Chapter 1, neurological settings can be manually intensive for HCPs and lifting aids are frequently used in these areas. This is a patient population that would benefit from further investigation.

There was a lack of research conducted with outpatient and community patients; this also needs to be addressed. Healthcare practitioners in the community must adapt their practice to each patient's environment and the equipment they have available (Tofts and Arnold 2012). Adult community physiotherapy settings are not stated within the specialties that demonstrate higher WRMSD incidence rate (Glover et al. 2005). Contrasting to community settings, outpatient physiotherapists have been found to have a high rate of hand and thumb injuries related to manual therapies often used in this setting (Glover et al. 2005). Performing these studies in the clinical setting can provide a more realistic and comprehensive account of the movements involved. It does, however, also mean there is less control over variable factors and there is a risk of losing some of the precision that can be attained in a laboratory setting.

2.7.2 Other Literature

The other literature included within this scoping review mostly consisted of narrative summaries of legislation or government statistics. The legislation surrounding moving and handling in the UK was last updated in 2002. Moving and handling training aims to teach the principles of safe manual handling, however, the evidence-base and justification behind the training is unclear (Haslam et al. 2007). There is no widely used training specific to AHPs for correct moving and handling of patients in a therapeutic manner.

2.7.3 Gaps in the Literature

Few studies have focused on AHPs performing manual patient handling; however, these staff groups are likely to be involved with therapeutic handling practices which are manually intensive. There are currently no guidelines or formal training provided to AHPs within the UK for safer therapeutic handling techniques, and this review found no evidence that such training occurs in other geographical locations. A priority for future research is to investigate therapeutic handling and potentially develop guidelines to reduce the risks involved.

There has been little detailed measurement of manual patient handling in healthcare settings with real patients, with many studies measuring trunk position or using video or photographs for full body analysis. Measuring patient handling in laboratory settings is more accurate via access to 3D motion analysis systems and volunteer simulated patients. However, involving simulated patients may not accurately reflect how healthcare staff move and handle real patients in the healthcare environment. Due to recent advances in technology, movement can be accurately recorded in the healthcare setting, allowing for further exploration in the real-world setting.

Of the reports included in this scoping review, one primary research study was conducted within the UK (Wade et al. 2017). More research is required internationally, but especially in the UK, to inform this local context. Research can allow for greater understanding of moving and handling in healthcare. A greater understanding of what is performed, how it is performed and why could help guide training content or methods of teaching to reduce the risk of injury for HCPs in the UK context.

Few qualitative studies assessed moving and handling of patients in healthcare. Ethnographic research and further investigation of perceptions and experiences of patient handling could allow for greater understanding of staff training and guidance to reduce risk of injury.

2.7.4 Strengths and Limitations of this Scoping Review

This scoping review followed a comprehensive search strategy and a priori protocol which was reviewed by an experienced research team with previous experience in scoping reviews. Despite the rigorous search strategy there is the possibility that some relevant articles were not included. This scoping review was restricted to the English language, and therefore it is expected that the entire literature base will not have been mapped. However, in this scoping review only one study was excluded due to not being written in English. The methodological quality of literature included in this scoping review was not assessed; however, in keeping with methodological guidance for scoping reviews (Peters et al. 2020) the aim was to map the available literature rather than to assess its quality or the implications of study findings. Most of the included research was conducted in the US and Canada, therefore there may be difficulty with generalizing findings to other healthcare contexts.

2.8 Conclusion

This scoping review comprehensively mapped the current literature surrounding manual patient handling in healthcare without the use of assistive devices. The scoping review identified a number of gaps within the literature: research investigating physiotherapists performing therapeutic handling; research conducted in the healthcare setting with patients; 3D investigation of movement in the healthcare setting; research within the UK; and perceptions or experiences of manual handling in healthcare. This scoping review formed the first step in a programme of research on manual patient handling. Due to the gaps identified from this scoping review, the research addressed therapeutic handling by physiotherapists during patient rehabilitation in the healthcare setting. This research could then investigate the specific physiotherapy patient handling tasks performed and the movement and postures involved with patients during treatments.

3 STUDY AIMS AND OBJECTIVES

Manual patient handling is a key aspect of many healthcare workers daily work in and out of hospital settings. Based on the scoping review, mapping of the literature and identification of gaps within manual patient handling in healthcare, the following aims and objectives were set for the study. It was identified that further investigation into therapeutic handling and handler movement during manual patient handling with genuine patients was required. In addition, the need for further research with physiotherapists performing therapeutic handling was identified. Therapeutic handling needed to be understood further to aid practice, improve training, and inform work practices or task schedules for patient-facing healthcare staff. Therefore, as a result of the findings of the scoping review, this study was designed to investigate physiotherapists' movement during patient handling in the clinical setting with patients on active treatment.

The overall aims of this doctoral study were to quantify physiotherapists' movement during therapeutic patient handling tasks and investigate whether there may be a relationship between patient handling and WRMSD. The findings of the scoping review presented above, and the overall aim of the research stated here were used to set specific research objectives. The objectives of this study were:

1. To quantify and describe physiotherapist movement and posture during a neurological rehabilitation treatment session through measurement of joint and segment angles.
2. To investigate what proportion of patient handling during a neurological treatment session is performed in a position previously reported to increase risk of injury.
3. To investigate if participating physiotherapists have experienced any musculoskeletal issues related to manual handling of patients and hypothesise possible patient handling tasks that may increase risk of injury related to body position or movement.

The design, materials and methods used to address the above objectives are detailed in Chapter 4: Materials and Methods.

4. MATERIALS AND METHODS

4.1 Introduction

The study aims and objectives were developed after identification of gaps within the literature from the scoping review reported in Chapter 2. This chapter will initially discuss and describe the research philosophy, methodology and study design. Following this, the research participants, materials, and methods of data collection, processing and analysis will be described and justified. The study is summarised in Figure 4.1.

4.2 Philosophy

This section initially discusses the terms used within research philosophy before discussing the philosophical underpinnings of this research. Within research, multiple philosophical approaches are found. This section will briefly introduce research philosophies before focussing on positivism and discussing this philosophy in detail. The other philosophies will not be discussed in detail as for this research, the aims and objectives dictated that a positivistic approach was required.

The main philosophies are positivism, interpretivism, postmodernism, pragmatism, and critical realism (Saunders 2019). Each of these philosophies is guided by the aim of the research and each has different underpinnings and typical methods used for data collection. Research philosophies can be defined as a 'system of beliefs and assumptions about the development of knowledge' (Saunders 2019). The underpinnings of philosophy can be separated into epistemological, ontological, axiological, and methodological (Saunders et al. 2011; Scotland 2012). These terms are described further in Table 4.1. To ensure a reliable research philosophy, these assumptions should be accounted for and kept consistent (Saunders et al. 2011).

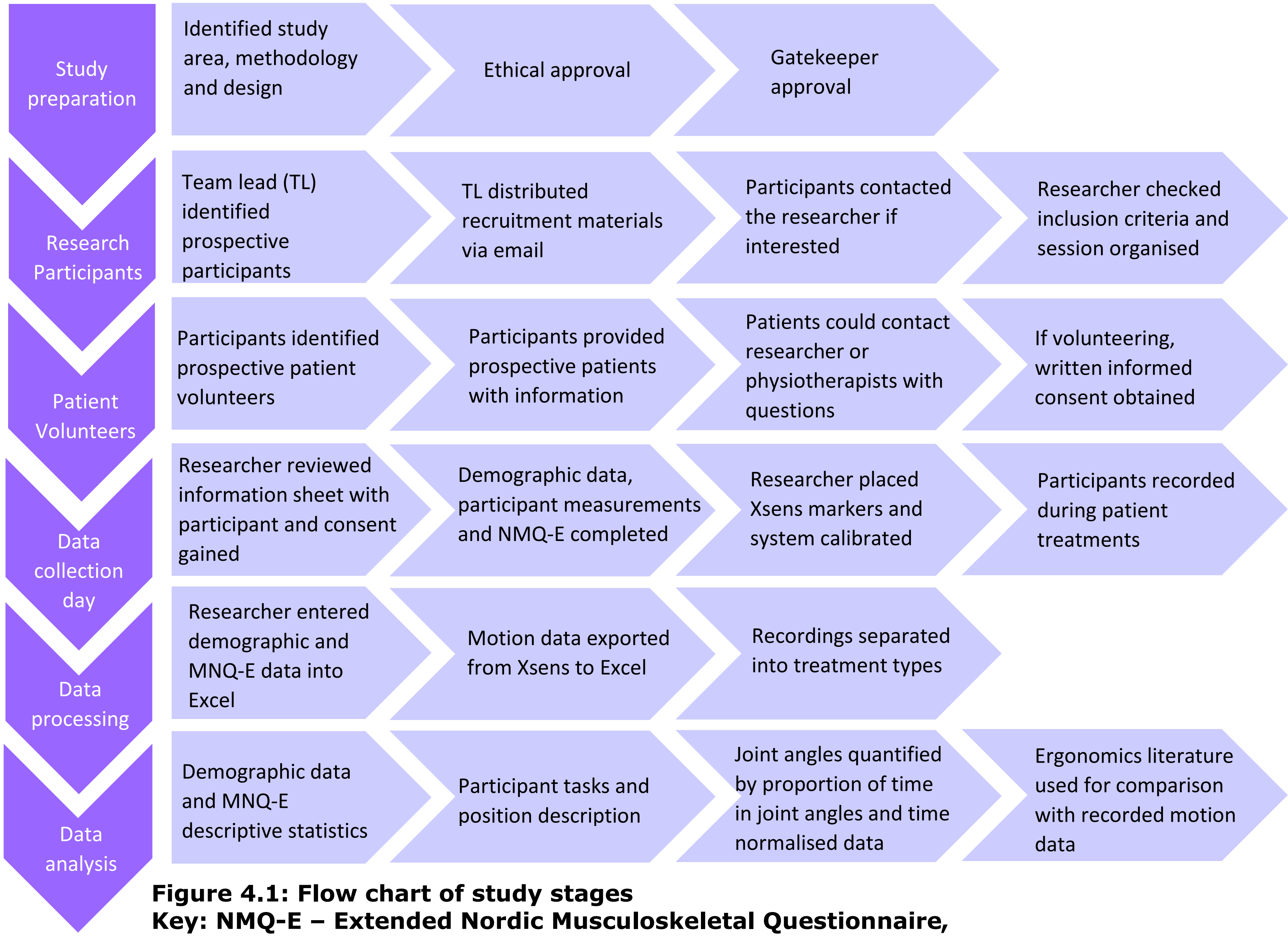


Figure 4.1: Flow chart of study stages
Key: NMQ-E – Extended Nordic Musculoskeletal Questionnaire, TL – Team Lead

Table 4.1: Research philosophy underpinnings (Mack, 2010; Saunders, 2019; Scotland, 2012)

Term	Meaning
Epistemology	The human knowledge and how it is communicated and acquired
Ontology	The nature of observing the research
Axiology	The values of the research team and how they can influence the research
Methodology	The overall approach used and the methods used to collect data

The positivist philosophy is also called the traditional scientific approach, using measurement to investigate or describe causality (Creswell 2014; Crossan 2003; Saunders et al. 2011). Positivist researchers are objective in their research, using careful measurement or collection of data (Creswell 2014). Positivism has been criticised, however, as it investigates facts but does not allow for detailed investigation of feelings and human behaviour (Crossan 2003). Research on physiotherapists' opinions of patient handling tasks, and which are considered to be higher risk, would arguably also be of benefit to the research base. It is important, however, to first understand how physiotherapists move during patient handling to provide a basis for further exploration into this area. Therefore, therapeutic handling tasks, positions and movement involved, potential risks and areas of WRMSD were chosen to be investigated. This research should allow for a base of knowledge which can direct further qualitative and quantitative research.

Research with a philosophy of positivism is deductive and based on a set of laws or rules and often involves testing a theory (Creswell 2014; Crossan 2003). Quantitative research methodology fits within positivism as it is based on quantifiable data that is statistically analysed and capable of testing hypotheses (Crossan 2003). Some assumptions in positivism are that the researcher remains objective (epistemology), the research and data gathered is real and ordered (ontology), the bias of the researcher is controlled and minimised (axiology), and the data collected from the research is quantitative (methodology) (Crossan 2003; Saunders et al. 2011).

This research used a 3D motion analysis system to measure human movement during patient handling tasks, and it also investigated WRMSD with a questionnaire from which quantitative data was gained. The objective measurement and quantitative data collected demonstrates that this research was driven by a positivist philosophy.

4.3 Methodology

Within research philosophies, empiricism is a major principle. Empiricism is at the heart of the scientific method and states that observations and measurements should be used to collect evidence (Thomas 2021). Findings are justified through evidence and experiences rather than theory (Thomas 2021). Data can be collected in natural or laboratory settings and can be passively observed or the researcher can be actively involved in investigations or interventions (Thomas 2021). Predictions can be made from empirical investigations. Empirical methods guided the choices of materials and methods used to observe and measure physiotherapist movement.

4.4 Study Design

This research employed a descriptive cross-sectional study design investigating physiotherapist movement during patient handling tasks in a rehabilitation setting. Descriptive research does not use a comparison group (Omair 2015), and a cross-sectional approach allowed for investigations of multiple outcomes at one point in time (Levin 2006; Mann 2003). Cross-sectional studies select participants based on specific inclusion and exclusion criteria for the research (Setia 2016). This study design was chosen as there was no deliberate intervention within the research with no manipulation of variables or changes of practice involved (Mann 2003). The aim of the research was to observe the naturally occurring patient tasks, treatments and handling that occur within neurological rehabilitation. Taking multiple measurements at one time period was assumed to be sufficient to capture representative movement of physiotherapists in the clinical setting as cross-sectional studies often collect data at one point in time (Levin 2006; Mann 2003).

This research investigated qualified physiotherapists working within Neurological and Stroke Rehabilitation wards in one hospital in the North of Scotland during a working day. Some benefits of a cross-sectional study design are that the study design can be used to identify associations and provide a basis for future research to be built upon (Levin 2006; Mann 2003). Additionally, the research can be relatively quick to complete (Levin 2006; Mann 2003). The main disadvantage of cross-sectional studies is that it is more difficult to make definite causal inferences due to the data being collected on one occasion (Mann 2003; Setia 2016). However, it is possible to identify associations when there is enough data (Mann 2003; Setia 2016). Therefore, as the research aim was to explore physiotherapist movement and incidence of WRMSD, a cross-sectional design was chosen as it could allow for a relatively quick investigation into therapeutic handling and guide future research.

4.5 Research Environment

The data collection was completed in three different wards within one hospital in the North of Scotland. Each of the wards had their own physiotherapy gym where most patient treatments were conducted. The three gyms had similar arrangements with neurological plinths and a variety of rehabilitation equipment available. The physiotherapy gyms also acted as an office base for the physiotherapist participants. Calibration of the Xsens MTw Awinda system was completed in the gym for each participant.

4.5.1 COVID-19 Measures and Considerations

At the time of applying for ethical approval and data collection, certain measures were in place due to the ongoing COVID-19 pandemic. Social distancing of 2-metres was maintained where possible. The researcher wore a fluid-resistant surgical mask (FRSM) for the duration of the data collection day. In addition, the researcher donned an apron and gloves when placing or removing the Xsens MTw Awinda system. The participants wore the same Personal Protective Equipment (PPE) when involved with any patient tasks (FRSM, apron, gloves). The researcher who attended the hospital sites was also an NHS employee. Therefore, they already followed the staff COVID-19 testing guidelines at the time. The researcher had also received both doses of the COVID-19 vaccine before starting data collection. Three days were left between using the Xsens MTw Awinda system on consecutive participants as a 'quarantine measure' to ensure no cross-contamination of COVID-19 between participants or wards. This measure was set following the findings that no infectious virus could be detected on cloth on day 2 and that the virus was susceptible to disinfection methods (Chin et al. 2020). Therefore, thorough cleaning and time between using the system was implemented to minimise contamination of equipment and reduce risk of COVID-19 spreading between ward environments. These measures were performed in accordance with advice sought from the Infection Prevention and Control department in the NHS Board where the research was being conducted.

4.6 Ethical Considerations

Ethics in research is considered so that the research is moral, justified, protects both the researcher and participants, and maintains research integrity (Lahman 2018). For this study, the main ethical considerations were recruitment, consent, confidentiality and data protection, and infection control.

4.6.1 Recruitment

Prior to participant recruitment, gatekeeper approval was gained. The gatekeeper then distributed all materials and information sheets to potential participants. As the gatekeeper identified and contacted potential participants, direct contact with the participants only occurred after they contacted the researcher first. Recruiting through a gatekeeper allowed for voluntary contact with the researcher and meant the participants were not coerced into participation. Additionally, throughout recruitment, it was made clear that participants did not have to participate or could withdraw at any point with no negative impact to themselves. Time between the stages of recruitment was provided for the participants to allow adequate opportunity to discuss and deliberate participation before providing consent.

Patient volunteers, despite not being the focus of the research, were involved in the study and therefore were considered within the ethical approvals. Minimal impact to the patient treatments was expected as the motion analysis system is lightweight, and the physiotherapists treated the patients as normal. The patients were provided with information sheets (Appendix 10) at least 48 hours prior to the data collection session to allow them to understand the research, ask questions and consider if they would consent to treatment during data collection. Only patients with mental capacity were included as they could understand why the researcher would be observing the session and that the research was not focused on them.

4.6.2 Informed Consent and Potential Harm

Informed consent is a key principle of ethics in research (Oliver 2010). Participants should be provided with adequate information about the research before volunteering to participate (Josephson and Smale 2021; Sivasubramaniam et al. 2021; Oliver 2010). Additionally, participants within research should be made aware of any potential risks or consequences of their participation (Oliver 2010). The process of informed consent minimises coercion into participation.

For this study, potential participants and patient volunteers were provided with an information sheet describing the research and what their participation would involve. The information sheets also detailed any potential risks or benefits to each participant group. The research involved manual handling of patients;

therefore, there was a risk of injury or physical discomfort to both the participant and patient. However, these movements and treatment tasks were those performed routinely in treatment sessions. If a participant or a patient became injured or experienced discomfort, they were welcome to withdraw with no negative impact. The researcher had no input to the treatment sessions, therefore the treatment patients received was not affected by data collection. Additionally, there was no negative impact to their treatment and care if they did not wish to participate. There were no direct benefits for both participants and patient volunteers, this was made clear on information sheets provided to both groups.

4.6.3 Confidentiality and Data Protection

Participants and patient volunteers have a right to confidentiality and anonymity. Risks related to personal data are reduced if only the essential identifiable data is recorded (Nichols-Casebolt 2012). It is also important to ensure the participants cannot be directly linked to the identifiable data collected (Nichols-Casebolt 2012). In this study, each participant was given an anonymised study identification number which was used for all data collection and analysis. Strategies are also required to ensure safe storage of data after collection (Nichols-Casebolt 2012). Any personal or identifiable data in this study was stored in a password protected file on a secure network folder at the university. Additionally, any paper data will be stored in a locked cabinet on university premises.

4.6.4 Infection Control

Infection control is necessary in healthcare settings to minimise the risk of contamination and spread of infections (National Infection Prevention and Control Manual (NIPCM) 2022). Additionally, the research was completed during the COVID-19 pandemic where heightened levels of PPE were required. The Xsens MTw Awinda system required attaching trackers to the participants with straps and a vest. The same participant would wear the system for the data collection day. The participant was able to wear the appropriate PPE over the system and was able to perform hand hygiene between sessions. The tracker units are hard plastic and were cleaned with the standard cleaning wipes provided within the hospital. The straps and vest were washed following manufacturers guidelines and were additionally left for a 72-hour ‘quarantine’ period between data collection sessions. The researcher followed PPE guidance and adhered to the implemented two-metre social distancing from participants after applying the system.

4.7 Ethical Approval

When applying for ethical approval, the previously discussed ethical considerations were outlined and all measures taken to ensure researcher, participant and patient volunteer safety and security were documented. Ethical approval was initially sought from RGU School of Health Sciences ethics committee. Approval was granted on the 30th November 2020 (Reference number IRAS 286201) (Appendix 5). Subsequently, the study was reviewed by the Proportionate Review Subcommittee of the London – Riverside Research Ethics Committee and approved on the 7th January 2021 (REC reference: 20/PR/0999) (Appendix 6). Permission to conduct the study locally was granted by NHS Grampian Research and Development (R&D) on the 12th February 2021 (Project no. 2020RG007E) (Appendix 7).

As initially shown in Figure 4.1, after gaining ethical approval, gatekeeper approval was sought from the physiotherapy team lead for the hospital. The team lead identified potential participants and distributed an introductory email with information sheets to potential physiotherapist participants (Appendix 8). The potential participants could then contact the researcher with any questions and for further information regarding participation.

4.8 Research Participants

4.8.1 Participant Population

Physiotherapists working within Neurological and Stroke Rehabilitation wards were chosen for this study as they are heavily involved in patient handling. This is a necessary component of their job as patients can present with significant physical and cognitive disabilities after a stroke or neurological disorder (Headway 2019). A wide variety of physiotherapy approaches are used within neurological rehabilitation (Bhalerao Gajanan et al. 2016). Many approaches utilise manual techniques with the physiotherapist assisting patients with movements or tasks. Neurological rehabilitation was found to be the second highest area for injury within physiotherapists after musculoskeletal outpatients (Glover et al. 2005). Within the physiotherapists who reported low back pain as their most serious injury, neurological rehabilitation was found to have the largest rate of initial injury with a higher distribution of spinal injuries found than in musculoskeletal settings (Glover et al. 2005). Musculoskeletal outpatient settings have a higher rate of injuries to the wrist and thumb due to the nature and style of patient treatments performed in that setting (Glover et al. 2005). Physiotherapists working within neurological rehabilitation were chosen due to the anatomical regions measured with the motion analysis system, and the interest in measuring trunk movement.

4.8.2 Inclusion Criteria

The potential participants contacted the researcher via email if they wished to participate in the research. Over email, a list of the inclusion and exclusion criteria was sent to the potential participants which could then be confirmed with the researcher. Inclusion criteria was set to include any physiotherapist working their normal duties. The data collection sessions were during the physiotherapists' working day and so the inclusion criteria were set to reflect this.

Inclusion criteria for physiotherapist recruitment were:

1. Adults 18-67 years of age

2. Qualified physiotherapist working within neurological or stroke rehabilitation within a hospital in the North of Scotland

3. Hold an up to date moving and handling passport

4. Fit and able to work (self-identified by the potential participants)

5. Have given signed informed consent to participate in the study

These criteria were set as they are indicative of the NHS working age (NHS 2019). Within NHS Scotland, all staff are required to have an up to date moving and handling passport (HSE 2016). The aim of these passports was to improve manual handling within healthcare settings through regular theory and practical training.

4.8.3 Exclusion Criteria

Exclusion criteria were set to exclude any participant who would not be able to complete patient handling activities due to illness or medical conditions.

Exclusion criteria for physiotherapist recruitment were:

1. Staff currently signed off work due to illness

2. Staff with altered duties or on a graded return to work after time off work

3. Pregnant staff

4. Any medical condition preventing them from performing the task such as severe musculoskeletal injuries limiting their patient handling abilities or skin issues that would react poorly to wearing the neoprene straps for an extended period.

These criteria were set to ensure staff safety during data collection. Staff who were signed off due to illness would not be able to attend the data collection session. Staff with altered duties may not be as regularly involved with patient handling which could affect the data collection. Staff who had a skin condition were not included as wearing the system could irritate their skin and cause discomfort. If any physiotherapists were unable to perform their normal work and patient handling activities due to current or previous illness or injury, they would be unable to safely participate in the research.

Physiotherapy students were excluded as this research was exploratory and focussed on qualified physiotherapists. Furthermore, to register with the Health and Care Professions Council (HCPC) as a Physiotherapist you must meet the standards of proficiency (HCPC 2013), and students do not meet these standards until they successfully complete their training. Students may not have the same level of experience and practice with manual patient handling compared to qualified staff members.

4.8.4 Participant Sampling

Identification and recruitment of research participants is summarised in Figure 4.2. Following confirmation of inclusion and exclusion criteria, the researcher organised a data collection session with the participants at least 48 hours after conformation; providing the participants time to consider and withdraw from the study if they wished. At the start of the data collection day, the researcher answered any additional questions the potential participants had. If the participants still wished to participate, they signed a consent form which the researcher countersigned (Appendix 9). The participants were made aware they could withdraw from the study at any time without having to provide a reason with no negative impact to themselves or their patients. Each participant was provided with a unique study ID which was then used for all data collection, processing and analysis; this ensured anonymity of the participants during data processing and analysis.

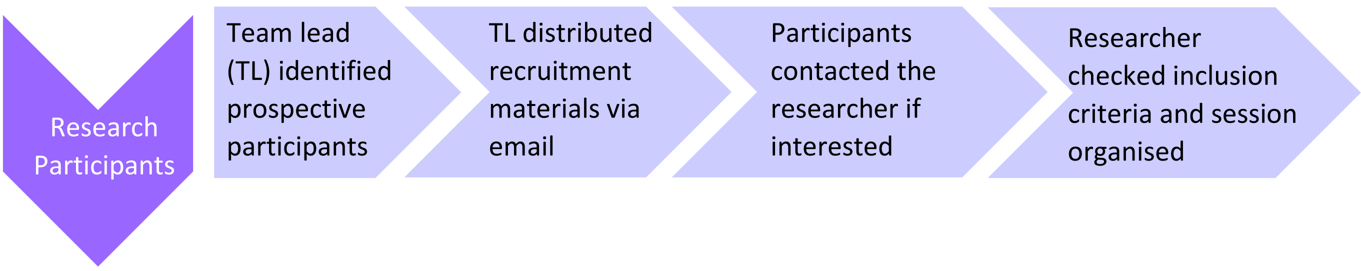


Figure 4.2: Identification and communication with potential research participants

Up to 11 physiotherapists were aimed to be recruited to the study. A power calculation to determine sample size was not completed as this project was exploratory and the sample size was limited by pragmatic concerns and thereby limited to qualified physiotherapists working within Neurological and Stroke Rehabilitation wards in the selected hospital in the North of Scotland. Previous literature has demonstrated a sample size of two (Jordan et al. 2011; Howard et al. 2013); a sample between seven to ten (Skotte et al. 2002; Marras et al. 2009; Hodder et al. 2010b; Kim et al. 2014; Wiggerman 2016); and a sample of over 20 (Daynard et al. 2001; Hodder et al. 2010a; Holmes et al. 2010). Therefore, the potential maximum sample size of 11 is similar to other patient handling literature. In the stroke and neurological rehabilitation wards each patient treatment was up to 45 minutes long, following clinical guidance that up to 45 minutes of rehabilitation should be offered to each patient (Duncan et al. 2005). The longer patient treatment sessions could, therefore, provide a large volume of data despite the potential smaller sample size.

4.9 Patient Volunteers

Measurement of the participants took place during usual patient treatment sessions throughout the physiotherapists' working day. The patients were not the focus of this study. As the data collection was during their treatment sessions, patient inclusion and exclusion criteria were set to ensure the safety of both participant and patient throughout.

4.9.1 Patient Volunteers Inclusion and Exclusion Criteria

Patient inclusion criteria:

1. Patient in the stroke or neurological rehabilitation unit at a hospital in the North of Scotland

2. The patient self-identified as fit for physiotherapy treatment

3. The patient has mental capacity, as assessed and documented by medical staff

4. The patient provides written informed consent

Patient exclusion criteria:

1. The patient is medically unwell or unfit for physiotherapy input

2. The patient refuses physiotherapy input

3. The patient is unable or unwilling to provide informed consent

Patients without capacity were not included in this research. The number of patients without capacity is variable and capacity may change during a patient's hospital stay. However, patients without capacity often formed a small proportion of the patients on each ward. Patients without capacity could have been included if consent had been gained through their next of kin; however, it was felt to be unethical to include these patients if they might not understand why the research was being conducted and that they were being observed. Patients who had capacity were able to understand the research and provide written informed consent. Despite excluding patients without capacity, there were ample patient volunteers with capacity in each ward for the research to be completed effectively.

4.9.2 Patient Volunteers Sampling and Consent

The patient volunteer criteria were sent to the research participants (physiotherapists) via email. This allowed the participants to identify potential patient volunteers in their ward. The participants provided the patients with an information sheet that clearly explained that the project focused solely on the physiotherapist movement and not the patient or the treatment they received (Appendix 10). The information sheet had the researcher's contact information for any potential questions. The information sheet was provided to the patients at least 48 hours before the data collection session. If the patients still wished to participate, they signed a consent form before their treatment session which the physiotherapist countersigned (Appendix 11). The patient volunteers were made aware they could withdraw from the study at any time without having to provide a reason with no impact on the treatment they received. The steps involved in identification and sampling of patient volunteers is displayed in Figure 4.3.

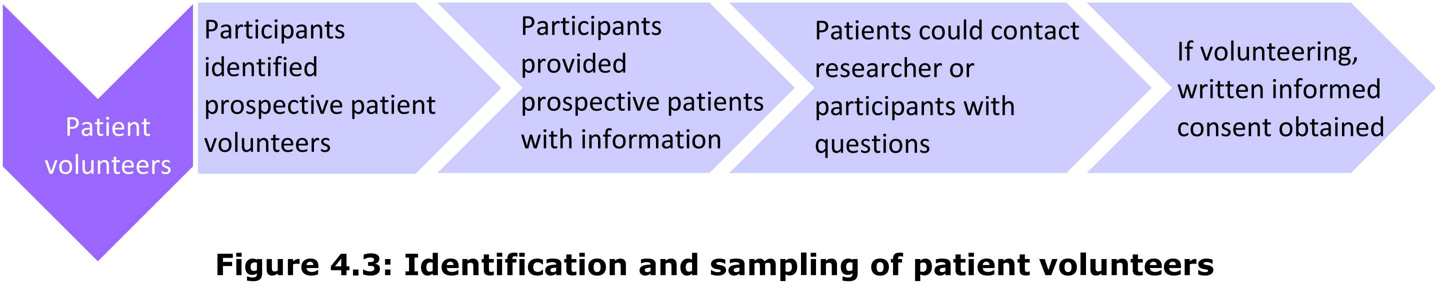


Figure 4.3: Identification and sampling of patient volunteers

No identifiable data was collected about the patient volunteers. For each treatment session the number of staff involved (one/two) and the weight of the patient was noted on the treatment observation sheet (Appendix 11). Patient weight is recorded regularly in an inpatient setting (Flentje et al. 2018). Patient weight is documented in nursing notes and was easily accessible to the participating physiotherapists. Level of assistance and weight were recorded as they could impact the physiotherapist's movement during treatment and were therefore of interest.

4.10 Materials

This section will discuss the materials used to collect the data required to address the research objectives. The materials will be presented here; how the materials were used within the data collection sessions will be outlined in Section 4.11.

4.10.1 Work Related Musculoskeletal Injury Questionnaire

Work-related musculoskeletal disorders have been widely investigated using many questionnaires and surveys (Gilchrist and Pokorná 2021; Glover et al. 2005). There are many questionnaires available to investigate WRMSD such as the standardised Nordic Musculoskeletal Questionnaire (NMQ), Extended NMQ, Northwick Neck Pain Questionnaire, and individually self-developed questionnaires (Çakıt 2019; Erick and Smith 2011; Khan et al. 2017; Smith and Leggat 2004; Wiitavaara and Heiden 2017). Creating a rigorous self-developed questionnaire can be time consuming and challenging (Burns et al. 2008). Steps should be taken to reduce bias and ensure the questionnaire is valid and reliable (Burns et al. 2008). A self-developed questionnaire was not used for this research due to the availability of previously developed and tested questionnaires, and the limited timeline of this research. Other available questionnaires were not chosen as they are less widely used in the research or specifically investigated one anatomical region (e.g., Northwick Neck Pain Questionnaire).

Traditionally the Standardised NMQ is one of the most widely cited questionnaires used to investigate musculoskeletal symptoms. This questionnaire was initially developed by Kuorinka et al. (1987) with the aim of creating a standardised tool for analysis of musculoskeletal symptoms in an ergonomic setting. The Standardised NMQ comprises 28 multiple choice questions in two sections. The first section investigates musculoskeletal symptoms in nine anatomical regions. The second section investigates musculoskeletal symptoms in three body parts with reference to the individual's working life. This questionnaire has been used extensively within healthcare, sport, manufacturing, teaching, and other manual industries (López-Aragón et al. 2017). Despite its frequent use, the method of administration can potentially affect its reliability (Dickinson et al. 1992; Kuorinka et al. 1987). Kuorinka et al. (1987) stated the reliability of the standardised NMQ ranged from 0% to 23% non-identical answers. Recent research has investigated the reliability of the standardised NMQ when adapted for different population groups and languages. These studies found the reliability of the standardised NMQ to be good, with kappa scores ranging from 0.51 to 1 (Gómez-Rodríguez et al. 2020; Namnik et al. 2016; Yona et al. 2020). Additionally, Chairani (2020) stated that the questionnaires Cronbach’s Alpha suggested good reliability (>0.9). Chairani (2020) also found that the questionnaire has strong validity as determined by the Corrected Item-total correlation (>0.6).

The standardised NMQ has been adapted into the Extended NMQ (NMQ-E) (Appendix 13). The NMQ-E investigates the same nine anatomical regions as the standardised NMQ. The regions are the: neck, shoulders, upper back, elbows, wrists/hands, low back, hips/thighs, knees, and ankles/feet. The NMQ- E diagram clearly illustrates each of these nine regions on the questionnaire sheet. The questionnaire consists of 11 questions. The questionnaire initially investigates 'trouble (ache, pain, or discomfort)' over four time points: lifetime, 12 months, 4 weeks, and on the day of administration. It also investigates age of onset, severity of musculoskeletal symptoms, and occupational impact. The NMQ-E investigates detailed information about any WRMSDs over the individual's career. This questionnaire was developed, validated and assessed for repeatability on student nurses by Dawson et al. (2009). They concluded that the NMQ-E was a sufficiently reliable tool for investigating musculoskeletal symptoms and the further effects on the individual. They also stated that the NMQ-E was reliable (intraclass correlation coefficients (ICC) 0.90) when self-completed by the individual. The NMQ-E has since been adapted for online use, for younger age groups, and translated into other languages (Alaca et al. 2022; Legault et al. 2014; Pugh et al. 2015).

The NMQ-E is a one-page questionnaire making it quick and easy for the physiotherapists to complete. The NMQ-E was chosen as it is a validated questionnaire investigating work-related musculoskeletal symptoms and their impact on the individual's work and personal activities.

4.10.2 Xsens MTw Awinda Motion Analysis System

Physiotherapist movement in a healthcare setting was measured using the Xsens MTw Awinda system comprising a portable wireless tracker-based motion capture and analysis. Xsens MTw Awinda has been shown to have the potential to accurately measure human movement inside or outside the laboratory environment (Lu Bai et al. 2012; van der Kruk and Reijne 2018). The trackers are derived from micro-electromechanical systems (MEMS) sensors, described further below (Xsens 2021). Recent developments have allowed the inertial units to decrease in size and weight whilst retaining the quality of motion capture (Lu Bai et al. 2012). This improvement and increased portability has expanded the possibilities of data collection outside of the laboratory environment, allowing it to be used in the clinical setting.

The manufacturer Xsens, has developed multiple systems intended for different uses within research, ergonomics, biomechanics, and animation (Robert-Lachaine et al. 2016; Xsens 2021). The MTw Awinda system uses 15 motion trackers (Figure 4.4). The trackers wirelessly connect to a laptop, allowing portable motion analysis (Xsens 2021). The Xsens MTw Awinda motion trackers connect to the Awinda Station, which has an external antenna and allows for a wireless range of 20m indoors; meaning it can easily follow a physiotherapist around a treatment room without losing signal. The MVN Analyze software package enables real-time viewing and recording of motion data. The trackers, or miniature IMUs, contain 3D linear accelerometers, 3D rate gyroscopes, 3D magnetometers, a barometer, and an internal battery (Xsens 2021). These components, together with advanced sensor fusion algorithms and biomechanical assumptions, allow for full body motion capture and analysis of movement. The trackers are placed on specific anatomical locations (Table 4.2) and measure the motion of segments. Each tracker is labelled with the body segment it is to be attached to via the Velcro backing on the tracker unit. The full description of the segments measured with Xsens can be seen in Appendix 14.

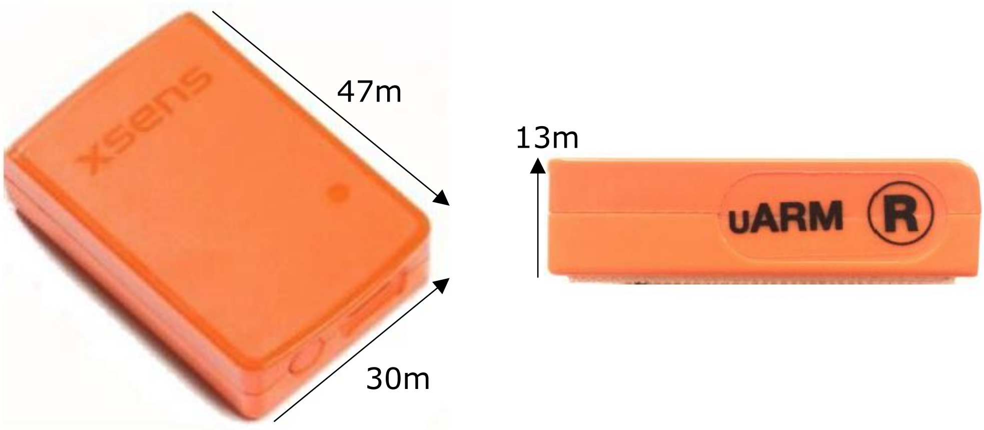


Figure 4.4: Motion tracker unit (Adapted from (Xsens 2021))

Table 4.2: Tracker locations (Xsens 2021)

Sensor	Anatomical location
Head	Over right ear
Sternum	Over sternum
Shoulders	Over left and right scapula
Upper arms	Middle of the upper arm
Lower arms	Just above the wrist
Sacrum	Over sacrum
Upper legs	Lateral side mid-thigh
Lower legs	Medial surface of tibia
Feet	Under tongue of shoe

It is important that the motion analysis system used for measurement is reliable to ensure high-quality data capture. The reliability and validity of the Xsens MTw Awinda has been investigated previously in lab-based, clinical, and non-clinical settings (Al-Amri et al. 2018; Kim and Nussbaum 2013; Robert-Lachaine et al. 2016; van der Straaten et al. 2018; van der Straaten et al. 2019). The most common method to investigate validity has been criterion-validity comparing Xsens MTw Awinda with laboratory-based optoelectronic systems, such as Vicon or Optotrak. Optoelectronic systems have well established accuracy and are the 'gold standard' for measuring human movement. Therefore, optoelectronic systems provide a good comparison (Al-Amri et al. 2018; Cuesta-Vargas et al. 2010; Fusca et al. 2018; Robert-Lachaine et al. 2016; Zhang et al. 2013).

Optoelectronic systems in a laboratory setting allow for more control and accuracy of measurement. However, they are expensive and when recording, the participant must remain within the calibrated camera field (Al-Amri et al. 2018; Cuesta-Vargas et al. 2010). Vicon cameras can be moved and set up to record movement out of the laboratory setting. However, the physiotherapy gym would need to have sufficient space for the cameras and tripods and the gym would be limited for other staff and patients to use during data recording. Additionally, it could be more difficult to control the reflective surfaces in the clinical setting than the laboratory environment. To reduce marker occlusion and movement, Vicon recommends the markers are attached directly to the participant's skin (Vicon 2021). To achieve this, the participants would be required to perform patient treatments in minimal clothing, or with a skintight body suit to attach the markers to. As this research was conducted in the clinical setting, performing treatments in minimal clothing may not be appropriate and participants may not feel comfortable to participate.

The Xsens system did require a skintight top, however, the participants were able to wear their normal clinical trousers. Additionally, the Xsens system did not require set up of cameras and also allowed more flexibility for the physiotherapist to move through the ward with the patient during the treatment. An example of this was when patients were able to walk further distances out of the physiotherapy gym and through the ward environment. If using the Vicon system, the physiotherapists' movement would only be measured for the length of the capture volume. If the physiotherapists were aware of the limited capture volume, this may impact their treatment to remain within this area. In addition, measurement in the laboratory environment may not reflect how individuals move in the clinical environment with real patients. If the physiotherapists are asked to perform a specific task in the laboratory environment, they may change how they perform the task due to increase awareness of being observed (Alvero et al. 2008).

Using a portable system, such as Xsens, allows for naturalistic measurement of human motion in the clinical setting with patients. As discussed in Section 1.6, there were ongoing COVID-19 safety measures in situ. This affected access to laboratories and potential participant recruitment. Using a system in the clinical setting allowed for investigation into moving and handling despite the national and local COVID-19 lockdown measures and resulting chance of laboratory and university closure.

A further benefit of the Xsens MTw Awinda system is its ease of use in terms of sensor application to the participant and resultant reliability in ease of data capture. Al-Amri et al. (2018) investigated inter-rater reliability between a clinically experienced individual and an experienced clinical movement scientist. Xsens and Vicon were used to examine three dynamic tasks: walking, squatting, and vertical jumping. It was found from the walk and squat task that the joint kinematics measured were reliable independent to the experience of the user. This suggests the system does not have to be used by an experienced movement scientist. For all three tasks, they found the Xsens system had excellent criterion validity to Vicon for lower limb angles in the sagittal plane (R^2 >0.8) (Al-Amri et al. 2018). It also had acceptable similarity in the transverse and frontal planes (R^2 0.4-0.8) (Al-Amri et al. 2018). The reliability for the vertical jump was lower than the other two tasks; however, vertical jumping was not performed during patient treatment sessions in this research.

Good agreement for the Xsens MTw Awinda system was found within-session and between-sessions when performing walking, side lunge, forward lunge, single leg squat, and sit-to-stand (van der Straaten et al. 2018; van der Straaten et al. 2019). Agreement was found to be higher within-session (ICC >0.7) than between-session (ICC 0.3-0.7) for all tasks and it was suggested that care is required with application of the pelvic sensor. Inaccurate placement of the pelvic sensor, or causing the sensor to move mid-task, affected the reliability of other joints. Taking this into consideration, after placing the pelvis belt and sensor, the participants were asked to bend forward, sit, and sit and lean forward. These movements would move the belt if placed unfavourably and it could then be adjusted or tightened if required. Between-operator and between-session ICC were found to be higher than within-session. The lower ICC within-sessions were likely due to individual variations in task execution (van der Straaten et al. 2019). The lower reliability values were found in the joints that are determined from the pelvic tracker movement (van der Straaten et al. 2019). The authors therefore recommended that for longitudinal studies, the same operator performs all the data collections for increased reliability (van der

Straaten et al. 2019). This research was not longitudinal, but the Xsens MTw Awinda system was operated by the same researcher throughout all data collection sessions.

Robert-Lachaine et al. (2016) investigated reliability and validity of full body motion analysis during a manual material handling task, comparing Xsens data with the Vicon system. The participants performed three repetitions of full active range of motion (ROM) for each joint measured by the Xsens system before completing a 32-minute manual material handling task where they lifted and moved boxes. They used root mean square error, waveform distortion, coefficient of multiple correlation, and Bland-Altman limits of agreement to assess and compare joint angles. They found that the Xsens system was an acceptable system compared to an optoelectronic system (Optotrak) when measuring full body movement during a manual handling task. They chose to measure for 32-minute periods as previous literature had suggested that longer trials are subject to higher mean error than short tasks. It was found previously that 20-minute tasks reached a maximum mean absolute error of 3.63°; the researchers stated that the tasks being performed affected the data with the IMUs remaining stable (Kim and Nussbaum 2013). The patient handling sessions were longer than the sessions in previous research, with each treatment scheduled to be 45 minutes following clinical guidelines. Each patient was recorded separately, rather than recording for the whole day, to reduce the risk of error during the data collection day.

A limitation of inertial and magnetic sensors is that significant error in data capture can be caused by magnetic distortions present in the surrounding environment (Xsens 2021). Xsens has developed a motion capture engine that uses motion data from trackers and advanced biomechanical modelling to remove the effects of magnetic distortions (Xsens 2021). This allows for freedom to use the system and collect data in any environment.

Although there are other motion analysis systems that could have been used for this research, fewer systems allow the same flexibility as Xsens to record in the clinical setting with minimal set up. As discussed previously, Vicon would require sufficient space and time to set up the cameras before the treatments which would be difficult in the clinical setting. Other possible portable motion analysis systems include Kinect and using video cameras for 2D recording.

The Kinect system is a markerless motion analysis system that has been used increasingly in clinical settings. Kinect demonstrated high maximum error values for joint positions (up to 50mm) (Mortazavi and Nadian-Ghomsheh 2018). Additionally, the joint measurement was more stable for the lower limb at 2m with the upper limb more stable at 3m (Mortazavi and Nadian-Ghomsheh 2018). Research using this system suggests that further refining of the system is required for it to be accurate for use clinically (Ma et al. 2019; Mortazavi and Nadian-Ghomsheh 2018).

Video recording for 2D joint analysis was not used as the Xsens system provided 3D joint information. Video recording could impact recruitment if physiotherapists or patients did not feel comfortable having their sessions recorded. Participants may feel uncomfortable to participate as the video recordings can be viewed multiple times after the session and are not anonymised (Asan and Montague 2014).

Prior to data collection, the Xsens MTw Awinda system was informally piloted to test the system during physiotherapy treatment movements and tasks. To achieve this, the system was worn and various patient handling movements and physiotherapist positions were performed and recorded. The recording was watched back to see if the avatars positions and calculated joint angles were accurate to the real-life movements performed. The results from this informal pilot found that the Xsens MTw Awinda system did manage to measure the different positions and tasks. Additionally, the system was lightweight and minimally invasive to the physiotherapist during patient handling.

The motion analysis model used in this research study was the 'full body no hands' Xsens model. The model used the anthropometric measurements taken for each participant and performed calculations to create a biomechanical model (Xsens 2021). This model excludes the two hand markers which removes measurement at the wrist joint. It was decided not to include the hand markers as they would interfere with hand hygiene required within NHS sites (NIPCM 2022). In addition, the hand is less frequently documented as a work-related injury within hospital settings (Glover et al. 2005). Within the wrist and hand, the thumb is the main area of injury with manual therapies the main risk factors for injury; such therapy is performed in a musculoskeletal outpatient, not neurological settings (Glover et al. 2005; Snodgrass et al. 2003).

Body measurements were taken as input variables for the Xsens MTw Awinda system, following the Xsens guidance (Xsens 2021) (Appendix 12). These measurements were used within the Xsens software to calculate segment lengths for each participant using anthropometric and biomechanical modelling (Xsens 2021). A measuring tape was used to measure height (with shoes on), shoulder height, hip height, shoe length, shoulder width, elbow span, wrist span, hip width, knee height, and ankle height. Details of all measurements are outlined in Table 4.3. The definitions of measurements were taken from the Xsens MTw Awinda user manual (Xsens 2021). The same researcher took the participants body measurements throughout the study, which should have improved the consistency of the measurements and reduced error.

The Xsens MTw Awinda system was chosen for this project as it would allow for field measurement of physiotherapists with real patients in the clinical environment. The system has been found to be a valid and reliable tool for measuring human movement and ergonomics outside of the laboratory environment. Xsens MTw Awinda is simple to use, quick to set up and calibrate. The same researcher applied the tracker units and calibrated the system throughout the project. The wireless tracker units limited interference with the physiotherapists' movement and patient handling. The trackers were worn under the PPE and allowed the physiotherapists to complete their working day as normal. After the Xsens MTw Awinda trackers were placed on the participant the researcher could follow social distancing guidance and remain two metres from the participants and patient volunteers throughout the data collection sessions.

Table 4.3: Participant measurements taken to facilitate Xsens motion analysis participant calibration (Xsens 2021)

Key: C7 – 7th Cervical Vertebra, ASIS – Anterior Superior Iliac Spine, T-pose – arms extended out to sides with palms facing down

Dimension	Description
Height	Ground to top of head when standing upright with shoes on
Shoulder height	Ground to 7th cervical spinal process (C7)
Hip height	Ground to bony prominence of greater trochanter
Hip width	Right anterior superior iliac spine (ASIS) to left ASIS
Knee height	Ground to lateral epicondyle on the femoral bone
Ankle height	Ground to lateral malleolus
Shoulder width	Right acromial angle to left acromial angle
Elbow span	Right olecranon to left olecranon with participant standing in T-pose
Wrist span	Right ulnar styloid to left ulnar styloid in T-pose
Arm span	Top of middle fingers of each hand in T-pose
Shoe length	Full length of shoe.

4.11 Methods

This section will describe the methods used to collect data during each participant session. The methods used for data processing and analysis will then be discussed.

4.11.1 Demographic Data and NMQ-E

After written informed consent had been gained (Section 4.8.4) various demographic data were collected. Each participant's age, sex, handedness, years qualified, and years working within neurological rehabilitation was collected on paper by the researcher. The researcher also provided the participants with a paper copy of the NMQ-E. They independently completed the questionnaire and returned it to the researcher.

4.11.2 Tracker Placement

The participant measurements (Section 4.10.2) were taken and entered into the Xsens MVN Analyze software. The measurements were used to set the body dimension within the Xsens MVN Analyze software scaled to each individual. The tracker units were then placed onto the participant following the order described previously (Table 4.2 in Section 4.10.2). The trackers were attached using FabriFoam® straps and a vest, which were worn over the participant's clothing. The trackers on the lower leg were applied under the participant's trousers. The uniform trousers were loose fitting at the lower leg and resulted in increased superficial movement when placed over the trouser. The straps were secured tightly to minimise soft tissue and clothing artefacts and movement during the recording session. Some of the trackers were strapped under the FabriFoam® straps to reduce the risk of them becoming displaced or detached during data collection. The tracker on the foot was an exception and was strapped to the dorsal surface of the shoe using tape to minimise movement on the shoe. The Xsens MTw Awinda system attached to a participant is shown in Figure 4.5. This figure also illustrates how the PPE was not affected by the Xsens MTw Awinda system and vice versa.

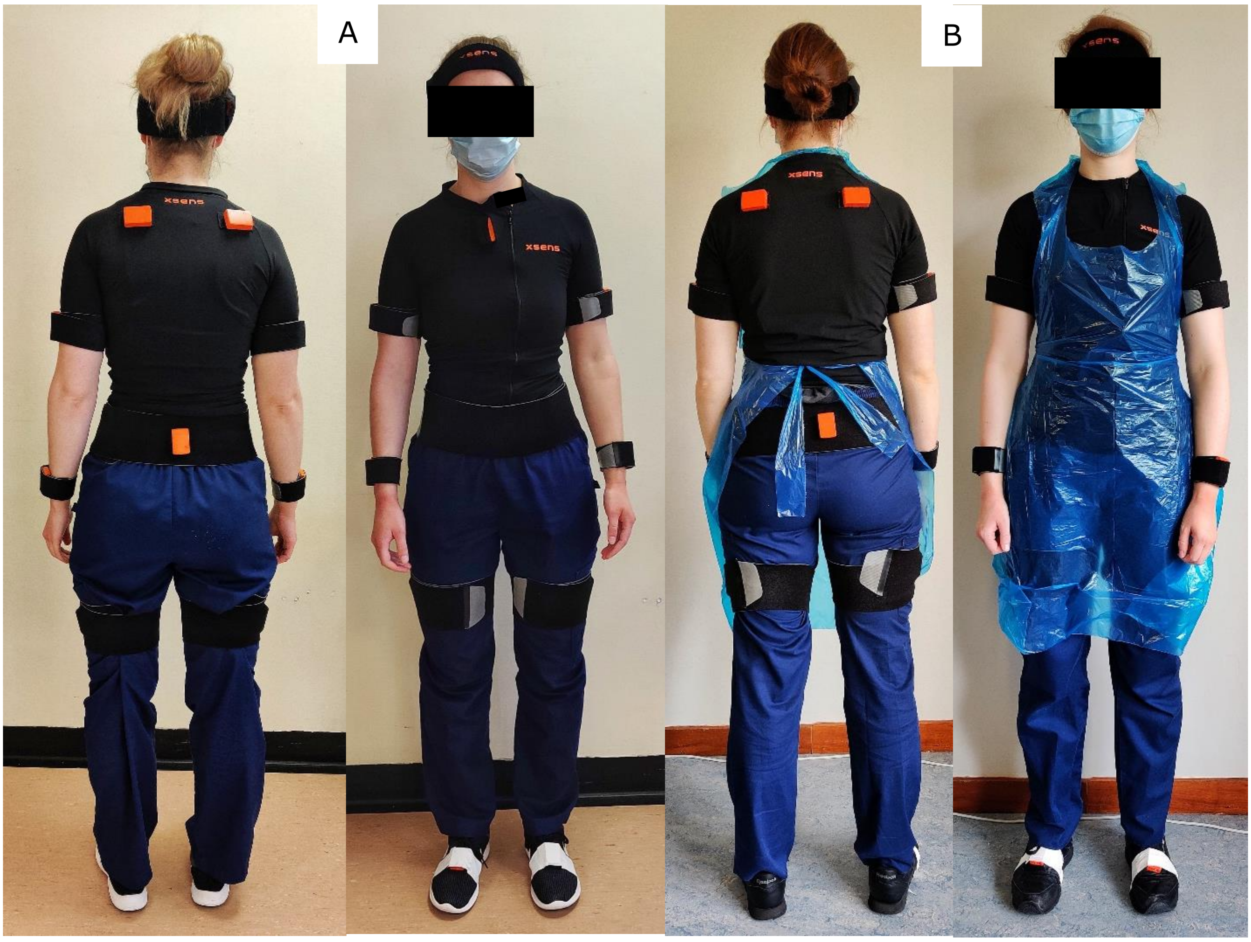


Figure 4.5: Full body tracker placement (A) without and (B) with Personal Protective Equipment

4.11.3 Calibration of Xsens MTw Awinda System

The system was calibrated after all the trackers were placed on the participant but prior to the first patient handling session. Calibration was completed to align the tracker units to the segments of each participant. Accurate calibration of the Xsens MTw Awinda system was important to ensure the data collected was of a high quality and that the system had magnetic immunity to the surrounding environment. There are different calibration sequences that can be used with Xsens MTw Awinda. The sequence chosen for this project was 'Npose + Walk' as this was the recommended sequence for best results when using the MTW system at the time of the study (Xsens 2021). This sequence included an Npose (Figure 4.6), which is a static standing posture, followed by a relaxed walk. The participant was asked to stand still with their feet parallel and one foot-width apart under the hips, back straight, shoulders relaxed, and arms straight and alongside the body with thumbs facing forwards (Xsens 2021). The walk involved the participant walking forwards in a relaxed manner for 7-8 metres before making a smooth U-turn and returning to the starting position and direction. The participant then stood still in N-pose until the calibration was finished processing. During the final step of the calibration, the participants were asked not to make any sudden or large movements until the processing was complete. The entire calibration process took approximately 30 seconds to

Figure 4.6: N-pose for static calibration (Xsens 2021)

complete.

Calibration performance can be categorised into one of four qualities: good, acceptable, fair, and poor. Xsens state the quality of calibration is based from standing still, expected segment alignment and detection of the calibration walk. No specific values or quality assessment is stated within the Xsens MTw Awinda user manual (Xsens 2021). Xsens state that good or acceptable quality calibrations are sufficient for data collection (Xsens 2021), however, an acceptable calibration should be considered for recalibration. To ensure quality data within this project, good quality calibration was aimed for each participant. Acceptable, fair, or poor calibrations were re-calibrated until a good calibration was achieved. It is worth noting that a good quality calibration does not guarantee that the calibration is anatomically correct. The location of extremities was checked to ensure that the calibration was anatomically accurate prior to data collection. If the avatar on MTw showed inaccuracies with location of the participant's feet and forearms, the calibration was repeated until it was visually accurate. When a good quality and anatomically correct calibration was achieved, that calibration was applied, giving a defined origin and heading. Within Xsens MVN Analyze, the origin is defined as the right heel, and the direction the participant is facing set as the positive X-axis. This is illustrated as a red triangle within the MTW interface.

After calibration, the participant was asked to walk for 10-20 seconds to 'warm-up the filters', following Xsens recommendations (2021), and to provide initial data for MTw. This increased the quality and stability of the motion capture data. After this process, the system was ready for data recording (Xsens 2021). The calibration was saved in case of the system crashing or closing unexpectedly. Saving the calibration allows for the previous calibration data to be loaded and applied without having to repeat the calibration process. In total, taking the participants measurements, application of the tracker units, and calibration took under 30 minutes. Calibration was completed at least twice, at the start of the data collection day and before the afternoon treatment sessions. Calibration was only performed in addition to these times if the sensors had moved during a session and the joint angle data were affected. Xsens has been found to have less than 5° root mean square error during recordings of over 90 minutes (Schepers et al. 2018).

4.11.4 Data Collection

Following the system calibration, the participants were asked to perform full body ROM movements. The participants were asked to perform full body active ROM from head to toe, the movements are outlined in Table 4.4. The researcher spoke them through the movement order so that all participants performed the same movements. The physiotherapists were standing during these movements. It was hoped that moving through full range would allow the participants to become more comfortable with the system and ensure that the straps and sensors were secure during movement. Performing full body ROM movements also allowed for measurement of each individual's joint ROM.

Table 4.4: Full body active ROM movements

Joint	**Movement**
Neck	Flexion and extension Side flexion left and right Rotation left and right
Shoulder	Flexion and extension Internal and external rotation Abduction and adduction
Trunk	Flexion and extension Side flexion left and right Rotation left and right
Hip	Flexion and extension Internal and external rotation Abduction adduction
Knee	Flexion and extension

After calibration and the active ROM movements were completed, the researcher asked if the participant felt comfortable with the system. If the participant had no concerns with the system, the patient handling recording could commence. If any part of the system felt uncomfortable or not secured, this was fixed by adjusting the straps or trackers and then re-calibrating the system prior to recording the first session. The physiotherapists were encouraged to perform their treatment sessions and patient handling tasks as normal throughout the data collection day. Due to battery life limitations, the Xsens MTw Awinda trackers were removed and re-charged during the physiotherapist's lunch break. The straps and vest were left on the participants to lessen the impact on their working day by having to re-apply them. The system was re-calibrated after the trackers were replaced to ensure a high quality of data collection. The physiotherapists verbally stated the beginning of the session to the researcher and recording then started. Recording was finished when the session was complete; this was also verbally stated by the physiotherapist being recorded. As the research was exploratory and the patient handling tasks were not known, the entire session was recorded to allow all patient handling to be included. Each patient treatment session was recorded separately to assist with management of data processing and ensure each recording was of a high quality. The physiotherapists included all work full-time, therefore there was potential to record up to five sessions during the data collection day.

4.11.5 Physiotherapist Movement During Patient Treatments

Physiotherapist positions and patient handling tasks were manually documented by the researcher during the session using the table found in Appendix 11. Time points when the physiotherapist stopped patient handling to move equipment or changed task were noted on paper by the researcher. The time points, observation notes and recorded data were used when processing the data. The patient handling task was observed and documented by the researcher. Additionally, the physiotherapist's position was noted with the patient task to provide a more comprehensive description. From observation of the treatment sessions, the physiotherapists position varied between standing, walking, sitting/perching, high kneeling, low kneeling, and half-kneeling. Physiotherapist positions were organised into standing, sitting, kneeling and half-kneeling to aid with description of physiotherapist positioning during patient handling tasks.

During recording, the physiotherapist was viewed real-time on the MVN interface as an avatar. The researcher observed the avatar throughout each session to ensure no trackers had moved from their calibrated position during tasks. If any trackers had moved the avatar would show unrealistic movements or body positions. If the trackers could not be quickly amended during the session, the time the error occurred was noted so the affected data could be excluded. The system was not re-calibrated during patient treatments as this would impact their treatment. Instead of impacting on the treatment, the 30 second re-calibration procedure was completed between patient treatment sessions.

After the final patient treatment session for each participant was completed, all the trackers and straps were removed and wiped using NHS standard cleaning wipes before being returned to the storage case. The vest and headband were washed between uses following manufacturing guidelines (Xsens 2021).

4.12 Model and Data Processing

4.12.1 Demographic Data

The demographic data collected on paper were collated by the researcher into Microsoft Excel© (Excel) for analysis. Descriptive statistics, such as mean and standard deviation, were calculated and the demographic results summarised in a table in the results chapter.

4.12.2 Extended Nordic Musculoskeletal Questionnaire

Data collected from the NMQ-E questionnaires were entered manually into Excel for analysis by the researcher. Data for each participant were entered for the nine anatomical areas investigated. Initially, the total number or injuries over the lifetime period was calculated for each region and presented as a percentage total. The average age at onset of WRMSD discomfort was then calculated for each region. The remaining questions of the NMQ-E questionnaire were all yes/no answers. For each of these questions, a total and percentage were calculated and displayed in a summary table in the results chapter.

4.12.3 Descriptive Data

The number of patient sessions performed in total was summarised with the average and standard deviation of session duration. The duration of each session was presented graphically for each physiotherapist to illustrate the variation in task duration. Patient tasks were organised into the area or movement the physiotherapist was treating. The patient tasks were: 1) lie-to-sit; 2) sit-to-lie; 3) sit-to-stand, 4) upper limb, 5) lower limb, 6) trunk, 7) standing and 8) walking. Helping patients with personal care tasks (e.g., dressing, donning of shoes or splints) and transfers of patients (e.g., using a full body hoist from bed to wheelchair) were excluded. This research focused on therapeutic handling of patients and personal care and transfers were considered out of the scope of this research. Within each of the patient tasks, physiotherapist position was also considered and organised into: 1) kneeling; 2) half-kneeling, 3) sitting, and 4) standing. This allowed for a more detailed investigation into physiotherapist position during each patient task.

4.12.4 Biomechanical Model

All motion analysis systems use biomechanical models and related assumptions to calculate body segment positions and joint angles. The Xsens MVN biomechanical model is based on the International Society of Biomechanics (ISB), Grood and Suntay recommendations, and Euler angle decomposition (Wu and Cavanagh 1995; Xsens 2021). Euler angles are used in calculating the biomechanics of rigid bodies; 3D joint movement is described with three angles around the anatomical axes represented (Karduna et al. 2000; Xsens 2021). The planes of motion and directions of joint movement within Xsens MNV Analyze are Z (flexion/extension), X (abduction/adduction), and Y (internal/external rotation) (Xsens 2021).

The segment origins differ in Xsens MTw Awinda to optoelectronic motion systems, such as Vicon, as the trackers are not placed on bony landmarks. The trackers are, instead, placed on anatomical regions as mentioned previously (Table 4.2 in Section 4.10.2). The overall approach to calculating body segment position based on tracker placement is described below. The shoulder joint angle calculations differ in Xsens MVN Analyze to the Euler extraction. Xsens MVN Analyze provides three shoulder joint angles: between C7 and the shoulder segment; between the shoulder segment and upper arm following Euler sequence ZXY calculations; and between the shoulder segment and upper arm following Euler sequence XZY calculations (Xsens 2021). The ZXY calculations provide full internal rotation, external rotation, flexion, and extension. The XZY calculations provide full abduction and adduction movements. Other joint angles measured using Xsens MVN Analyze are all based on the Euler sequence ZXY.

Xsens MVN Analyze calculates positions of body segments with respect to an earth fixed global reference frame (Xsens 2021). This global reference frame defines the: x-axis as positive when pointing to local magnetic North; y-axis according to right-handed co-ordinates (West); and z-axis is positive when pointing up (Figure 4.7). During the system calibration the body frames are aligned with the global reference frame. The body frames are defined as: x-axis forwards; y-axis up, from joint to joint; and z-axis pointing to the right. The

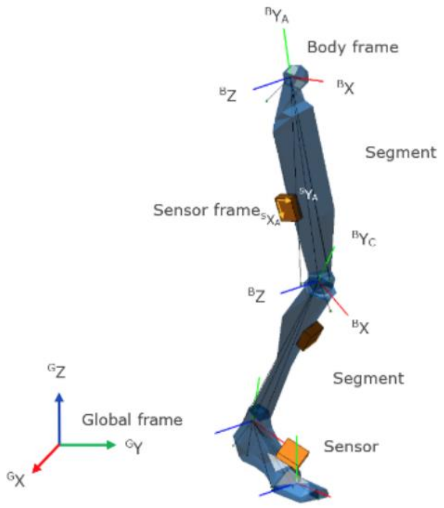


Figure 4.7: Global reference frame (x red, y green, z blue) and body reference frames (Xsens 2021)

body frames are used as an intermediate to calculate joint angles (Xsens 2021). The Xsens MVN Analyze segment definitions are detailed in Appendix 14.

4.12.5 Motion Analysis Data

When the physiotherapist stated the end of the patient treatment, the recording was stopped. The recordings could then be processed and saved within the Xsens MVN Analyze software (MTw Studio BIOMECH) (Xsens 2021) as an MVN file. Each MVN file contained the measured inertial sensor and kinematic data for each segment (Xsens 2021). The 3D (Z, X, Y) joint angle data were then exported as an MVNX file with a 'frame skip' of 5 frames set. Frame skipping allows for down sampling of the data by skipping certain frames (Xsens 2021). Xsens MVN Analyze recorded data at 60 frames per second (fps), therefore the exported data was the equivalent of 10 fps after applying the frame skip to the data. Frame skipping was applied when exporting data as the movements conducted during patient handling tasks are slower and controlled compared to sporting movements for example. Lower frame rates have been used previously in motion analysis research with benefits including ease of set up and analysis of data (El-Sallam et al. 2013).

To check the effect of the selected frame skip sample data were piloted for data processing; data were placed into bins of joint angle ranges and the time within each bin calculated for both 60fps and 10fps data. The time spent in each joint bin was equal for both recording speeds. Therefore, an output rate of 10fps was used for all data exporting and processing. Additionally, it aided data management within excel by reducing the number of rows of data as the recordings were over 30-minutes in total. The researcher imported each MVNX file into Excel. Within Excel, each column represented an axis of joint motion for each of the joints measured. Each row within Excel contained data for each frame, meaning ten rows was one second worth of data.

4.13 Data Analysis

4.13.1 Joint Movement Description

Previous literature investigating WRMSD in physiotherapists and allied health professionals concluded that the low back was the most reported area for injury, with incidence rates varying for other anatomical region (Anderson and Oakman 2016; Campo et al. 2008; Glover et al. 2005). The main areas of interest and analysis were informed by previous research findings with a focus on the trunk (cervicothoracic and lumbosacral junctions), neck and shoulders as these are the most frequently documented anatomical regions of injury (Caponecchia et al. 2020; Gilchrist and Pokorná 2021; Milhem et al. 2016). Lower incidence rates of injury were reported at the elbows, knees, and hips.

Joints that were fully excluded from data analysis were the elbow, Thoracic (T9T8), Lumbar (L4L3) and ankle. The elbow and ankle were excluded because they were an area of less frequent injury and the trackers on the feet were frequently moved during data collection. The tracker movement affected the quality of data recorded at the ankle. The joints T9T8 and L4L3 were excluded as the upper, middle, and lower back movement was measured by cerviothoracic (C7T1), thoracolumbar (T12L1) and lumbosacral (L5S1), respectively. Additionally, the movement found at T9T8 and L4L3 was similar to the other trunk joints when compared using pilot data. Therefore, trunk motion was adequately measured and described using the three included joints (C7T1, T12L1 and L5S1), whilst also remaining feasible for data management.

At the shoulder girdle (T4/shoulder), the sagittal plane (Z) motion described axial rotation of the clavicle forwards and backwards. This plane of motion was excluded as the movements were small and deemed not clinically relevant to the research. At the knee, the coronal (X) and transverse (Y) planes described abduction/adduction and tibial rotation respectively. Only the sagittal plane (Z) motion at the knee was included because the other two planes of motion at the knee demonstrated a small ROM and deemed not clinically relevant to the study. The joints and movements that underwent analysis and description are displayed in Table 4.5. As this research was exploratory, data from these joints was included to allow for a comprehensive description of physiotherapist movement during manual patient handling tasks.

Anatomical regions of interest were based on previous research stating the most frequently reported anatomical regions of work-related injuries are the lower back, neck, shoulders, and upper back (Caponecchia et al. 2020; Gilchrist and Pokorná 2021; Milhem et al. 2016).

In Excel, data were separated into patient handling tasks based on the treatment type as described previously. The start and end frame count from Xsens was used to identify and separate each patient handling task. Each patient handling task was then selected and placed into a separate Excel worksheet to for further data processing. The physiotherapist's position during patient tasks initially described using a proportion of time spent in joint ranges. To achieve this, each joint ROM was organised into 5° ranges and the amount of time in each range calculated for each range. A macro was recorded in Excel to automate each stage of data processing. The joint angles were assigned a 5° bin range. The bin ranges were then counted and the percentage time for that patient task calculated for each 5° range. Five degrees were chosen as a range to allow for separation of data through the entire joint range for all joints. Five degrees allowed for separation and description of joint motion for both joints with a smaller and larger range of motion. The joint bins also were chosen to aid comparison to other literature which reference joint angles and percentage time in those positions (Ariëns et al. 2001). Data were then displayed using histograms and described in-text.

Table 4.5: Joint movements measured with Xsens MVN Analyze and discussed in this research

Joint	Plane	Movements	
C1Head, T1C7, L1T12, L5S1	x	Lateral bend to left	Lateral bend to right
	y	Axial rotation to right	Axial rotation to left
	z	Extension	Flexion
T4Shoulder	x	Elevation	Depression
	y	Retraction	Protraction
Shoulder	x	Adduction	Abduction
	y	External rotation	Internal rotation
	z	Extension	Flexion
Elbow	z	Extension	Flexion
Hip	x	Adduction	Abduction
	y	External rotation	Internal rotation
	z	Extension	Flexion
Knee	z	Extension	Flexion

Additionally, lie-to-sit, sit-to-lie and sit-to-stand tasks were time normalised over the duration of a task and illustrated graphically. The decision to time normalise these three tasks (lie-to-sit; sit-to-lie; sit-to-stand) was taken due to the start and end points of the task being the same for all participants. Other tasks, such as upper limb or lower limb treatments, varied with different movements being performed and therefore did not have clear cut-off points for time-normalisation. The tasks were time-normalised to allow for investigation of patterns of movement during the duration of patient handling tasks. Lie-to-sit, sit-to-lie and sit-to-stand task data were time normalised by using a spline function within Excel. All tasks were time normalised to a count of 100, allowing comparison of all participants. The time normalised data were presented for each physiotherapist position to allow for comparison within each task. A descriptive analysis commenting on general patterns of movements or positions, and the relation to observed patient handling tasks accompanied the graphs for each task.

4.13.2 Ergonomic Comparison

The joint postures at the neck, trunk and shoulders during patient handling tasks were interpreted with the Rapid upper Limb Assessment (RULA) tool. Additionally, ergonomics literature was used to identify postures and time maintained that have previously been found to increase risk of injury (Ariëns et al. 2001; Delleman and Dul 2007; Hoogendoorn et al. 2000; Naveen 2016; Palmerud et al. 2000; Punnett et al. 2000; Vieira and Kumar 2004). There are many ergonomic assessment tools available. The RULA was chosen as it has shown moderate to good inter-rater (ICC 0.54-0.72) and intra-rater (ICC 0.50-0.77) reliability and has been used with healthcare populations previously (Dockrell et al. 2012). Additionally, it has been found to be more sensitive and precautionary than the Rapid Entire Body Assessment (REBA) and Ovako Working posture Assessment System (OWAS) (Kee 2022). The RULA is also stated to be more precautionary than the OWAS, and therefore potentially more protective to workers (Kee 2022).

The RULA tool is used to assess working postures. A numerical score is associated with joint positions and the forces involved. The scores are totalled, and the final scores used to guide whether further investigation or change is recommended. The positions of risk at the shoulder, neck, trunk, and final scores are shown in Figure 4.8. These scores are taken from the RULA worksheet (Figure 4.8). The RULA was used as a guide to identify any tasks or physiotherapist positions that could score higher when ergonomically assessing them.

Many working positions or postures have been found to increase the risk of WRMSD (Ariëns et al. 2001; Naveen 2016; Vieira and Kumar 2004). The literature has stated an individual’s risk of injury is higher if certain joint angles are maintained for a certain percentage of the working day (Ariëns et al. 2001; Naveen 2016). Some examples of these at-risk joint angles are trunk forward flexion greater than 60 degrees for 5% of their working day; trunk rotation greater than 30 degrees for 10% of their working day; shoulder abduction greater than 15 degrees for 33% of their working day; and shoulder flexion greater than 90 degrees for over 10% of their working day (Ariëns et al. 2001; Naveen 2016; Vieira and Kumar 2004). These values and time periods vary within the literature but were able to provide suggestions into quantification of positions or postures that may increase risk.

Most patient moving and handling literature stated activities increasing an individual's risk of injury were repetitive movements; working in the same position for a prolonged period; bending and twisting your back; lifting and transferring patients; and assisting patients during gait (Campo et al. 2008; Chung et al. 2013; Glover et al. 2005). Values for joint angles or proportion of their working day, however, were not stated in addition to these risk factors. The proportion of time the physiotherapists maintained a joint position during patient handling tasks was used and compared with the values from previous literature. The literature calculated these risk factors from a full working day, in this study physiotherapists were only recorded during the patient handling tasks as other tasks during the day involved documentation, breaks, cleaning of equipment or meetings and as these do not involve manual handling of patients they were deemed out of the scope of this research.

Comparison of the data measured in this research to previous findings was displayed in a table for each joint discussed. The joint movement was initially compared against the RULA position and scoring, with additional comparison against ergonomics literature. The RULA scoring ranges were applied to the joint 5° bin ranges at the neck, trunk and shoulder to illustrate proportion of the task time spent in each scoring range. The RULA was not used as intended, but rather for a crude assessment of the physiotherapist postures during patient handling. The RULA is illustrated in Figure 4.8 and defines a scoring system representing risk of musculoskeletal disorder (Middlesworth 2021). The RULA assesses the worker's upper arm, lower arm, wrist, neck, trunk, and leg position. The RULA additionally can assess for twisting, repetition and force involved. When using the RULA, the worker is assessed and scored by an observer, and the resulting score is used as a guide for musculoskeletal risk. A RULA score of 1-2 is acceptable, 3-4 requires further investigation and change may be needed, 5-6 requires further investigation and change soon, and a score of 7 requires investigation and implementation of change Figure 4.8. The data presentation from joint movement description was amended to show the associated scores and joint positions. This allowed for clearer illustration of the percentage time of the tasks spent in each joint range and associated RULA score. The joint positions and potential scores were additionally described in-text.

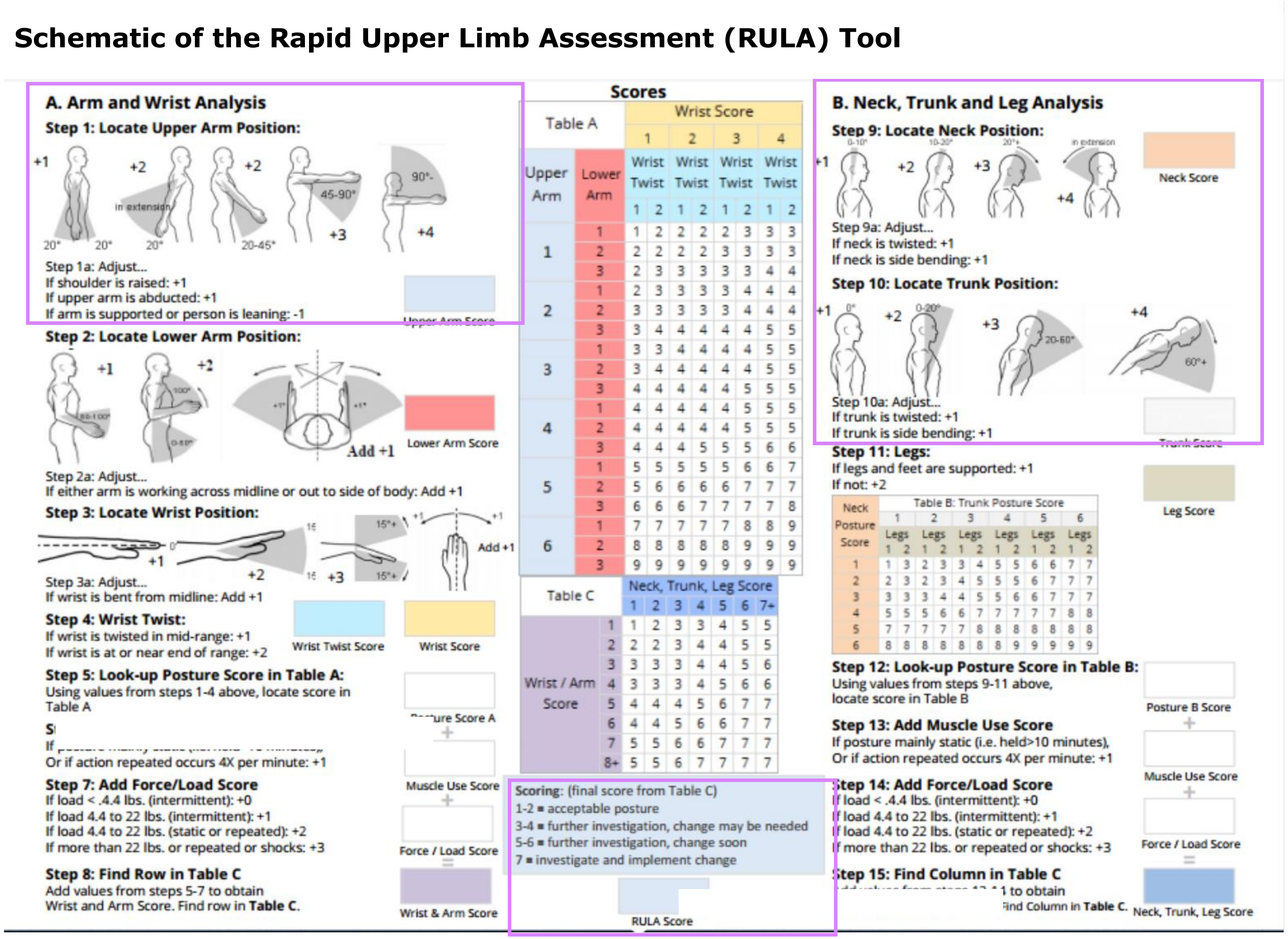


Figure 4.8: RULA with scores used within this research highlighted (Adapted from Middlesworth 2021)

4.13.3 Extended Nordic Musculoskeletal Questionnaire Analysis

Incidence of WRMSDs over the participants' working career were summarised in a table and described in-text. Anatomical regions found to have a higher incidence were highlighted in text. Any regions found to have WRMSDs were then further analysed over three time periods: 12-month; one-month; and on the day. Following the structure of the NMQ-E, work and personal impacts were then analysed and a count of any effects for each anatomical region illustrated in a table. There is no recommended method to analyse and present the data from the NMQ-E, however, other research has presented the findings in a similar manner (Dawson et al. 2009).

4.14 Summary of Methods

This chapter has discussed the philosophical underpinnings, study design and methodology of this research. The chapter then presented and justified the methods used to investigate each of the three research objectives set previously. The following chapter will present the study findings, and they will be discussed in Chapter 5.

5. RESULTS

5.1 Introduction

This section outlines the results of the study in relation to the previously stated research questions (Section 3). Initially section 5.2 outlines the participant demographics, then describes how the physiotherapists moved during each of the eight tasks. For each of the eight tasks, the duration spent in joint angles is displayed for each physiotherapist position. Where possible, the joint angle data is compared with previously published ergonomics literature and the RULA tool. Physiotherapist positions and postures that are suggested to be unfavourable ergonomically will be identified. Finally, the results will report the findings from the NMQ-E and any possible relationships with positions, tasks, or ergonomics.

5.2 Participant demographics

Ten physiotherapists who worked in neurological rehabilitation participated in the data collection sessions. Table 5.1 summarises participant demographics. All the participants were female, most (90%) were right-hand dominant, and a range of staff seniority levels and years of experience were represented in the sample.

Table 5.1: Participant demographics

Characteristic	**Summary**
Sex	10 female
Handedness	9 Right, 1 Left
	Average (SD)
Age (years)	35.9 (10.4)
Years qualified	13.65 (10.8)
Years in neurological rehabilitation	10.15 (10.1)

5.3 Overall Description of Data Collected

During data collection, six participants treated four patients, with the remaining four participants treating five patients during the day of recording. In total, participant movements were recorded during 44 patient treatment sessions. A variety of patient assistance levels were included. Most patient sessions were double (31/44 sessions), with two staff members providing treatment. Nine patient sessions were with one member of staff, and four involved three staff members. The number of staff involved in the treatment session was dependent on the patient's level of disability or mobility. Other staff members involved in treatment sessions were other physiotherapists or healthcare support workers. The patients involved in the treatment sessions ranged from independently mobile to requiring a full body hoist for transfers due to significant physical disability.

The average duration for each patient session was 40-minutes and 03 seconds (SD: 8-minutes 44 seconds); each participant's session durations are shown in Figure 5.1. Most treatment sessions were performed in the physiotherapy gym for that ward (37 of 44). The other seven sessions were performed at the patient's bed space. Twenty-four treatment sessions started in the patient's room before moving through to the physiotherapy gym for the treatment session. The patient either attended the gym themselves or was brought through by another physiotherapy staff member for the remaining 13 gym-based sessions. As this research was exploratory and it was not known what the session would entail, recording started when the physiotherapist being recorded stated they were beginning. This was either in the patient's room or in the physiotherapy gym.

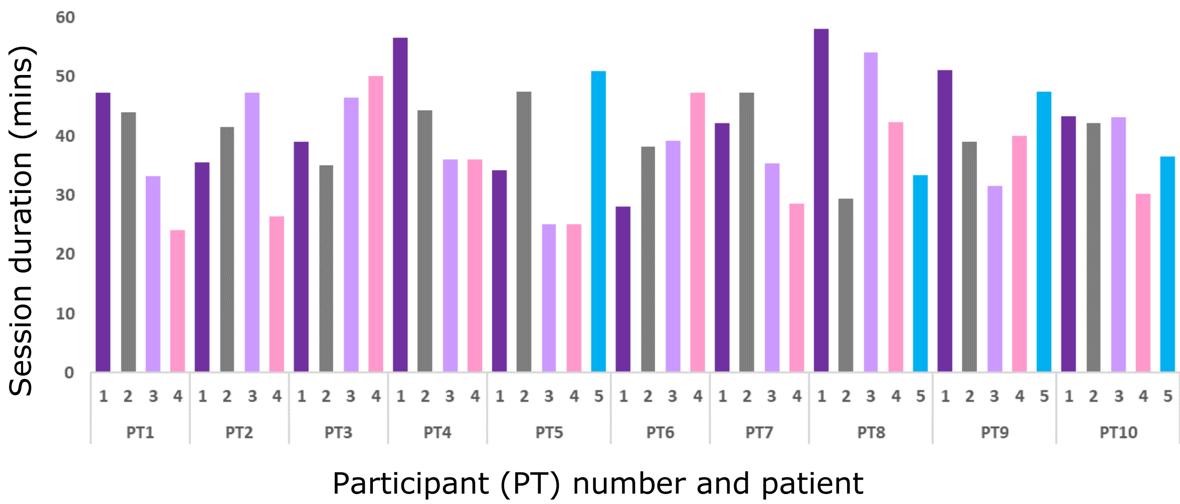


Figure 5.1: Patient treatment session duration

Tasks performed during the patient treatment sessions were organised into eight tasks by the researcher during data processing and analysis. Organisation depended on the area of the patient's body being treated or the task being performed by the patient. The tasks were: 1) lie-to-sit, 2) sit-to-lie, 3) sit-to-stand, 4) upper limb, 5) lower limb, 6) trunk, 7) standing and 8) walking. Stand-to-sit was not included as a separate task to sit-to-stand tasks as they were performed only three times within the sessions. Organising the patient treatment tasks allowed for more specific description of physiotherapist movement during each task as physiotherapist position varied depending on the task. The average number of tasks per patient session was 12.5 (SD: 4.5) with the average duration for each task being 114 seconds (SD: 80.3 seconds).

Table 5.2 provides a summary of example treatment tasks performed for each of the eight task groups. As discussed in Section 1.4, the aim of therapeutic handling is to improve patient function and independence (Smith et al. 2014).

Table 5.2: Patient task and movements

Task	Patient movement	Physiotherapist handling
Lie-to-sit and sit-to-lie	Assist patient from lying down to sitting Assist patient from sitting to lying down	Assist at patient trunk or legs in kneeling or standing
Sit-to-stand	Sitting to standing Standing to sitting	Support at hips and knees, trunk in sitting, kneeling, or standing
Upper limb	Stretches of hand/fingers/wrist/elbow/shoulder Sensation at forearm/hand/fingers Joint compression/distraction at joints of upper limb Active movement of wrist/elbow/shoulder Functional task with upper limb (reach and grasp, stacking cones etc.) Scapula movement	Assist at patient upper limb with hand hold and support at elbow De-weight upper limb Sitting (perch sit, sitting on stool), standing next to patient, half kneeling onto plinth
Lower limb	Stretches of ankle/knee/hip Sensation at foot/ankle Mobilisation of joints of foot and ankle Active movement of ankle/knee/hip Stability and strength exercises (bridges, bent knee fall outs, clams) Small knee bends	Assisting patient movement in kneeling or sitting on plinth Providing resistance to patient in kneeling Hands on facilitation of muscles in standing next to patient/ sitting or kneeling on plinth
Trunk	Stretches (knee rolls) Sitting balance Soft tissue release Active movement (rotations, forward lean, reclined sit to upright sit)	Assisting trunk stretches in standing/kneeling Assisting patient from reclined sit to upright sit in kneeling Sitting balance/upper limb tasks in kneeling/sitting
Standing	Standing static balance Standing dynamic balance Lateral weight transfer	Supporting at patient hips and knees (sitting on stool) Facilitating patient weight to midline at pelvis (sitting on stool, kneeling behind on plinth) Facilitate muscle activity at core, hips, and knees (sitting on stool, standing)
Walking	Static stepping Side stepping Step up/down Walking with or without aid	Assisting lower limb and foot placement (sitting on stool) Assist with balance/weight transfer (Standing next to patient hands at trunk/hips)

From observation of the treatment sessions, equipment was used to assist patients with sit-to-stand, in standing and when walking. It was observed, however, that the physiotherapists would therapeutically handle the patients in addition to the equipment facilitating their movement or position. Lifting aids used included stand aids (e.g., Encore, ARJO walker) as illustrated in Figure 5.2. Other equipment used in patient treatments were additional plinths, foam cubes for support and walking aids (e.g., wheeled zimmer frames, walking poles or sticks).

Figure 5.2: Patient lifting aids, A: ARJO Sara Plus B: ARJO walker (ARJO, Bedfordshire, UK),

5.4 Physiotherapist Movement and Positioning

This section describes and quantifies the physiotherapist movement (research objective 1, section 3) during each of the tasks. The joint ROM is separated into 5-degree bins to allow for illustration and to provide an overview of joint position during the tasks. Subsequently for lie-to-sit, sit-to-lie and sit-to-stand, joint angles are time-normalised over the entire task and displayed graphically. The data displayed in this section is an average of the physiotherapist movements for each position within each of the eight tasks. No inferential statistics were ran for the data included in this research, the differences identified in the results are based on description alone. Joint movements for each plane and direction of movement are outlined previously in Chapter 4. The neutral position (0°) for each joint is defined from the standard anatomical position. Each joint segment axis direction is determined from the calibration position, in this research the calibration position was relaxed upright standing (Xsens 2021) (Figure 5.3).

Figure 5.3: Xsens calibration position

The physiotherapist movements are initially described by anatomical region: axial skeleton, upper limb then lower limb. Following each anatomical region description, the physiotherapists' overall movement for that task is summarised. Movements for all joints within the axial skeleton describe the physiotherapist movements as lateral bend (coronal plane), axial rotation (transverse plane), and flexion/extension (sagittal plane). A neutral (0°) position at the axial skeleton is the head and neck directed forward and the trunk in a relaxed upright posture. Movements within the upper limb are presented for the physiotherapists' shoulder girdle (T4/Shoulder) and shoulder joint. The movements in each plane of motion for the included joints are outlined previously in chapter 4. As discussed previously (Section 4.13.1), movements in the sagittal plane for the shoulder girdle (clavicle rotation) and the elbow were not included in the results. These movements were deemed not clinically relevant for this study based on previous literature investigating WRMSD in physiotherapists (Glover et al. 2005).

Since physiotherapists commonly use both upper limbs during manual patient handling, left and right limbs were analysed separately. Movements at the lower limb describe physiotherapist hip and knee movement while assisting patient tasks. The ankle was excluded in this study due to inaccuracies in data collection secondary to physiotherapist positioning and movement knocking the sensors and affecting the quality of data recording. In addition, the ankle has been documented as a less frequent area of injury in physiotherapists (Glover et al. 2005).

The hip movement describes abduction/adduction (coronal plane), external/internal rotation (transverse plane) and flexion/extension (sagittal plane). Movement at the knee describes flexion/extension (sagittal plane). As with the upper limb, left and right lower limbs are analysed separately. Not all joint movement graphs are included in the results chapter. Only movements that contained informative and sufficiently rich data are presented to aid with readability. To assist with accessibility of reading the graphs, the axes for each task differ to fit the data for that task. All other movements are found in Appendix 16.

Each of the eight tasks are now considered in turn, starting with lie-to-sit.

5.5 Lie-to-sit

The physiotherapists assisted lie-to-sit 14 times during the data recording sessions. The average duration for these tasks was 64 seconds (SD: 63 seconds). Figure 5.4 illustrates the variety of positions physiotherapists assisted this task and the frequency of each. Kneeling was the most common position for this task (42.9%). The physiotherapists kneeled on the floor next to the patient or half-kneeled on the bed near the patient. From observation, the physiotherapists aided the patients during this task either by supporting at the patient’s trunk or lower limbs. To aid this movement the physiotherapist guided the patient as they moved to sitting and rotated to sit over the end of the bed. When assisting at the trunk the physiotherapists either had hands on either side of the trunk or one hand reaching across the cervicothoracic junction. When assisting at the lower limbs, the physiotherapists held the patients' legs and assisted with lifting and turning over the edge of the bed. Assisting at both trunk and legs, the physiotherapist used a ‘scooping’ method to rotate the patient and assist them into sitting.

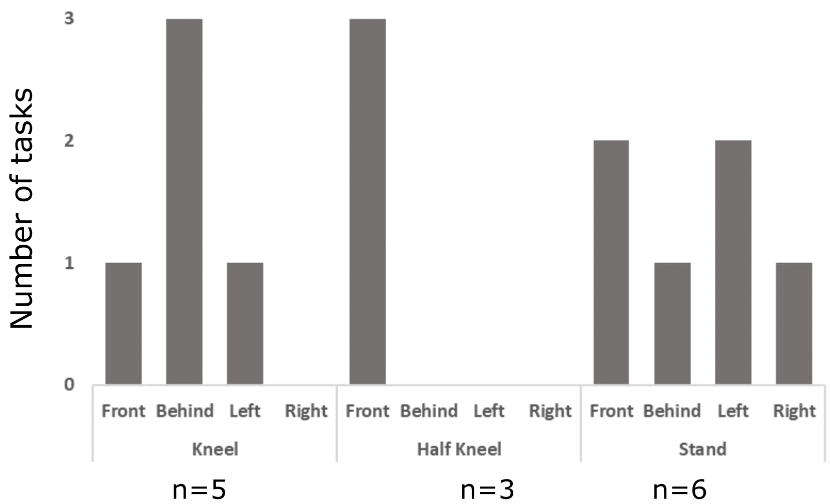


Figure 5.4: Frequency of physiotherapist positioning in relation to patient during patient lie-to-sit and sit-to-lie task (n=number of physiotherapists)

5.5.1 Proportion and Joint Angle Data Lie-to-sit Task

Neck movement (Head/C1)

The neck was generally near a neutral posture for both side bend and rotation when assisting lie-to-sit in kneeling or standing positions (Figure 5.5A, C). When the physiotherapist was half-kneeling there was slightly more rotation to the left than other positions (Figure 5.5B). The physiotherapist was initially kneeling to the left of the patient, when the patient then sat up over the edge of the bed the physiotherapist was then in front of the patient. The rotation at the neck is thus likely due to the physiotherapist turning their head toward the patient.

During lie-to-sit tasks, kneeling showed the neck was mostly extended between neutral to 10° extension (Figure 5.6A). Half-kneeling illustrated more time of the task was spent in a more extended angle than kneeling and standing positions, with a peak in task time between 21-25° extension found (Figure 5.6B). Standing showed more of an even spread of task time than the other positions with a peak in task time spent between neutral to 5° flexion (Figure 5.6C). When the physiotherapist was kneeling and half-kneeling the neck would need to extend when looking up to the patient or other staff member. When in standing, the neck may extend if the trunk is flexed forwards.

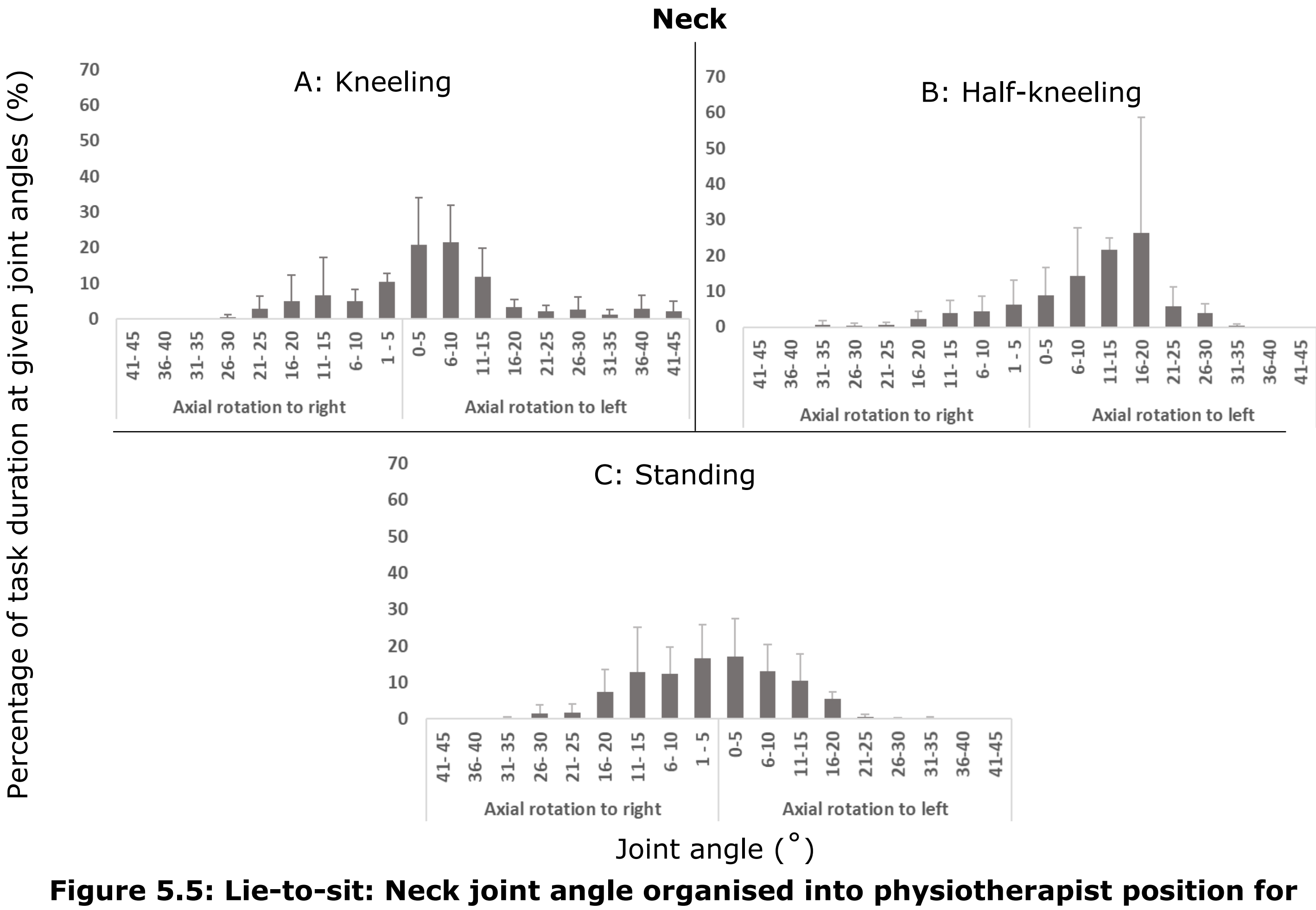


Figure 5.5: Lie-to-sit: Neck joint angle organised into physiotherapist position for right and left rotation with data collected in contiguous 5-degree bins (+1SD)

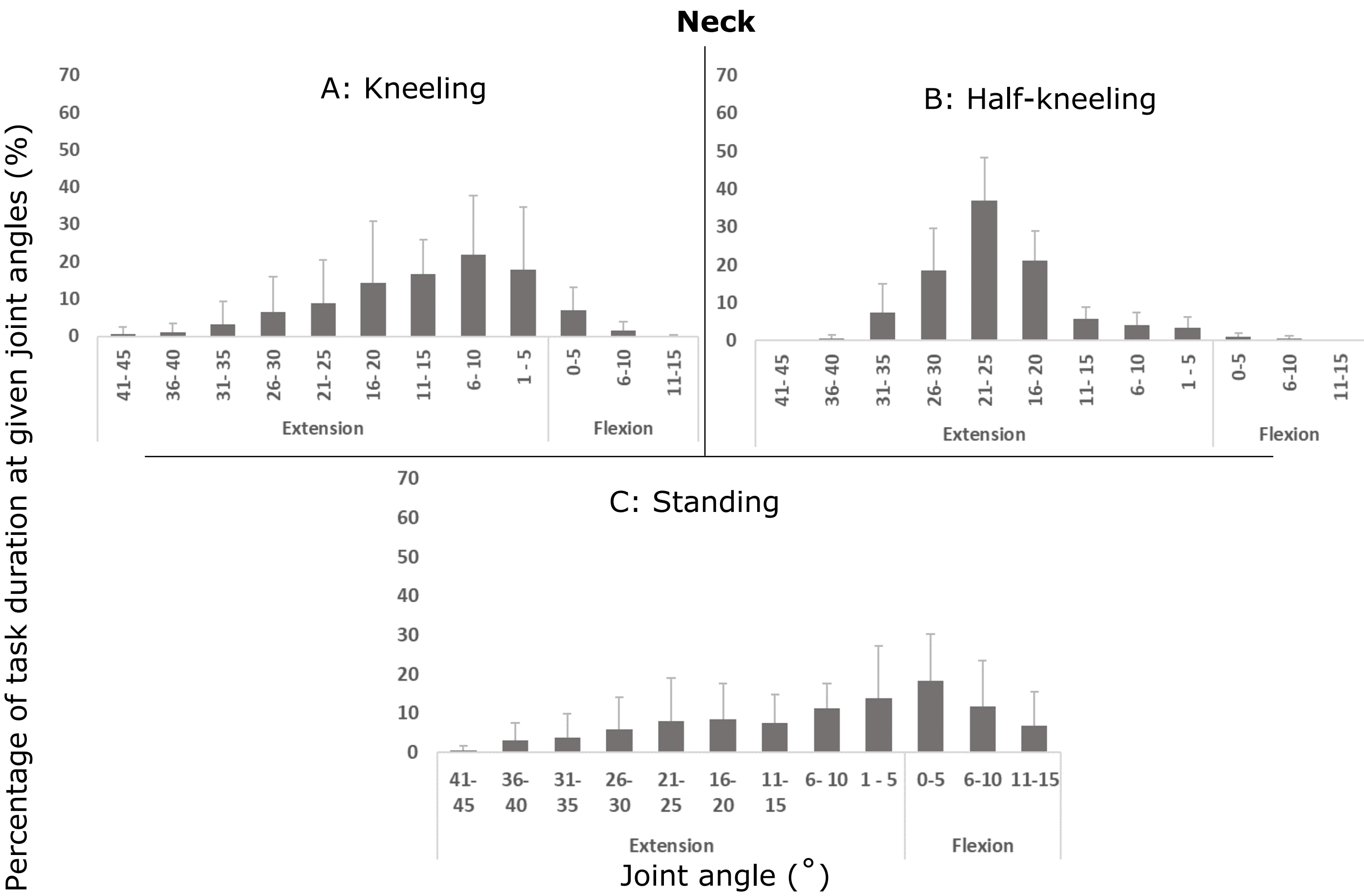


Figure 5.6: Lie-to-sit: Neck joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Cervicothoracic movement (C7/T1 Joint)

The cervicothoracic junction was generally within 10° of the neutral posture for lateral bend and rotation for all physiotherapist positions. The cervicothoracic junction illustrated the highest flexion angles when standing (max = 25-30° flexion) (Figure 5.7C), with the lowest flexion angles measured when the physiotherapists were in kneeling positions (Figure 5.7A). When the physiotherapists were in half-kneeling, 57% of the task time was spent between 6-10° cervicothoracic flexion (Figure 5.7B). This suggests that there was less cervicothoracic movement when facilitating lie-to-sit in a half-kneeling position to the other three physiotherapist positions. The increased flexion angle in standing could be related to the physiotherapist stooping down and reaching towards the patient when lying in bed.

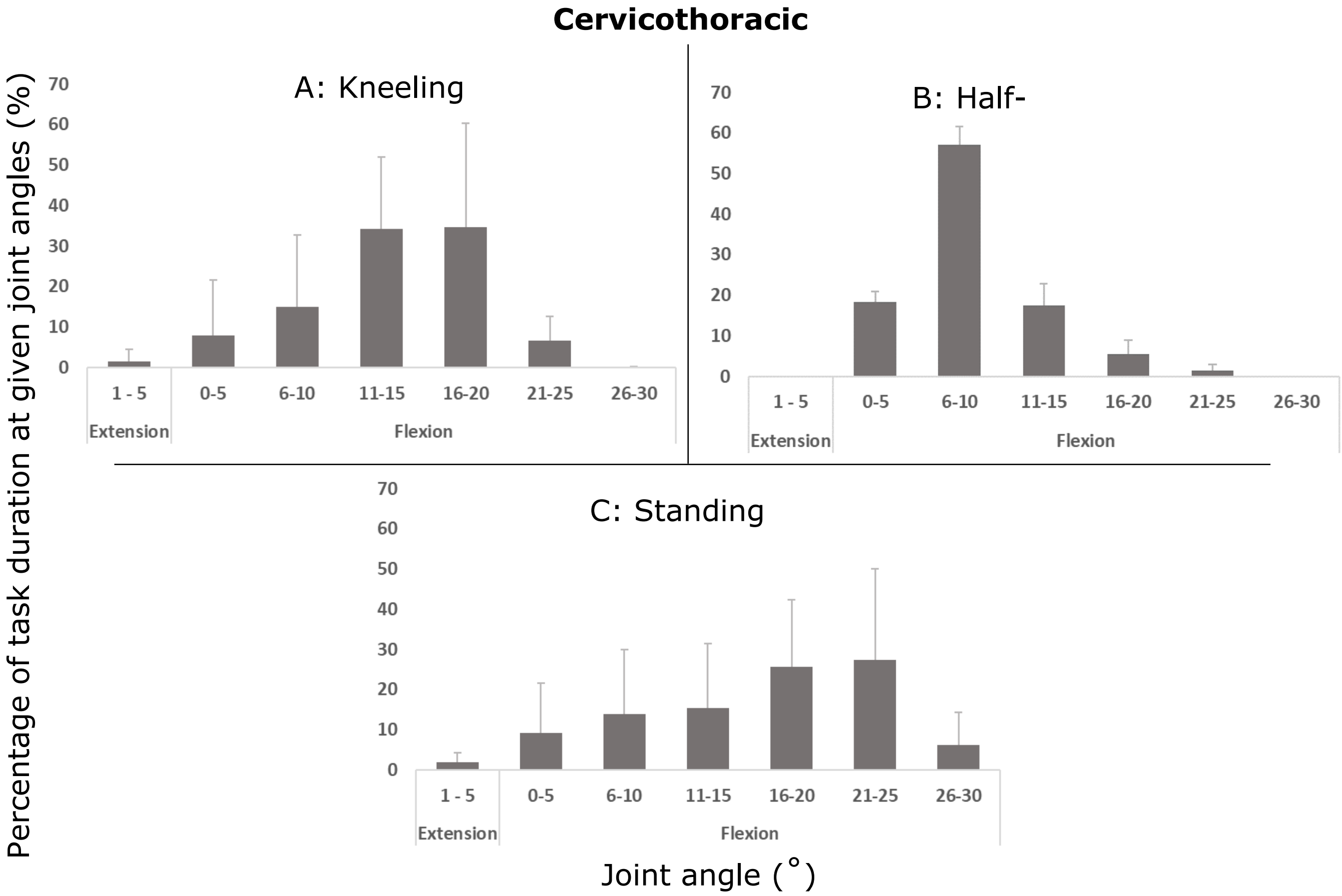


Figure 5.7: Lie-to-sit: Cervicothoracic joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Thoracolumbar movement (T12/L1 Joint)

The thoracolumbar junction was found generally to be near a neutral posture for both side bend and rotation for all physiotherapist positions. Kneeling showed more of a neutral thoracolumbar posture during lie-to-sit compared with the other physiotherapist positions (Figure 5.8A). Half-kneeling and standing positions showed the duration of lie-to-sit tasks was spent in thoracolumbar flexion; suggesting flexion was maintained in these two positions (Figure 5.8B, C). This thoracolumbar flexion would be in combination with the cervicothoracic flexion found previously when in kneeling and sitting positions, suggesting the trunk, as a whole, was flexed.

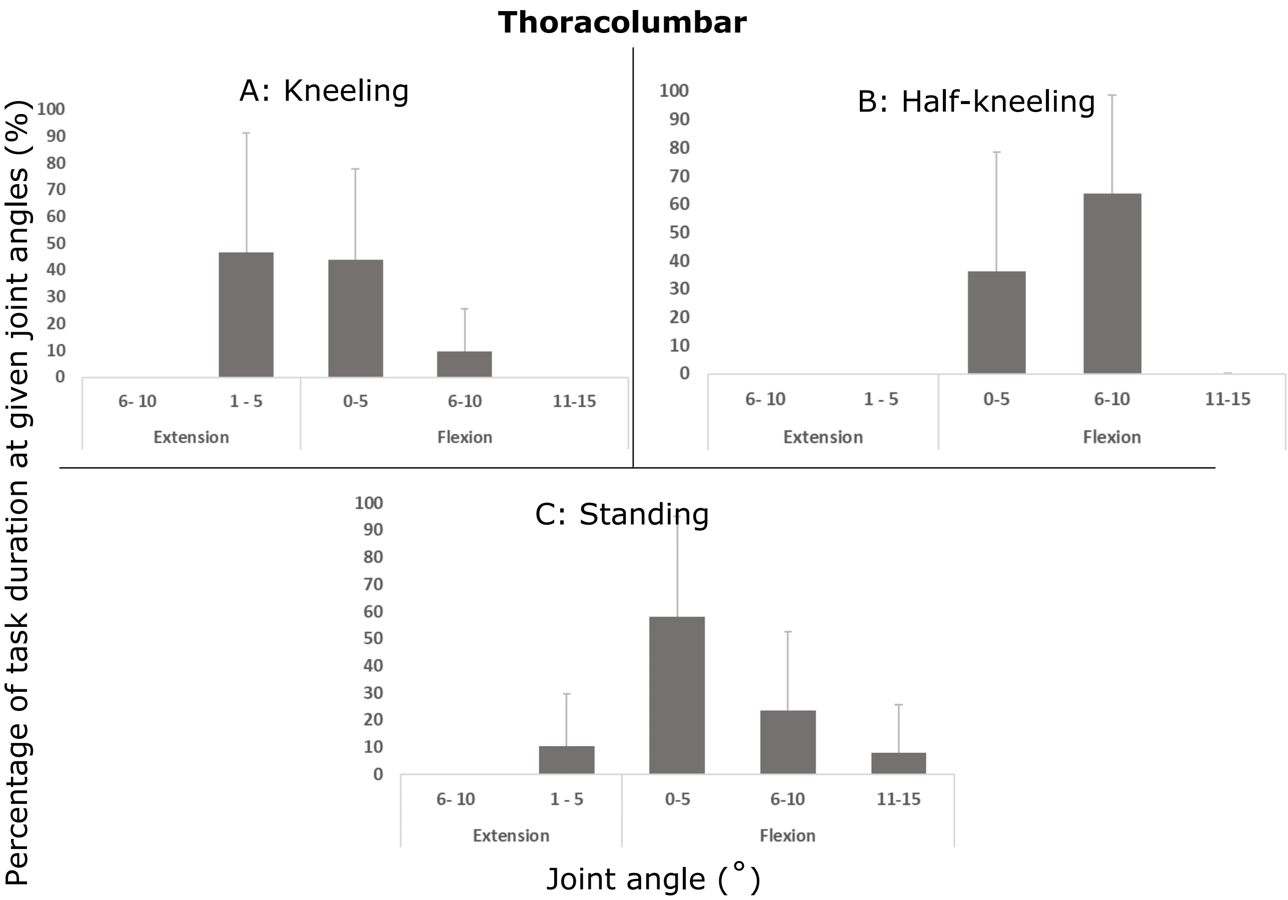


Figure 5.8: Lie-to-sit: Thoracolumbar joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Lumbosacral movement (L5/S1 Joint)

The lumbosacral junction was found to be generally around the neutral posture for side bend in both kneeling and standing positions. A slight left bend was found when the physiotherapist was in half-kneeling which could be a result of an asymmetrical base of support (BoS) when half-kneeling. The lumbosacral junction was found to be within 5° of neutral rotation for all physiotherapist positions.

Adopting a kneeling position showed a larger duration of the task was spent around neutral, with most of the task time spent between 10° lumbosacral extension to 10° lumbosacral flexion (Figure 5.9A). A half-kneeling position showed an increase in flexion angles with a peak in task time spent between 11-15° lumbosacral flexion (Figure 5.9B). Standing illustrated a larger range in joint ROM measured when compared with the two other physiotherapist positions.

Movement at the lumbosacral junction ranged from 0-5° extension to 26-30° flexion, with a peak between 6-10° flexion (Figure 5.9C). Kneeling could have limited the amount of lumbosacral flexion achieved due to the increased hip flexion required when kneeling. Conversely, the increased lumbosacral flexion angles found when the physiotherapists were standing could be a result of a more neutral hip position.

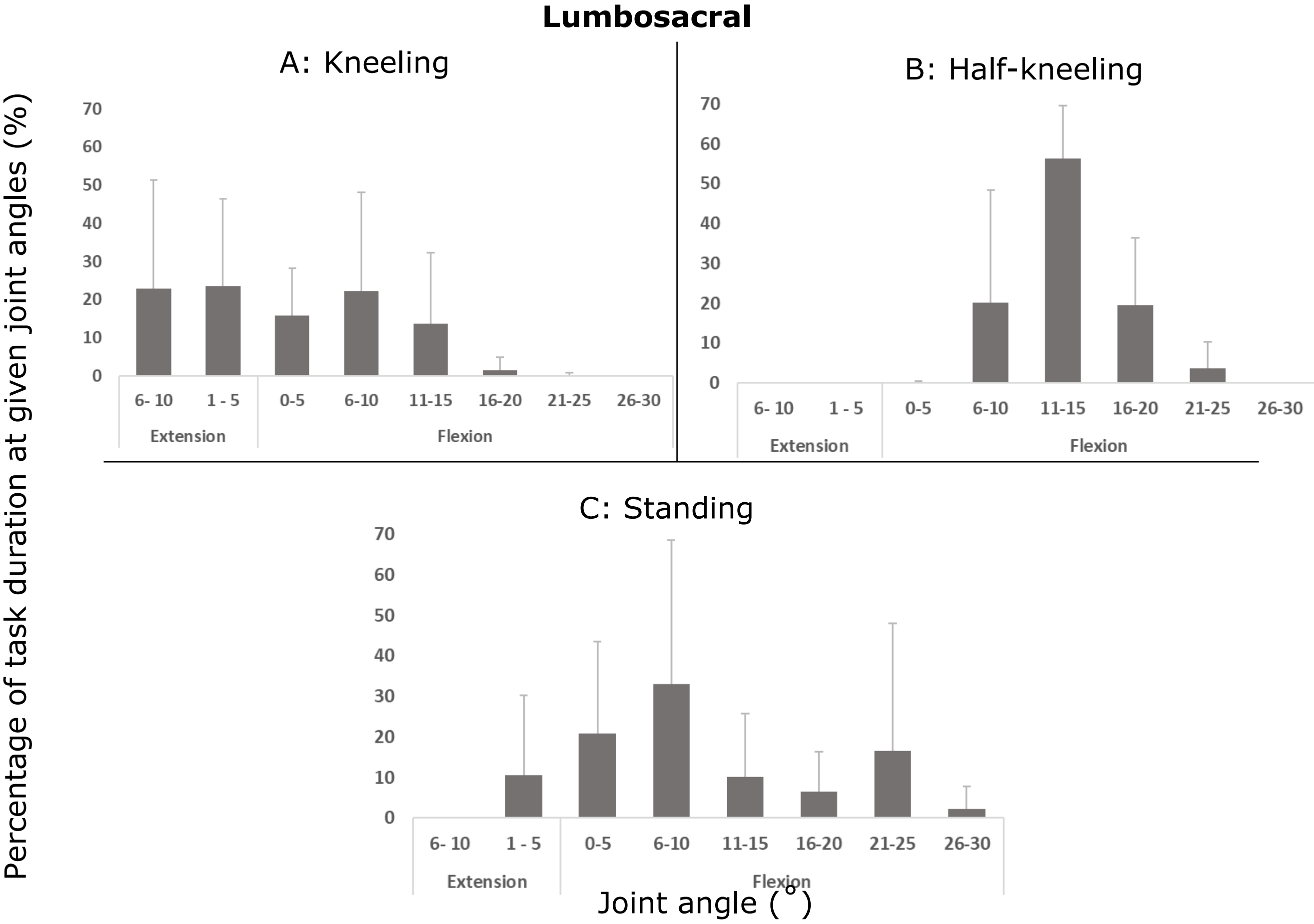


Figure 5.9: Lie-to-sit: Lumbosacral joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Shoulder Girdle movement (T4/Shoulder Joint)

The shoulder girdle was found to be mostly elevated and protracted for all positions during assisting lie-to-sit. The left and right shoulder girdle showed similar patterns of duration in joint angles. It was observed that the physiotherapists were reaching and facilitating with both upper limbs during lie-to-sit tasks. As both upper limbs were involved, this could explain the similarities between both physiotherapist positions and also left and right sided movement.

Shoulder movement

Assisting patients from lie-to-sit in kneeling and half-kneeling positions showed similar patterns of rotation ROM for both left and right sides during lie-to-sit. Standing showed slight asymmetries in shoulder abduction pattern for left and right. The left shoulder demonstrated a peak in task time spent between 16-30° abduction, with the right shoulder peak time between 11-20° abduction (Figure 5.10C). The left and right asymmetry could be related to the physiotherapist position in relation to the patient. If the physiotherapist was standing to one side of the patient, one shoulder would be required to abduct further to reach over/under the patient. If the physiotherapist was in front of or behind the patient, the arms could be positioned at the hip and knee, or the hip and shoulder which would require asymmetrical arm positions.

The shoulder was found to show a similar pattern of rotation for all physiotherapist positions, with a larger portion of the task duration spent in internal rotation. A smaller spread of joint ROM was found when the physiotherapists were half-kneeling. This smaller ROM could be related to decreased variation in movement measured as a result of fewer trials of lie-to-sit recorded in half-kneeling. Internal rotation is a functional position, allowing the physiotherapist to reach towards the patient. The shoulders were more flexed when in half-kneeling; with a peak in task duration spent between 55-60° shoulder flexion (Figure 5.11B). Shoulder flexion when kneeling and standing showed that movement was more evenly distributed between neutral to 90° during the task (Figure 5.11A, C).

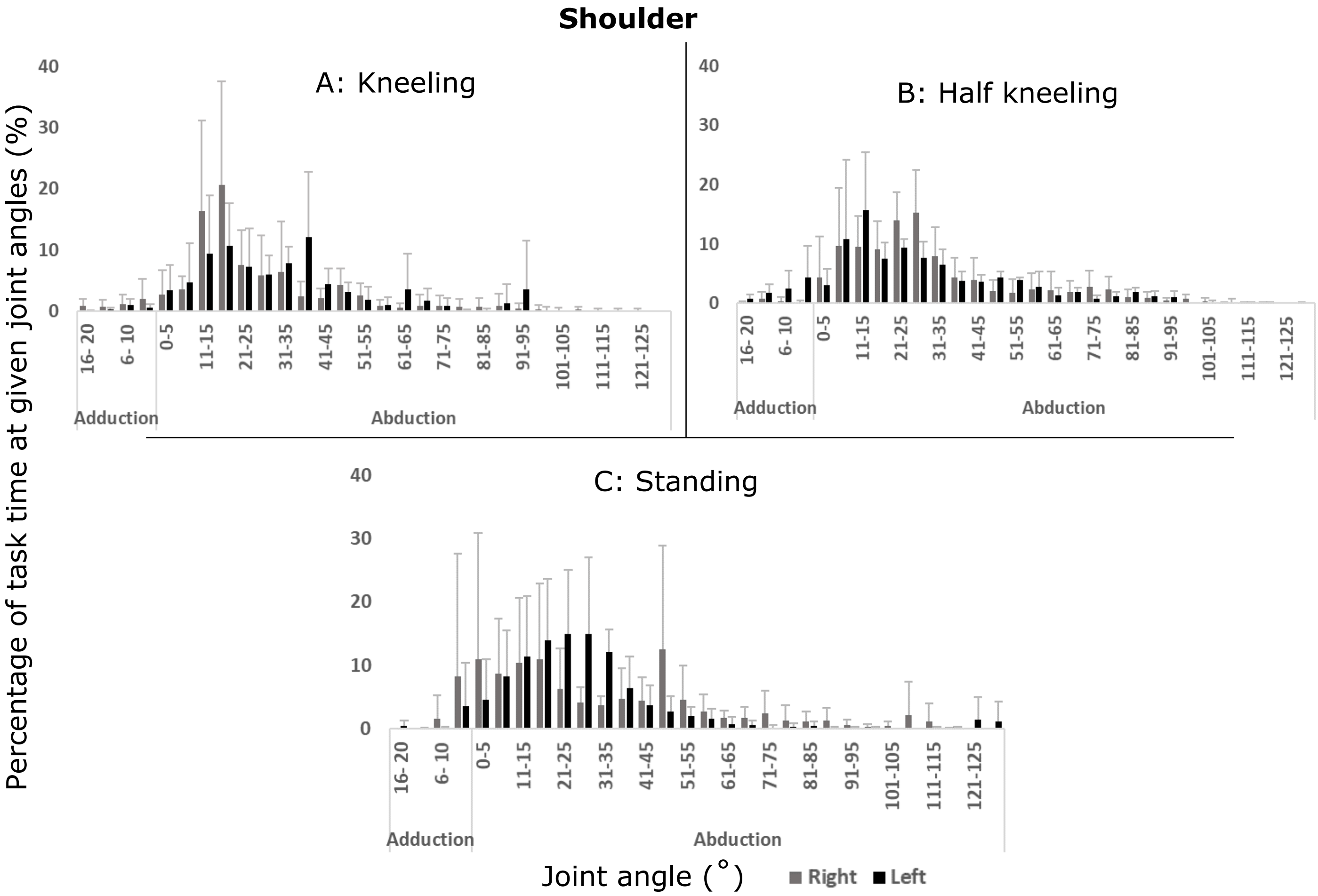


Figure 5.10: Lie-to-sit: Shoulder joint angle organised into physiotherapist position for adduction and abduction with data collected in contiguous 5-degree bins (+1SD)

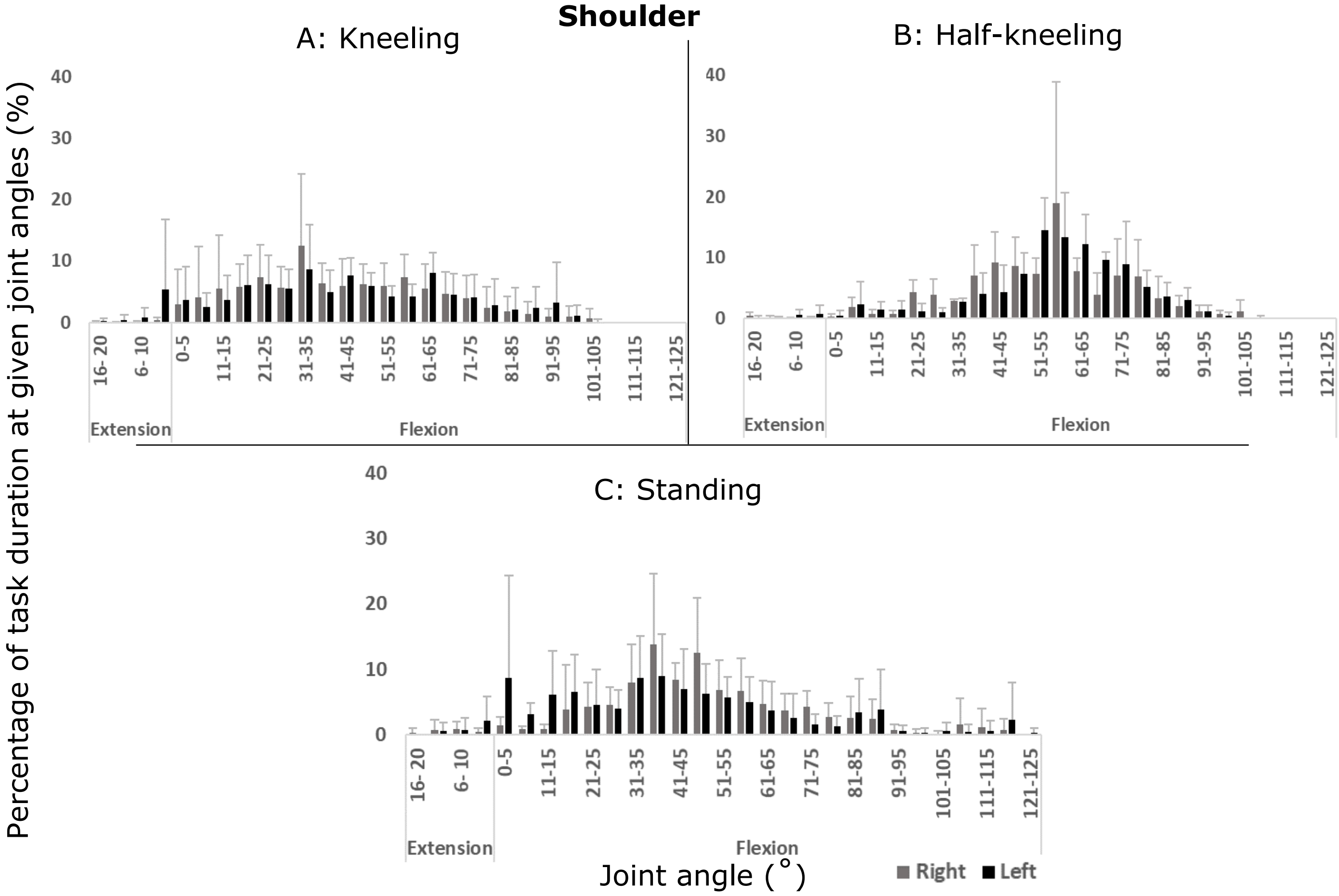


Figure 5.11: Lie-to-sit: Shoulder joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Hip movement

The hips were found to be slightly more abducted when in kneeling than in the other physiotherapist positions. The hips may abduct more in kneeling to provide a larger BoS. When facilitating lie-to-sit from a standing position, the hips showed more task time was spent within 10° hip adduction and abduction. Kneeling and half-kneeling positions demonstrated more duration of the task in an internally rotated hip position (Figure 5.12A, B), with standing showing slightly more task duration externally rotated (Figure 5.12C). Kneeling showed more variation in hip rotation compared to half-kneeling and standing positions. Kneeling also showed greater variation in hip flexion ROM during lie-to-sit tasks when compared to standing (Figure 5.13A, C). This is expected, as less hip flexion is required for standing, but it could also suggest a wide variation in kneeling positions and that the kneeling position is not static during the lie-to-sit task. However, the physiotherapist would not be expected to remain static through the movement.

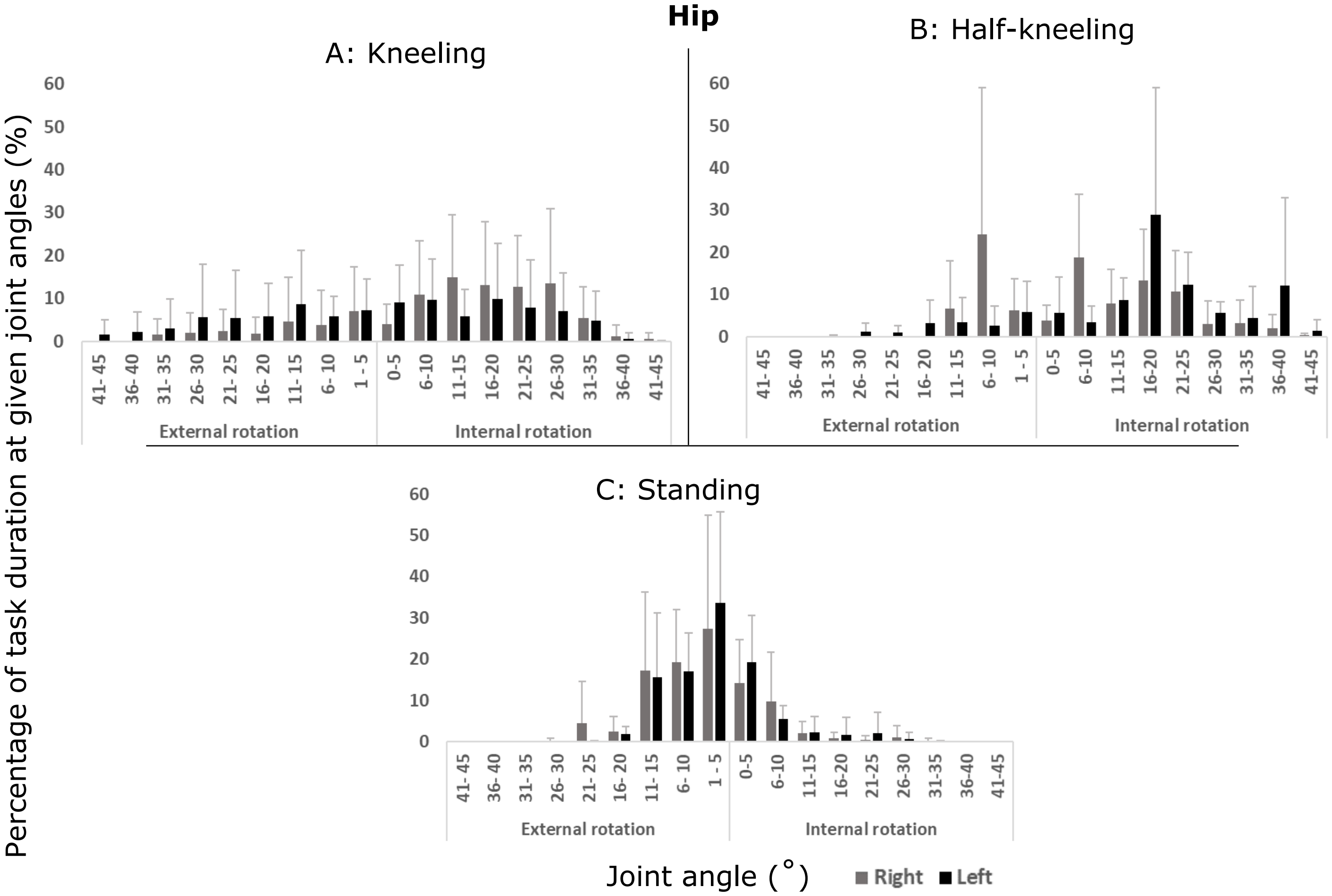


Figure 5.12: Lie-to-sit: Hip joint angle organised into physiotherapist position for internal and external rotation with data collected in contiguous 5-degree bins (+1SD)

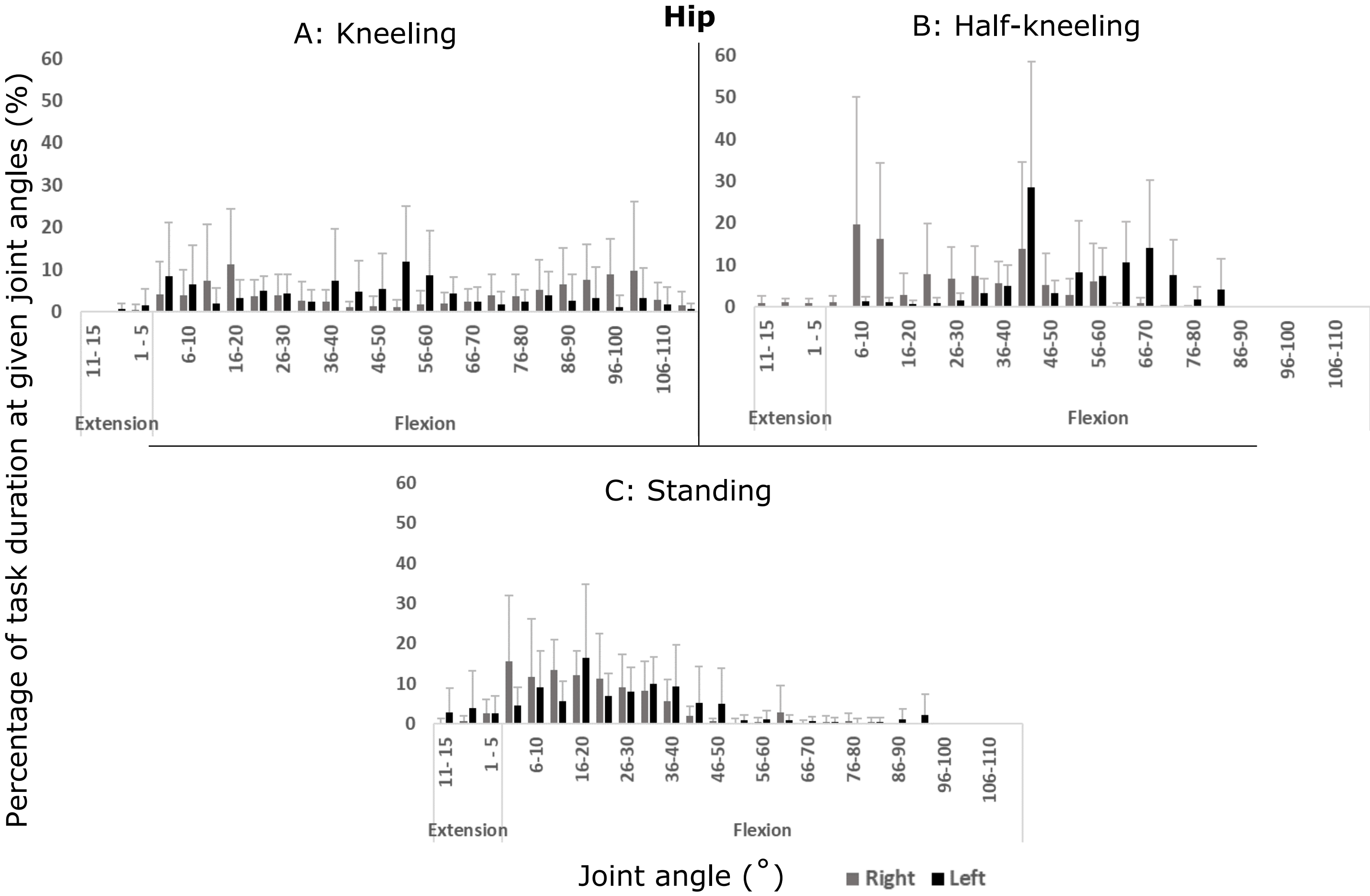


Figure 5.13: Lie-to-sit: Hip joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Knee movement

Kneeling and half-kneeling positions demonstrated a wide range of joint ROM measured during lie-to-sit tasks from neutral to end range knee flexion. When the physiotherapists were kneeling, a small portion of the task was spent with the knees extended near a neutral position (Figure 5.14A). It was also found that a small portion of the task time was spent near neutral for the right knee when in half-kneeling (Figure 5.14B). However, due to the large quantity of data recorded, a small amount of erroneous data may remain. The erroneous data would explain the larger knee extension angles measured, which may not be anatomically correct. The task time spent with the knee extended to neutral is related to a small portion of the lie-to-sit task where the physiotherapist moved to standing. However, most of the task was performed with the physiotherapist in kneeling or half-kneeling. When assisting lie-to-sit from a standing position, a large ROM at the knee was measured with more of the task time spent between neutral to 20° flexion (Figure 5.14C). This knee flexion up to 20° suggests the physiotherapists mostly maintained soft knees during the task.

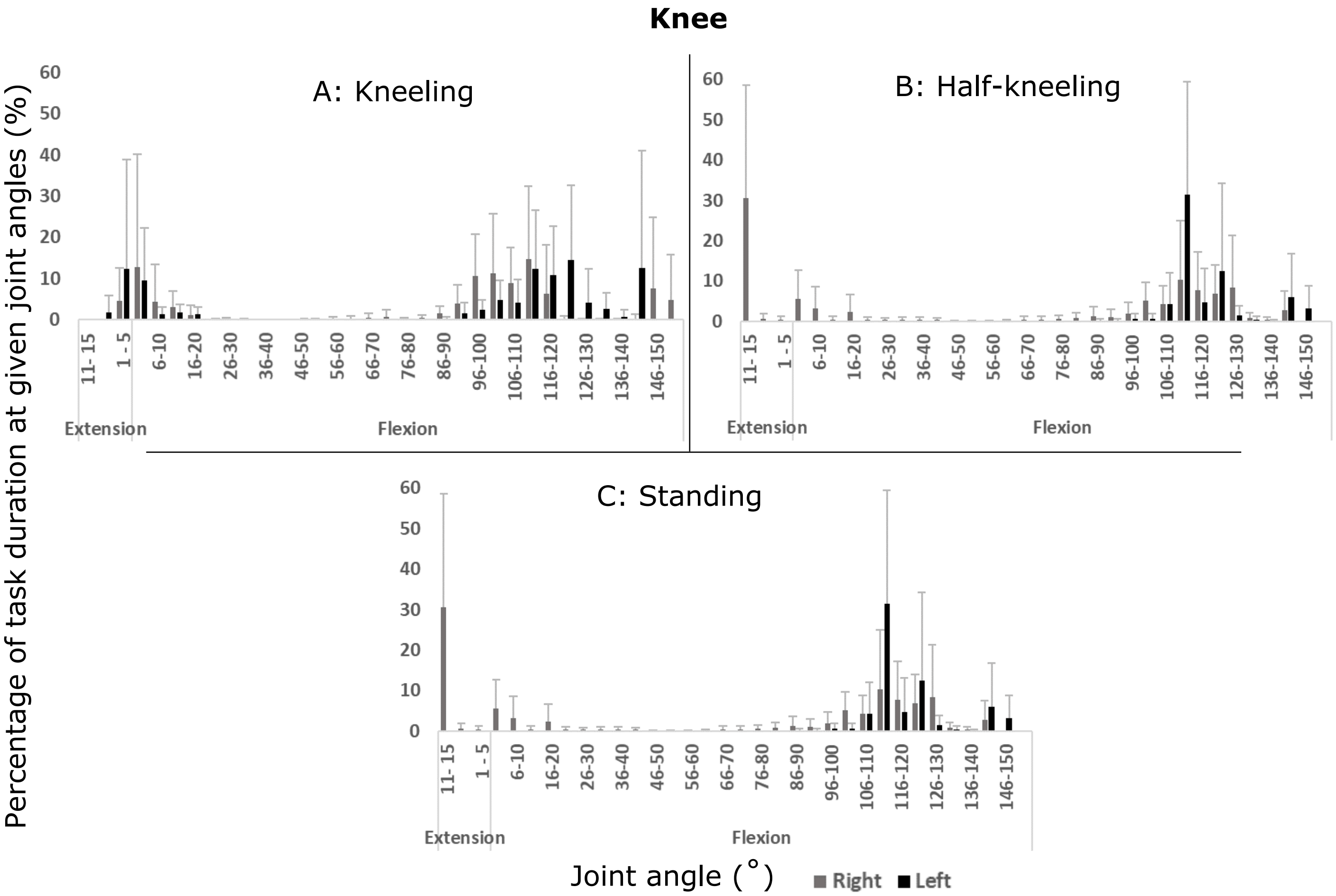


Figure 5.14: Lie-to-sit: Knee joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Lie-to-sit Description of Movement Summary

Physiotherapist movement during lie-to-sit tasks has been described in terms of joint angle and percentage duration of the lie-to-sit task. Differences between joint movement and physiotherapist positions were found, especially at the physiotherapists' trunk and lower limbs. Physiotherapist movement and the differences found previously were further described over the duration of the lie-to-sit tasks by time normalising the data.

5.5.2 Physiotherapist Movement Time Normalised During Lie-to-sit

This section illustrates the physiotherapists’ joint angles when assisting a patient from lie-to-sit for each position used by the physiotherapist. The duration of the task has been normalised for all recordings (0 to 100% of task). This allowed for comparison of all physiotherapists independent of the duration taken to complete the task. The start of the lie-to-sit task was defined as the patient lying down and the physiotherapist verbally instructing the patient to start the movement. From observation, all patients were in supine lying at the start of the task; if the patient moved into side lying it was part of the lie-to-sit task. The end of the lie-to-sit task was defined when the patient was in a static upright sitting position.

The data are presented as an average movement for each position to allow for comparison. Using the findings from the previous section describing joint motion, only certain movements will be described. In particular, only movements in the sagittal plane are described at the physiotherapists’ trunk and hips, as the other planes of motion showed little movement or most of the task was near neutral.

When the physiotherapists were assisting lie-to-sit from a kneeling position there was little movement found at the thoracolumbar and lumbosacral junctions during lie-to-sit tasks. The cervicothoracic junction maintained 10 to 20° flexion throughout. The maximum flexion measured at the cervicothoracic junction was 33°. The full active ROM measured for each joint before the patient tasks is presented in (Appendix 15), suggesting that when kneeling the cervicothoracic junction was in mid flexion range when kneeling to facilitate lie-to-sit (Figure 5.15A). The physiotherapists’ left and right lower limbs followed very similar patterns of movement throughout lie-to-sit tasks with an increase in hip and knee flexion measured. Towards the end of the lie-to-sit tasks the physiotherapists’ hips moved towards 40-50° flexion (Figure 5.15A). This suggested the physiotherapists were in high kneeling at the start of the task and moved to low kneeling when the patient was sitting at the end of the task. When kneeling, the upper limbs potentially performed more movement during the task.

When the physiotherapists were half-kneeling, there was a mix of kneeling on the floor and on the plinth. Half-kneeling showed the highest angles of neck extension (10-30° extension) compared to kneeling (5-15° extension) and standing (neutral to 18° extension) (Figure 5.15B). Initially in half-kneeling, the physiotherapists' necks were more extended before moving towards the neutral posture during lie-to-sit tasks. The lumbosacral junction maintained the highest angle of flexion (10-15° flexion) when in half-kneeling compared with kneeling (neutral to 7° flexion) and standing (5-12° flexion) (Figure 5.15B). A slight increased flexion angle was measured towards the end of the task time.

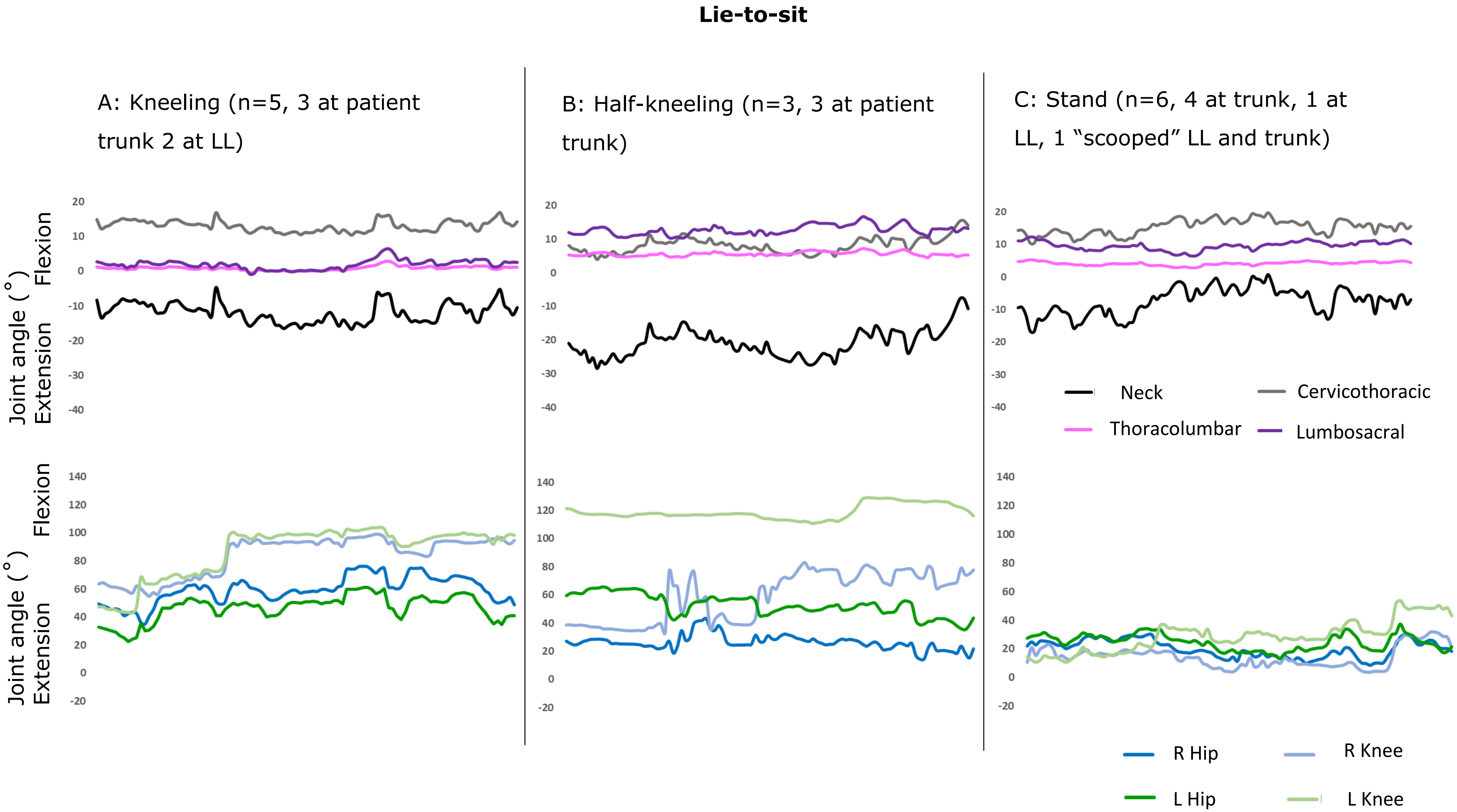


Figure 5.15: Lie-to-sit: Time normalised joint angle for trunk and lower limbs averaged across patients and organised by physiotherapist position

The physiotherapists' lower limb movement when half-kneeling showed an increased angle of flexion at the physiotherapists' left knees. Increased left knee flexion was likely due to the physiotherapist placing this knee on the plinth. Both the left and right knees increase in flexion during the task (Figure 5.15B), potentially due to the physiotherapist moving and 'sitting' back onto their lower limbs as the patient moves to upright sitting. A general pattern of the physiotherapists' hips becoming less flexed over the task time was measured, suggesting the physiotherapists moved into a more upright position towards the end of the task. This contrasts with the cervicothoracic junction becoming more flexed at the end of the task. Cervicothoracic flexion could be a result of reaching to the patient once they had completed the lie-to-sit or compensatory movements from the neck moving towards neutral from an extended posture.

When in standing, the physiotherapists' lower limbs showed the least movement during the task compared with kneeling and half-kneeling positions. Increased lower limb flexion was found towards the end of the lie-to-sit tasks (Figure 5.15C), potentially from the physiotherapists crouching or bending over to the patient when they are sitting. The trunk was flexed at the cervicothoracic, thoracolumbar and lumbosacral junctions when facilitating lie-to-sit tasks in standing. The lumbosacral junction illustrated a decrease in flexion angle during the first half of the task time. The lumbosacral junction then showed an increase in flexion angle over the second half of the lie-to-sit tasks. However, when the physiotherapists were standing, the cervicothoracic junction showed an opposite pattern of movement of flexion to the lumbosacral junction (Figure 5.15C). This small opposition of movement could be uncomfortable for the physiotherapists, with the back moving into a more 'slumped' posture. The slight hip flexion (20°) with nearly extended knees and trunk flexion suggests a trunk top-heavy position when standing and assisting the patient.

5.5.3 Lie-to-sit Summary

Physiotherapist movement during assisting a patient from lie-to-sit was described and quantified. It was observed during the patient treatment sessions that there was variation in physiotherapist position in relation to the patient, location of assistance on the patient, and physiotherapist movement during the lie-to-sit tasks.

Assisting the patient from lie-to-sit was performed more often than sit-to-lie (n=5) within the patient treatments recorded in this study.

When assisting lie-to-sit, kneeling was found to show the least movement away from neutral for the neck, thoracolumbar and lumbosacral joints (Figure 5.6Figure 5.8Figure 5.9). The shoulders and hips showed a larger spread of joint angles measured during the lie-to-sit tasks which could be related to the larger ROM available at these joints. The spread of joint angles could also suggest these joints were constantly moving during the task with little time spent in one position. Less movement was seen at the physiotherapists' hips and knees when assisting lie-to-sit from a standing position. However, there was a spread in joint movement found at the physiotherapists' shoulder and cervicothoracic joints. The physiotherapists could have been rounded at their upper back when reaching their arms towards the patient. Half-kneeling was the only position to illustrate more time in slight left bend at the lower back. The left bend is potentially due to the physiotherapists position in relation to the patient, or from the asymmetrical BoS provided when in half-kneeling.

The next section will describe and quantify physiotherapist movement during the next patient handling task: sit-to-lie.

5.6 Sit-to-Lie

Sit-to-lie was assisted a total of five times during data collection sessions. Sit-to-lie was performed less than lie-to-sit in this study (n=14) as patients were often positioned into their wheelchairs after treatment sessions. There were fewer occasions when the patient returned to their bed after treatment, and therefore less recordings of sit-to-lie. The average duration for sit-to-lie tasks was 46 seconds (SD: 53). Kneeling was the most common position used by the physiotherapists during sit-to-lie tasks (4 of 5), with kneeling to the left of the patient used for two of the five tasks (Figure 5.16). There was only one recording of sit-to-lie performed from a standing position. The graphs throughout the sit-to-lie section of the results chapter therefore do not illustrate SD error bars for the standing joint angle data.

From observation of the sessions, the physiotherapists assisted the patient from sit-to-lie either at the patients' trunk or lower limbs when kneeling. When the physiotherapist was standing, they assisted at the patients' lower limbs. When assisting the trunk, the physiotherapists would have their hands on the patient's trunk and guide them down with gravity from sitting to lying. When assisting at the lower limbs, the physiotherapists would lift and guide the patient's lower limbs up on top of the mattress.

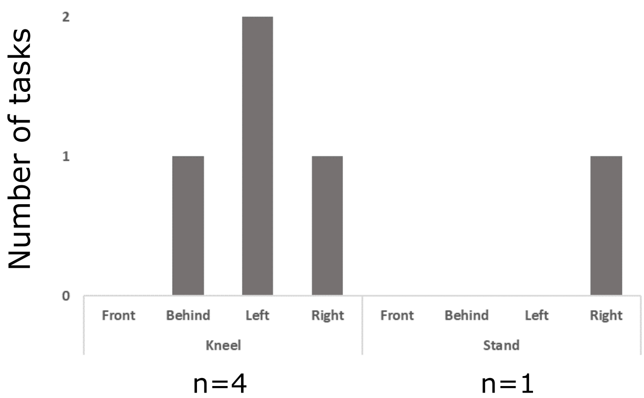


Figure 5.16: Frequency of physiotherapist positioning in relation to patient during patient sit-to-lie tasks (n=number of physiotherapists)

5.6.1 Proportion and Joint Angle Data Sit-to-lie Transition

Neck movement (C1/Head Joint)

The neck was generally near neutral for side bend and rotation when the physiotherapist was in a kneeling position (Figure 5.17B). A larger range of side bend was measured when in standing (20° left bend to 15° right bend). However, only one physiotherapist facilitated sit-to-lie from a standing position. When the physiotherapists were in kneeling and standing positions, a wider range in joint motion was measured for rotation but the peak time was between neutral to 5° right rotation (Figure 5.17C, D). Slight extension was measured at the neck when the physiotherapist was kneeling, with the peak in time found between 11-15° extension (Figure 5.17E). When the physiotherapist was standing, the neck was found to be in extension ranging from neutral to 35° extension, with a larger spread of joint angles measured (Figure 5.17F). The physiotherapist was standing to the right of the patient during the sit-to-lie task.

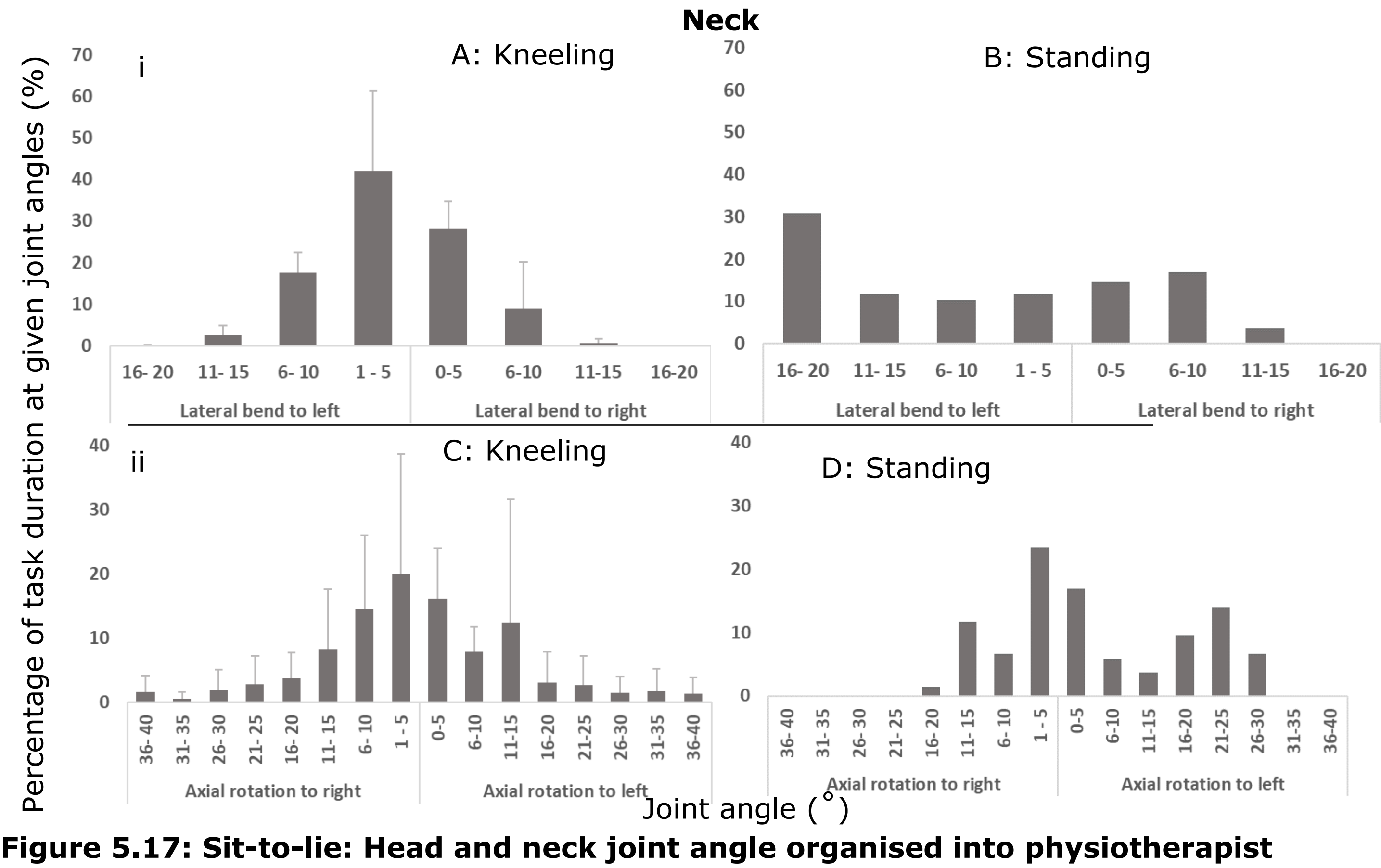


Figure 5.17: Sit-to-lie: Head and neck joint angle organised into physiotherapist position for i: lateral bend and ii: rotation with data collected in contiguous 5-degree bins (+1SD)

No clear preference to side bend or rotation was measured despite the physiotherapist position in relation to the patient.

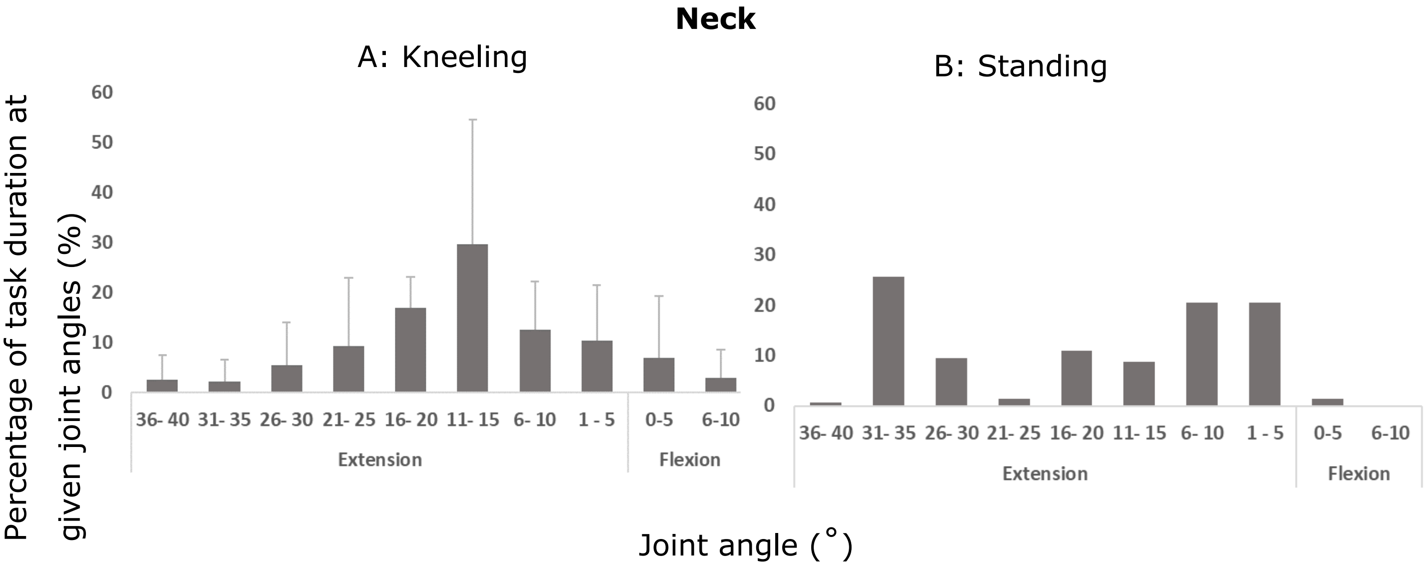


Figure 5.18: Sit-to-lie: Head and neck joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Cervicothoracic movement (C7/T1 Joint)

The cervicothoracic junction was generally within 10° of neutral for lateral bend and rotation in both standing and kneeling positions. This joint was generally flexed when assisting sit-to-lie from a kneeling position, with a peak in task time spent between 11-15° cervicothoracic flexion (Figure 5.19A). When standing, cervicothoracic flexion ranged from neutral to 20° flexion during sit-to-lie tasks

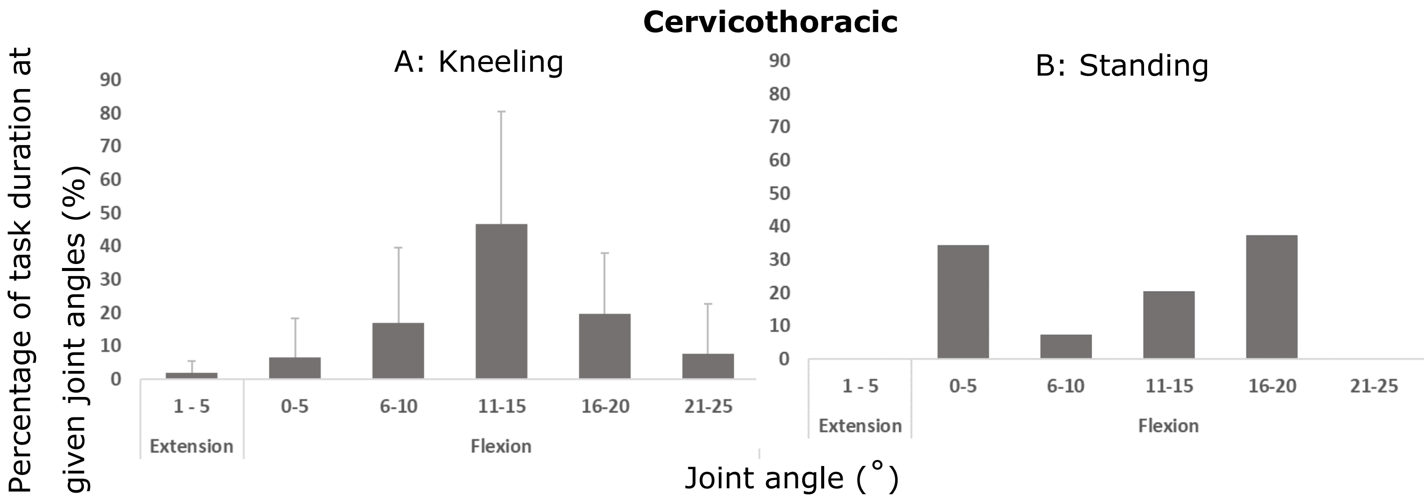


Figure 5.19: Sit-to-lie: Cervicothoracic joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

(Figure 5.19B). The cervicothoracic flexion found in both kneeling and standing could be due to the physiotherapist rounding at their upper back when leaning down towards the patient.

Thoracolumbar movement (T12/L1 Joint)

A small ROM was measured at the thoracolumbar junction for all planes of motion in both kneeling and standing positions. Most of the task duration was spent within 5° of neutral for rotation and side bend when kneeling and standing. When the physiotherapist was in standing the thoracolumbar flexion was mostly between 6-10° flexion and when kneeling, 5° extension to 15° flexion was found. However, most of the task time was spent between neutral to 5° flexion in kneeling. When in standing, the flexion at the thoracolumbar junction could be related to the flexion found at the cervicothoracic junction. If the physiotherapist was leaning forward towards the patient, the trunk flexion was likely from multiple segments of the spine.

Lumbosacral movement (L5/S1 Joint)

When assisting sit-to-lie from kneeling and standing positions, the lumbosacral junction was generally near neutral for both rotation and side bend. When the physiotherapist was in a standing position, lumbosacral flexion was found throughout the duration of the task (Figure 5.20B). In standing, flexion was found at the lumbosacral, thoracolumbar and cervicothoracic junctions. Flexion at all three joints suggests the trunk was forward flexed and also rounded when assisting-sit-to-lie from a standing position. The kneeling position showed a larger range in movement from 15° extension to 30° flexion (Figure 5.20A). The lumbosacral extension when kneeling could be due to the physiotherapist slightly leaning back to allow movement of the legs over the edge of the bed.

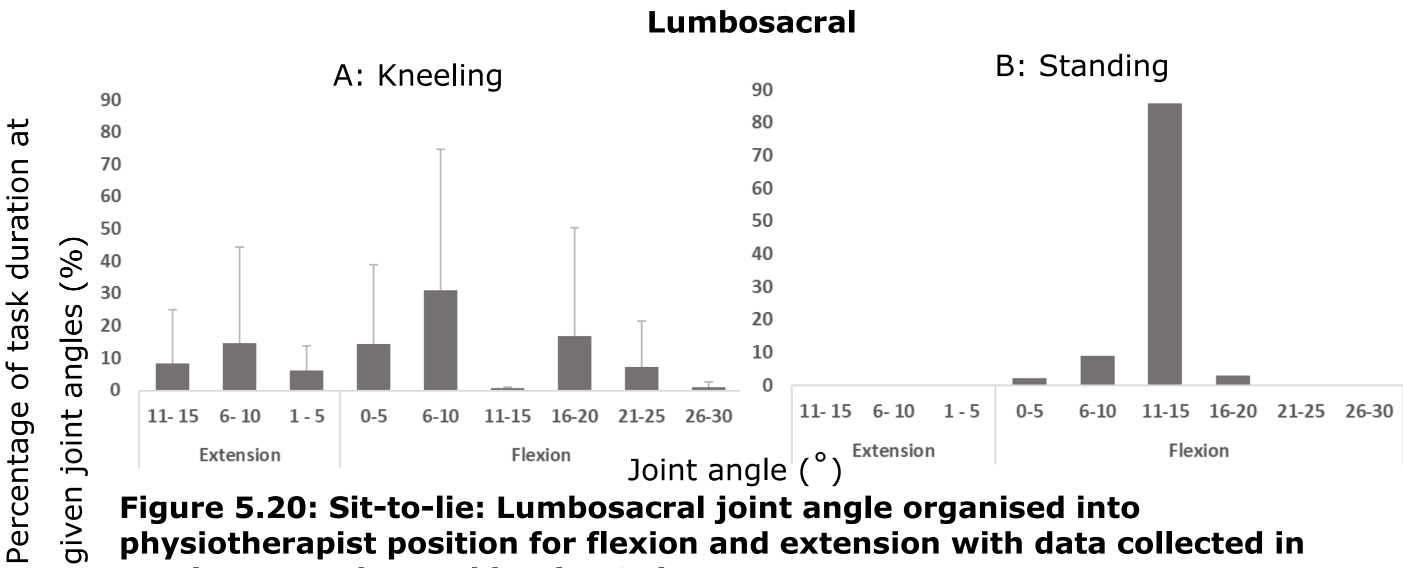


Figure 5.20: Sit-to-lie: Lumbosacral joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Shoulder girdle movement (T4/Shoulder Joint)

The shoulder girdle was mostly elevated and protracted for both standing and kneeling during sit-to-lie tasks. It was observed that both the physiotherapists' upper limbs were reaching forwards to the patient when assisting sit-to-lie. When reaching forwards and assisting with patient movement, the shoulder girdle would likely protract and elevate.

Shoulder movement

Assisting sit-to-lie from standing and kneeling positions showed similar patterns of movement at the shoulder. A peak in task time was spent between 16-20° abduction. The shoulders were slightly more internally rotated during the task for both physiotherapist positions. When assisting sit-to-lie from a standing position, more shoulder extension was measured (Figure 5.21B) than in a kneeling position. Standing showed a slight peak in task time spent between 46-65° shoulder flexion. Kneeling showed a slight peak in task time spent between 26-40° flexion (Figure 5.21A). This flexion angle could be related to the physiotherapist reaching forward to the patient which would require the shoulder to flex forwards. When the physiotherapist was in standing, they assisted with lifting and moving the patients' lower limbs into the bed.

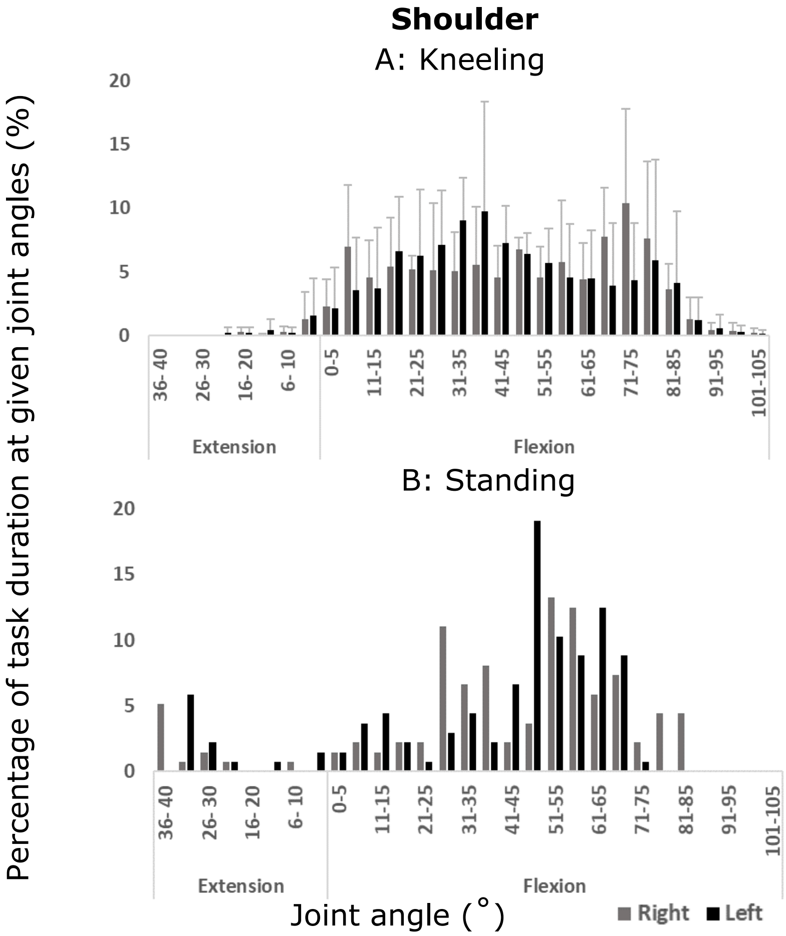


Figure 5.21: Sit-to-lie: Shoulder joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Hip movement

The hips were slightly more abducted when kneeling compared to standing, similar to lie-to-sit tasks. Increased abduction could be to increase the BoS for the physiotherapist. Additionally, it was observed that the physiotherapist was leaning and reaching forwards to the patient, which could increase abduction at the hips to allow the trunk to move forwards. Kneeling and standing positions showed a similar pattern of rotation at the hips, with more of the task spent within 10° of neutral hip posture. When the physiotherapists were kneeling, the hips showed a larger variation in hip flexion measured during the task compared to standing (Figure 5.22A). The standing position showed a peak in task time was spent between 46-55° flexion (Figure 5.22B). Similar to observations during the lie-to-sit task, the physiotherapist moved position as the patient moved from sitting to lying down.

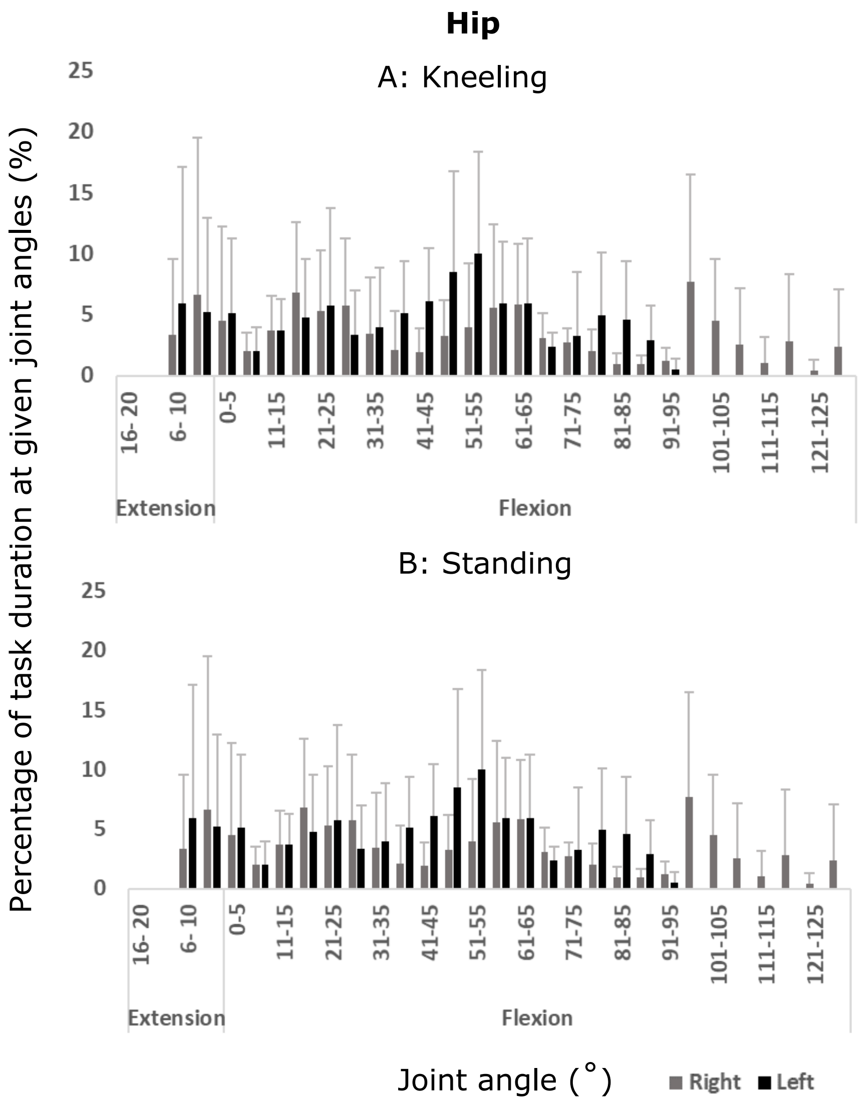


Figure 5.22: Sit-to-lie: Hip joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Knee movement

When the physiotherapists were in a kneeling position, peaks in knee flexion were seen between 11-20° and 106-110° flexion. The two peaks are, again, potentially related to the physiotherapist moving into a standing position for a small portion of the task duration (Figure 5.23A). When the physiotherapist was in standing the ROM measured at the knee was small (Figure 5.23B). A smaller ROM would be expected, and the increased flexion angles likely related to the physiotherapist lowering down when assisting the patient.

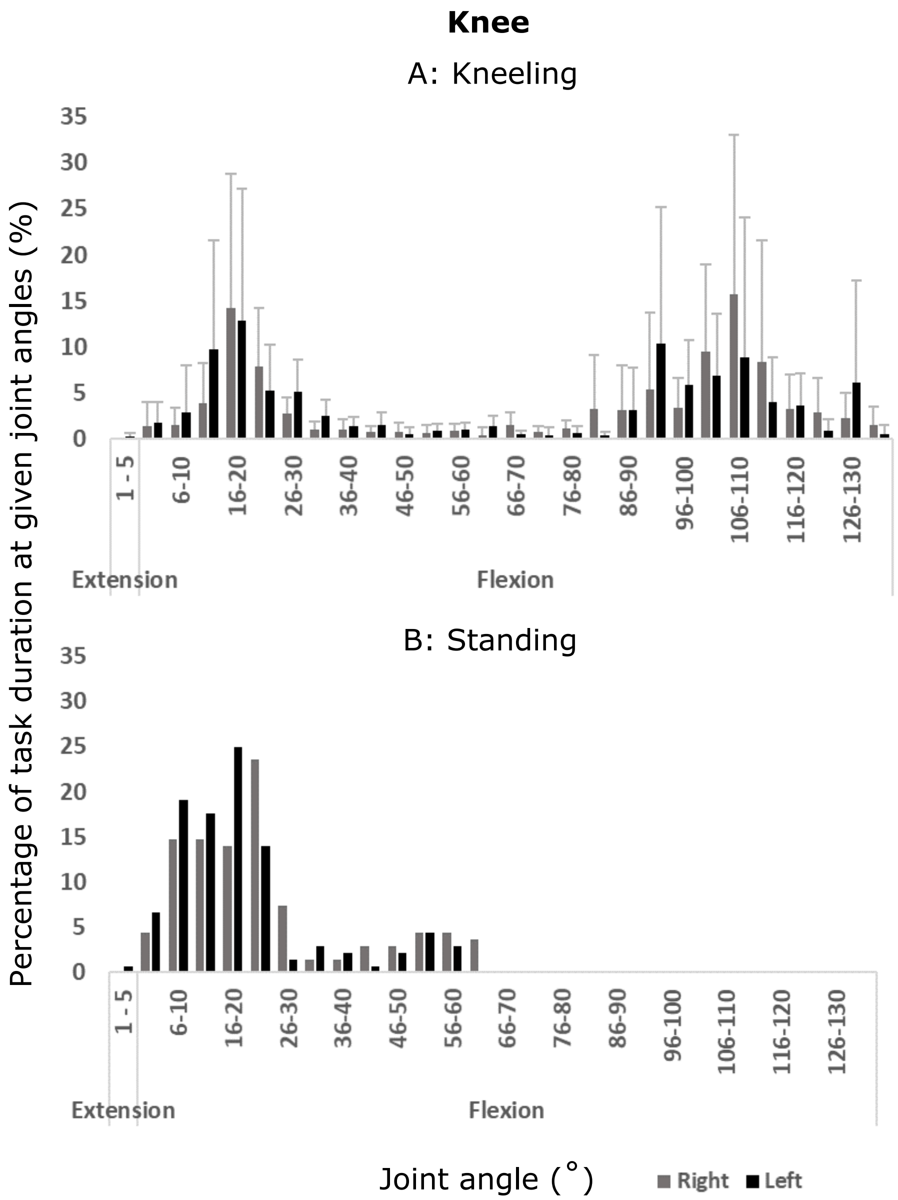


Figure 5.23: Sit-to-lie: Knee joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

This previous section described and quantified physiotherapist movements during sit-to-lie tasks. As this task had clearly defined start and end points, the data were also time normalised. This allowed description of the trunk and lower limbs over the duration of the sit-to-lie task.

5.6.2 Physiotherapist Movement Time Normalised During Sit-to-lie

There were five recordings assisting patients from sit-to-lie from four physiotherapists. The start of the movement was defined as when verbal instruction was given by the physiotherapist and ended with the patient in positioned into lying in their bed. Fewer sit-to-lie tasks (n=5) were performed than lie-to-sit (n=14), with the physiotherapists only assisting the patient from kneeling or standing positions. When the physiotherapists were in a kneeling position, the neck was in slight extension throughout the task with no clear pattern of movement seen. The cervicothoracic junction maintained 10-17° flexion throughout the task. The lumbosacral junction initially showed a slight decrease in flexion angle before increasing in flexion for the second half of the task duration (Figure 5.24A). The lower limbs showed an increase in flexion ranging from 20-60° flexion before slowly decreasing in flexion angle over the course of the task duration (Figure 5.24A). At the end of the task a sharp decrease in flexion angle was measured which positioned the physiotherapists lower limbs near neutral. The physiotherapist initially moved into low kneeling before moving to high kneeling, then standing for the end of the task.

One recording of the physiotherapist assisting lie-to-sit was performed from standing (Figure 5.24B). The physiotherapist assisted with the patient’s lower limbs for this task. There was an initial increase in trunk flexion at the beginning of the task which was then maintained throughout. The neck and cervicothoracic junction rapidly extends halfway through the task before maintaining this position until the end of the task where there is an increase in flexion again. The neck showed a larger extension angle in standing (maximum 35° extension) than in the kneeling position (maximum 20° extension). There was minimal movement at the thoracolumbar junction apart from a minor increase in flexion. The lumbosacral junction flexed from neutral at the beginning of the task, with further small increases in flexion throughout. The lower limbs were in a relatively neutral position in the first third of the task before rapidly flexing as the physiotherapist moved to a squat position for a short portion of the task. The lower limbs then extended as the physiotherapist moved back to a standing position. This corresponds to the change in angle found at the neck.

In summary, differences in segment angles and patterns of movement were identified between the different positions the physiotherapists adopted. Differences were also potentially due to the area on the patient where assistance was provided. No clear pattern was seen between physiotherapist positions or areas of facilitation between sit-to-lie and lie-to-sit. However, there were a small number of recordings for the latter. For future research, further investigation into area of assistance/facilitation could provide further insight into physiotherapist movement and positioning.

Sit-to-lie

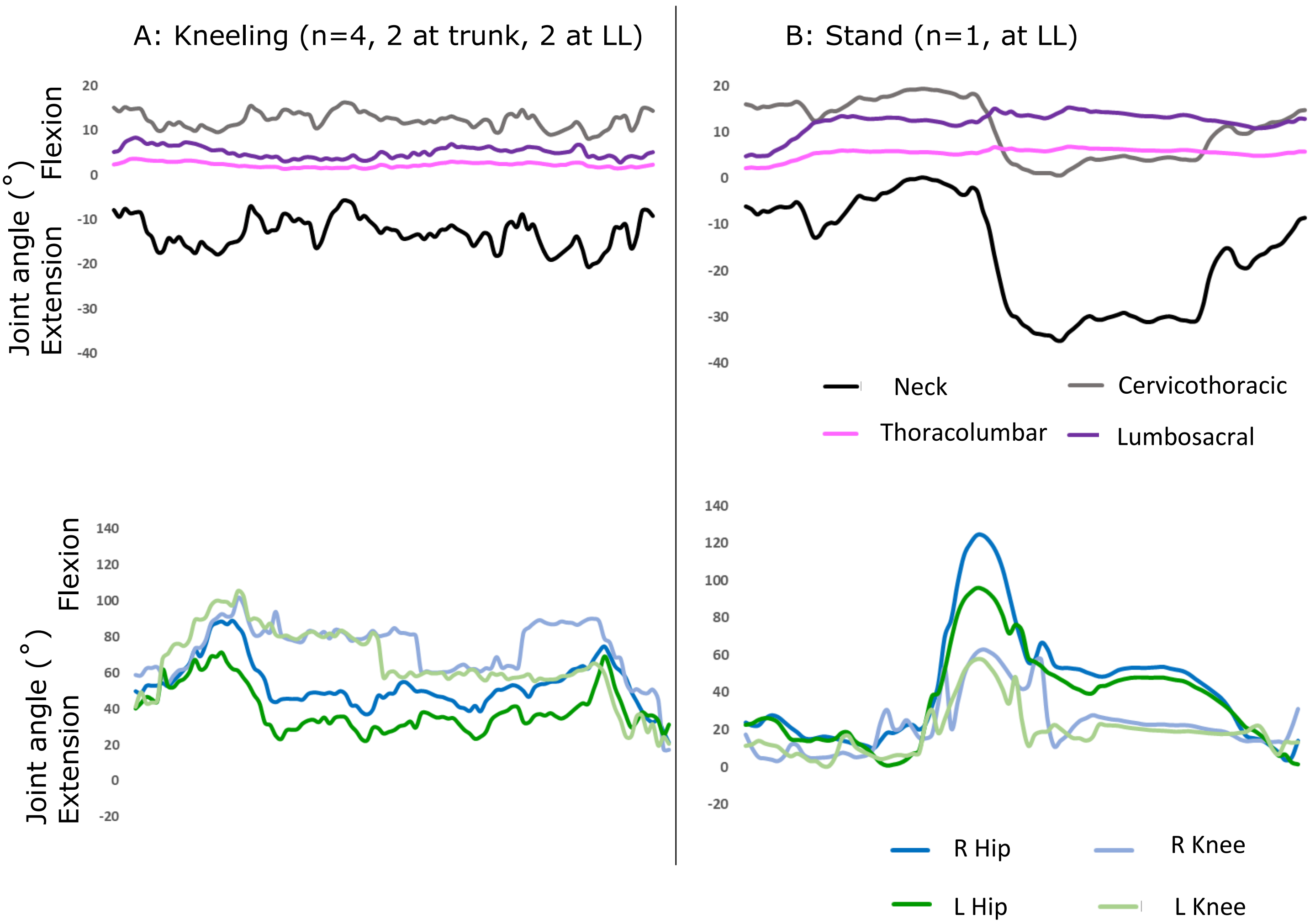


Figure 5.24: Sit-to-lie: Time normalised joint angle for trunk and lower limbs averaged across patients and organised by physiotherapist position

5.6.3 Sit-to-lie Summary

When assisting sit-to-lie, differences were seen between kneeling and standing positions for the trunk and lower limbs. Flexion was found at the cervicothoracic, thoracolumbar and lumbosacral junctions, suggesting the physiotherapists were forward flexed and also rounded at the trunk when in standing. This position could be due to the physiotherapist bending and leaning down to the height of the patient. The patients' beds height could be changed to assist the physiotherapist, however, despite this the physiotherapist may have had to lower down to the patient. Kneeling showed the physiotherapist movement at the lumbosacral junction was spread from extension to flexion, which is in contrast to standing, which showed 86% of the task time was spent between 11-15° lumbosacral flexion. The kneeling position may limit lower limb movement, therefore requiring more movement from the hips and above to facilitate patient movement.

Sit-to-lie was assisted fewer times than lie-to-sit. During the recorded sessions, the patients were often seated into wheelchairs after the physiotherapy treatment. By remaining in a seated position this could improve their seated exercise tolerance or aid with mealtime eating and drinking (Gillen 2016).

Similarities were seen across physiotherapist positions for both lie-to-sit and sit-to-lie. The neck was slightly extended for all positions maintained by the physiotherapist and the trunk generally flexed. The head was likely extended to allow the physiotherapist to look up to the patient or other staff member, even in standing. The shoulders illustrate a functional position likely related to the physiotherapist reaching forwards to the patient. The lower limb joint angles generally depended on the physiotherapist position. However, a large range was found within kneeling dominant postures as the physiotherapists stood temporarily, and also moved between low and high kneeling during the task to assist the patient. Variation in physiotherapist movement was found between both lie-to-sit and sit-to-lie tasks, and also physiotherapist positions in each task. A range of techniques and facilitation methods were used by the physiotherapists.

5.7 Sit-to-stand and Stand-to-sit

The data presented in this section describes the physiotherapist movement while facilitating patients performing sit-to-stand and stand-to-sit movements within treatment sessions. Most of the facilitation recordings are of sit-to-stand which was often performed prior to treatments with the patient in standing. The stand-to-sit transition was often very quick and did not require as much physiotherapist involvement as sit-to-stand. Sit-to-stand was performed therapeutically to improve lower limb strength, balance, and coordination. Improving the patient's ability to sit-to-stand could aid with functional movements, transfers and improve independence (Kim et al. 2015). Physiotherapists adopted a range of positions during treatment to aid the patient depending on the amount of assistance required and the location at which this assistance was needed. For example, some patients required assistance at the hip and knee due to significant lower limb weakness affecting their ability to weight bear; others required support at the trunk and hip for slight assistance into standing and maintaining balance once upright. Some tasks used equipment such as lifting aids, but the physiotherapist was still required to manually aid the patient with these tasks despite the equipment.

Sit-to-stand tasks were performed and recorded 79 times during the 44 recorded treatment sessions, compared to three times for stand-to-sit. Figure 5.25 illustrates the physiotherapist position in relation to the patient during these recordings. Sitting was the most frequent position adopted by the physiotherapists (42 of 79 recordings), either sitting on a stool or the plinth. Figure 5.26 illustrates the physiotherapist position when facilitating sit-to-stand from sitting in front of the patient. The average duration for the sit-to-stand treatment task was 24 (SD: 44 seconds). The task start was defined when the physiotherapist verbally instructed the patient to stand and ended when the patient was in upright standing.

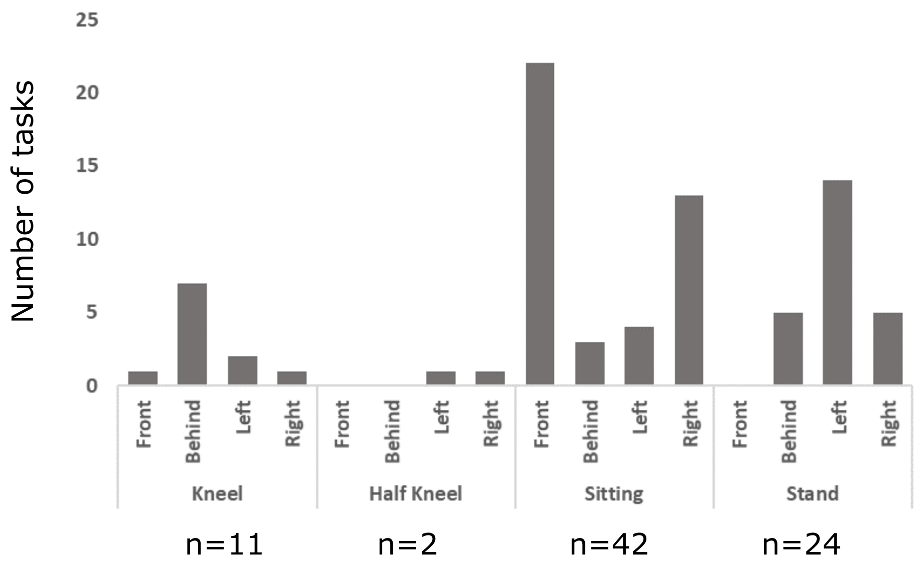


Figure 5.25: Overview of physiotherapist position in relation to patient during sit-to-stand tasks (n=number of physiotherapists)

Figure 5.26: Facilitating sit-to-stand from sitting in front of the patient

5.7.1 Proportion and Joint Angle Data

Neck movement (Head/C1 Joint)

The neck was mostly within 5° of neutral posture for side bend when in kneeling, standing, and sitting positions. When half-kneeling, 43% of the task duration was spent between 6-10° right bend. The neck was also generally within 5° of neutral rotation when in kneeling, standing, and sitting positions. The largest proportion of time was spent between 6-10° right neck rotation when in half-kneeling (26% of task) (Figure 5.27B). The neck was mostly extended when the physiotherapists were kneeling, half-kneeling or sitting (Figure 5.28A, B, D). More of the task duration was spent with the physiotherapist closer to neutral posture when in a standing position (Figure 5.28C). Kneeling, half-kneeling and sitting positions would place the physiotherapist below the patient in standing, and neck extension would be required to look up to the patient. When in standing the physiotherapist may have extended at the neck when lowering down to assist the patient from sitting. This would potentially be for a short period of the task and would fit with less time measured in neck extension than the other three physiotherapist positions.

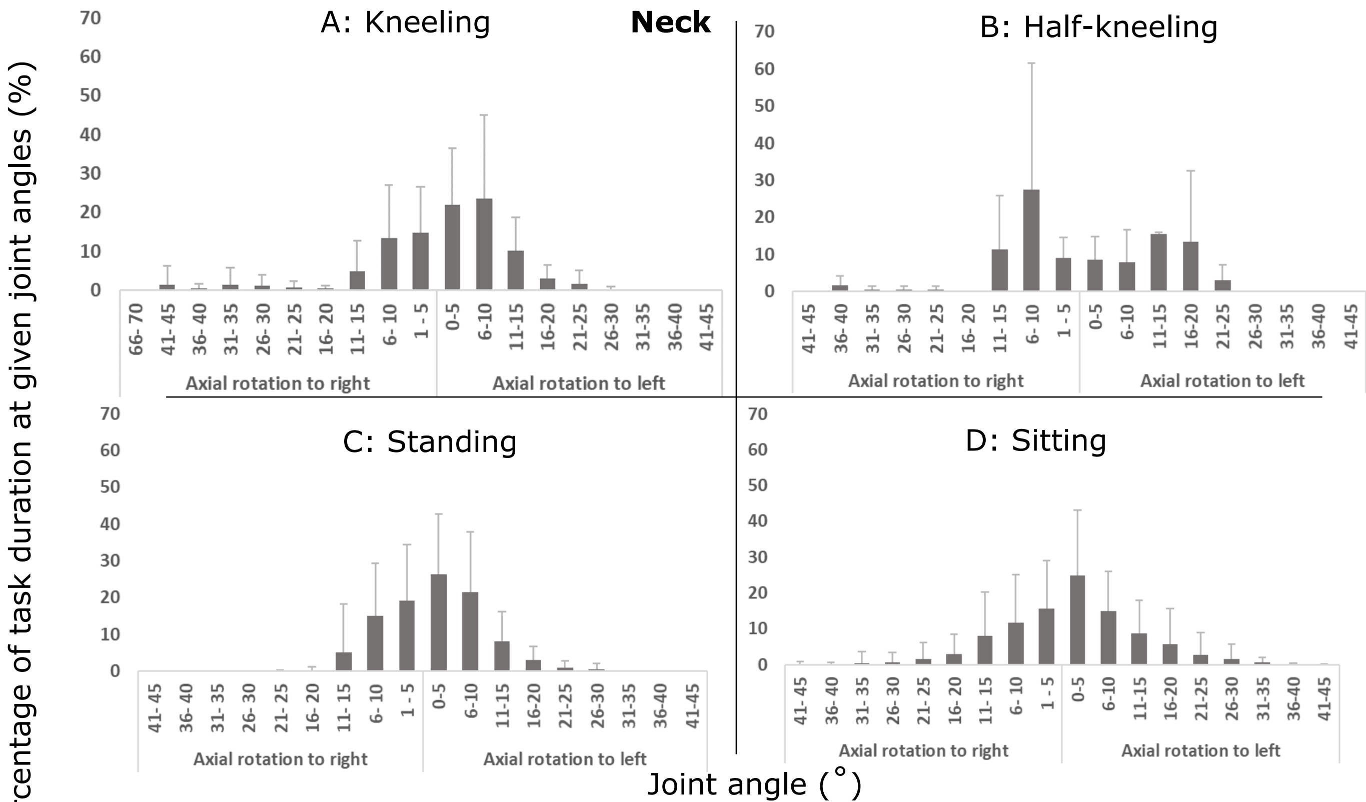


Figure 5.27: Sit-to-stand: Head and neck joint angle organised into physiotherapist position for right and left rotation with data collected in contiguous 5-degree bins (+1SD)

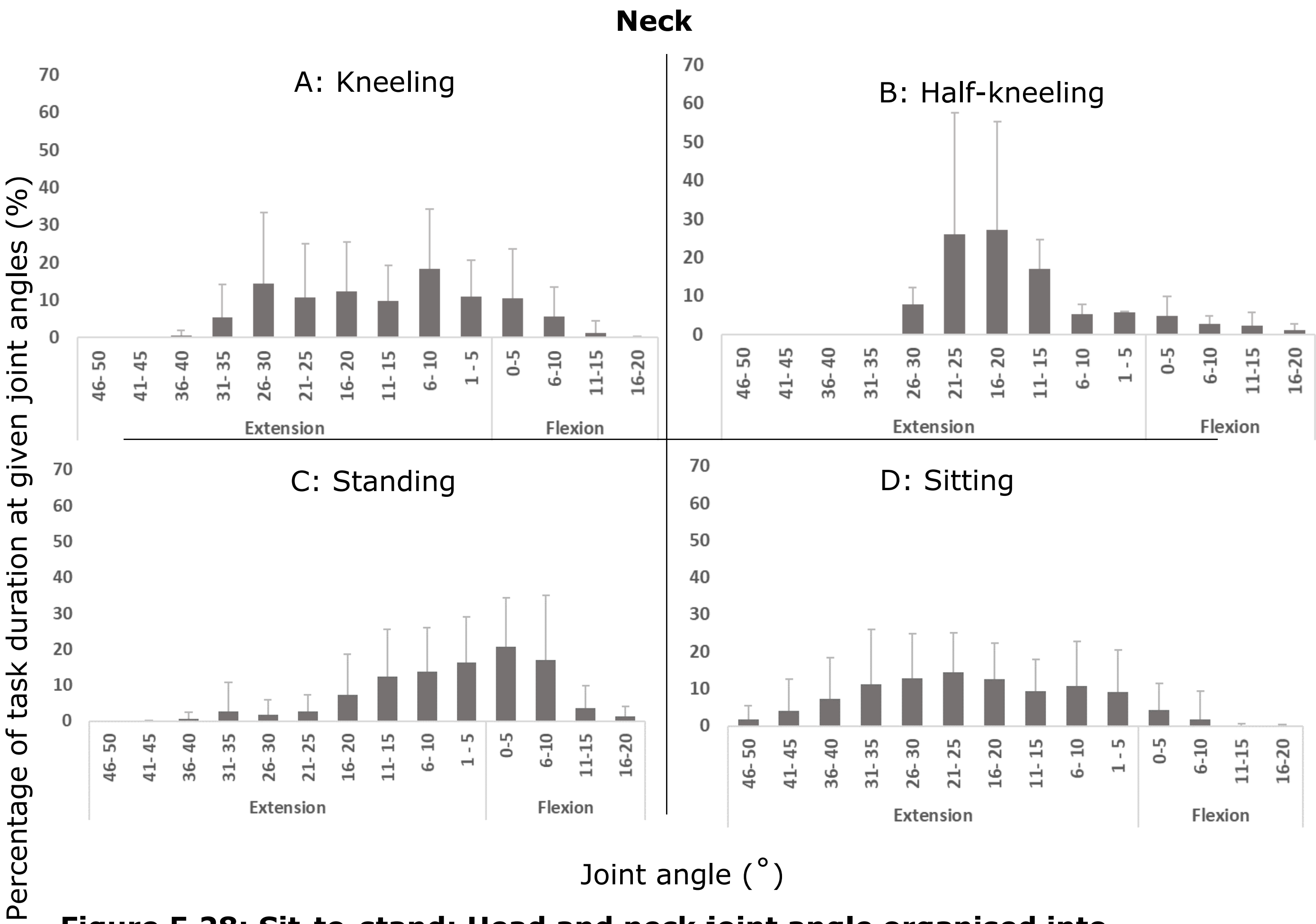


Figure 5.28: Sit-to-stand: Head and neck joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Cervicothoracic movement (C7/T1 Joint)

The cervicothoracic junction was mostly within 5° of neutral posture for side bend and rotation in all physiotherapist positions. This joint was primarily flexed during sit-to-stand tasks in all physiotherapist positions. Half-kneeling showed the least variation in joint range measured with most of the task duration spent between 6-15° cervicothoracic flexion (Figure 5.29B). Standing involved the greatest time spent at higher cervicothoracic flexion angles; with 34.7% of the task spent between 21-25° flexion (Figure 5.29C). Kneeling and sitting positions showed similar patterns of task time in joint angles (Figure 5.29A, D). When the physiotherapists were kneeling and sitting, the cervicothoracic junction was found to range from neutral to 25-30° flexion. This flexion is in combination with neck extension as found previously (Figure 5.28A, D).

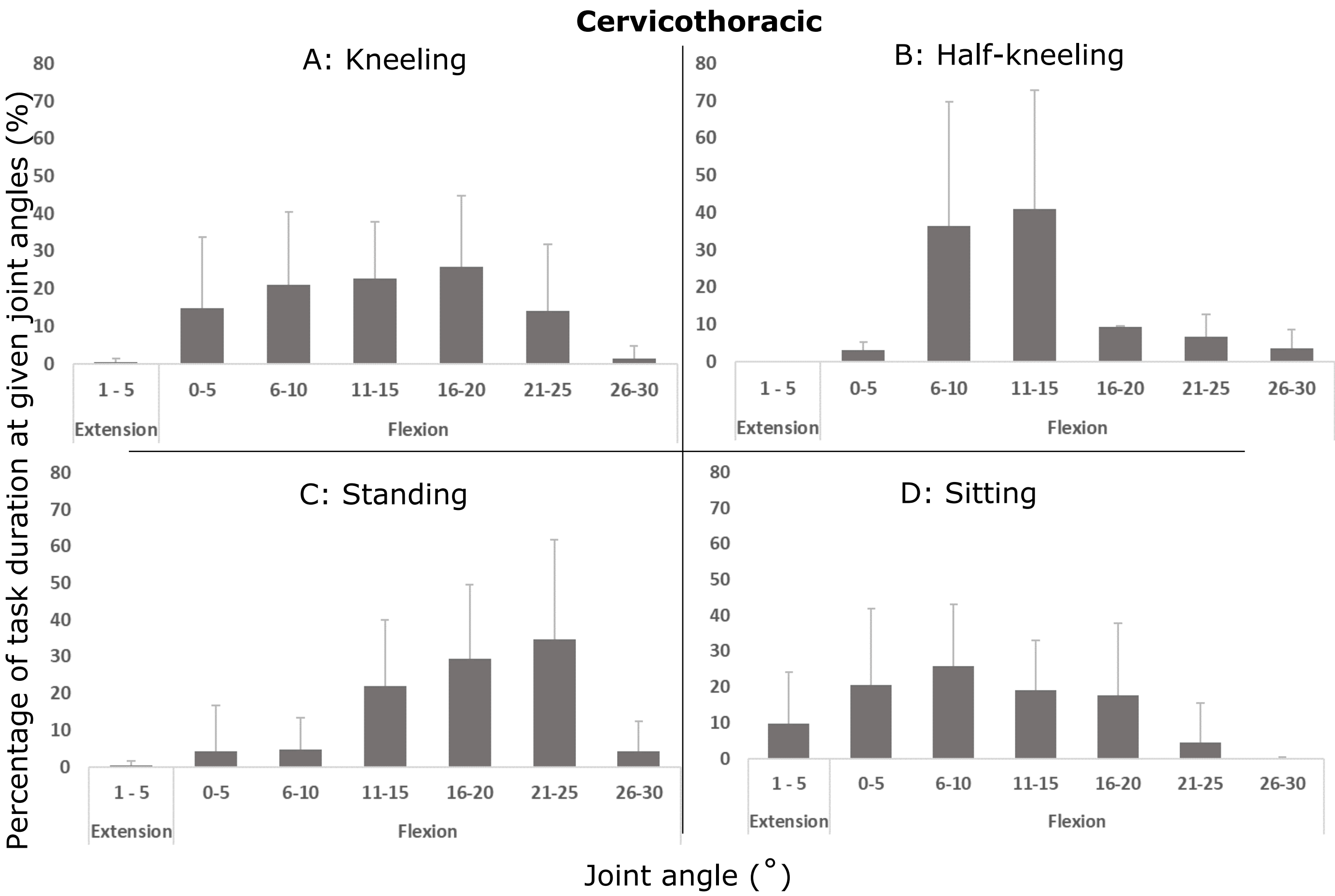


Figure 5.29: Sit-to-stand: Cervicothoracic joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Thoracolumbar movement (T12/L1 Joint)

Little ROM was measured overall at the thoracolumbar junction, likely due to the anatomy of the joint and the biomechanical model used to calculate joint angles. Most of the task was spent within 5° of neutral posture for side bend and rotation in all physiotherapist positions. Despite the small ROM measured, some differences were visible between positions for flexion and extension movements. Kneeling and standing positions were closer to the neutral posture during sit-to-stand tasks with a peak spent between neutral to 5° thoracolumbar flexion (Figure 5.30A, C). However, half-kneeling and sitting positions demonstrated the greatest proportion of task time was spent in the slightly greater thoracolumbar flexion of 6-10° (Figure 5.30B, D). Flexion at the mid-back could suggest the physiotherapists' backs were slightly rounded forwards when in half-kneeling and standing positions.

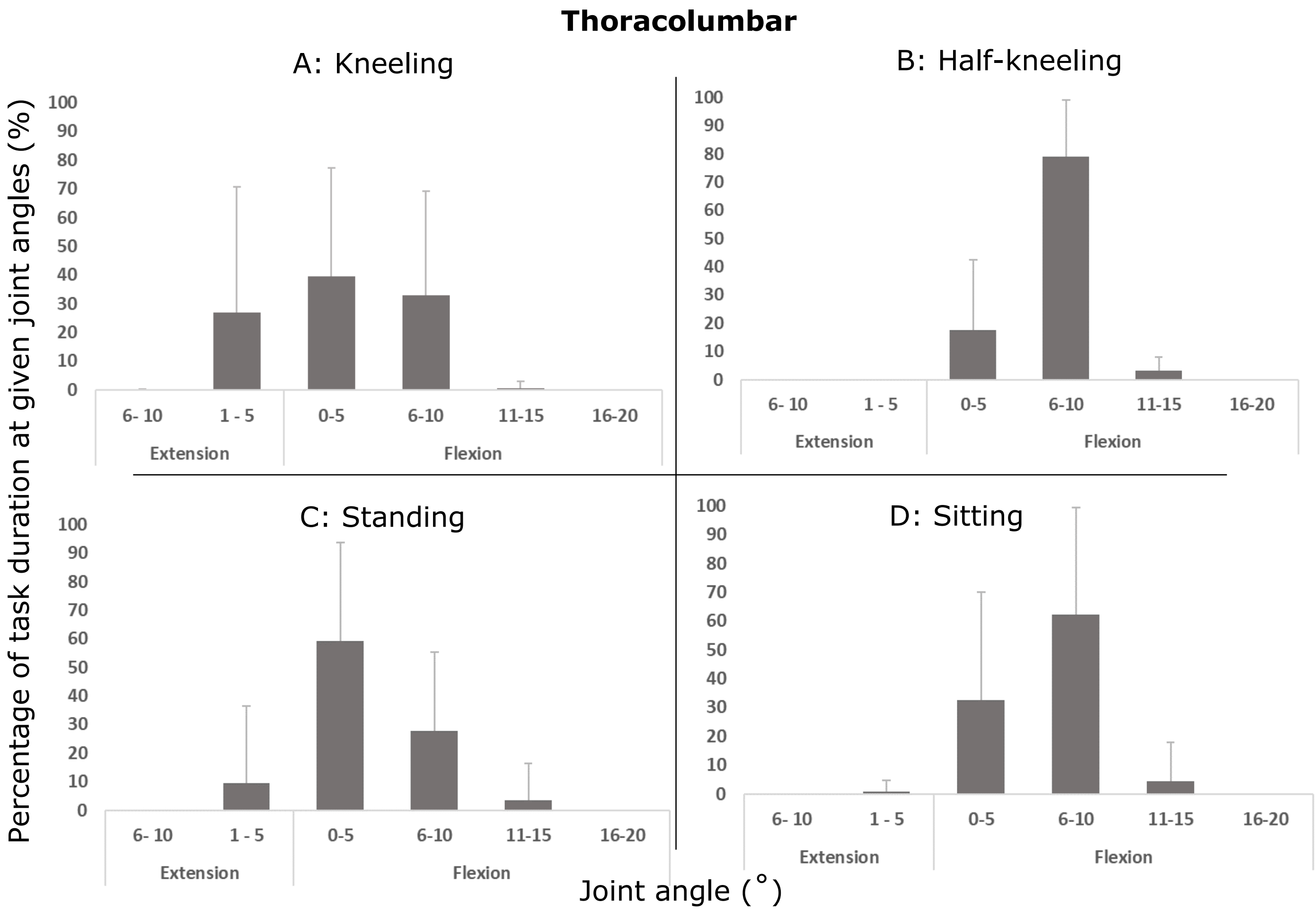


Figure 5.30: Sit-to-stand: Thoracolumbar joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Lumbosacral movement (L5/S1 Joint)

The lumbosacral junction was generally within 5° of neutral posture for side bend in kneeling, standing, and sitting positions. There was a small difference in the half-kneeling position, where 40% of the task was spent between 6-10° right bend. In all physiotherapist positions, most of the sit-to-stand task was spent within 5° of neutral lumbosacral rotation. When assisting from a standing position, the physiotherapists were more often stood to the left of the patient (n=14). Minimal movement away from neutral trunk rotation and side bend was measured despite being to the left of the patient more often. When in standing, the physiotherapist could potentially position themselves to reduce twisting and side bending movements while facilitating sit-to-stand.

Kneeling and standing positions showed a larger range of lumbosacral flexion and extension than the other positions (Figure 5.31A, C). Kneeling showed more lumbosacral extension than the other positions with 17% of the task spent between 6-10° extension (Figure 5.31A). Physiotherapists in half-kneeling and sitting spent the greatest duration of the task between 11-15° lumbosacral flexion (Figure 5.31B, D). Half-kneeling and sitting positions demonstrated increased cervicothoracic, thoracolumbar and lumbosacral flexion which suggested trunk flexion occurred at all segments of the spine measured in this study. Flexion found at the three segments of the spine describe a forward flexed and rounded trunk posture during facilitation of sit-to-stand when in half-kneeling and sitting positions.

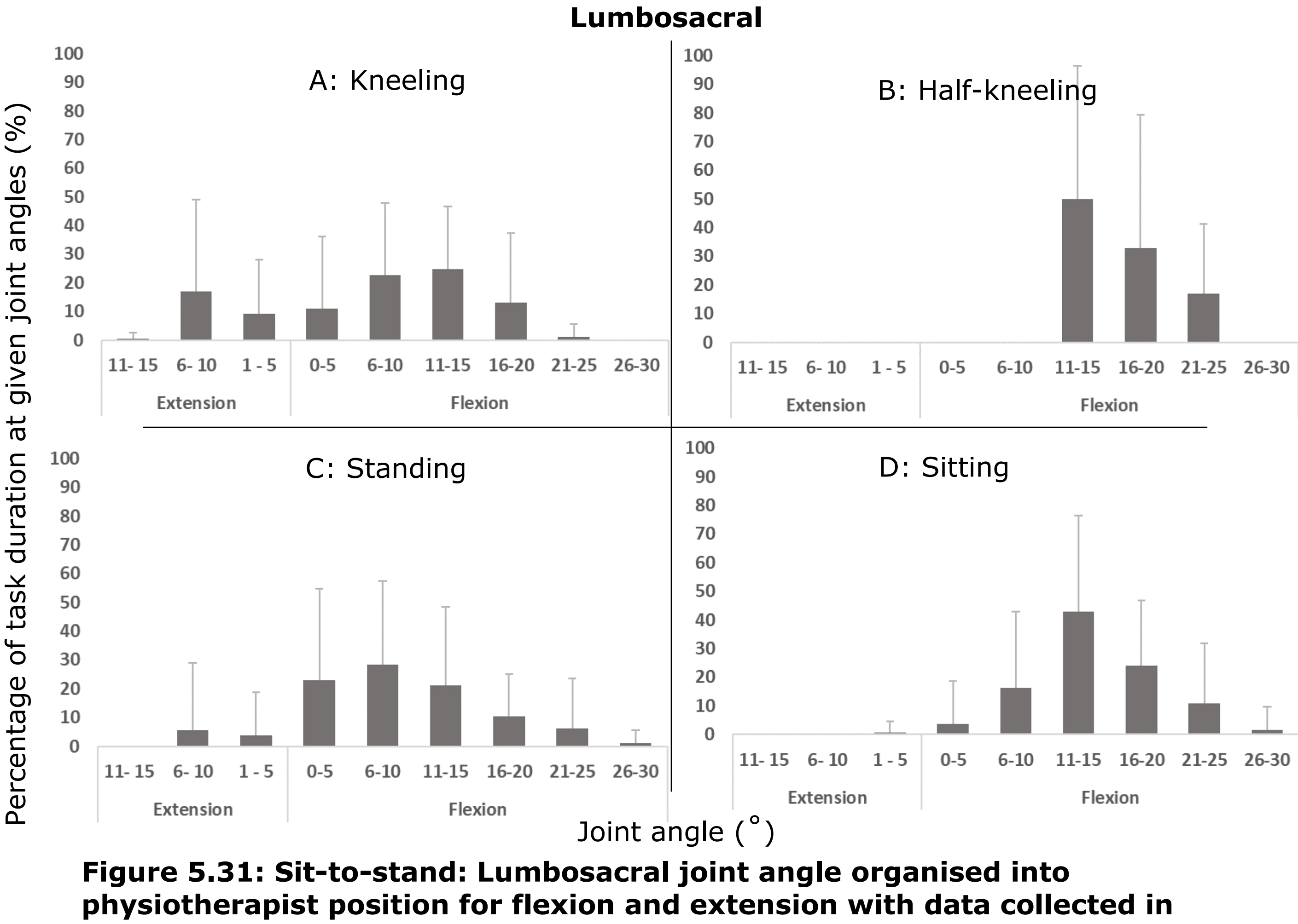


Figure 5.31: Sit-to-stand: Lumbosacral joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Shoulder Girdle movement (T4/Shoulder Joint)

For all physiotherapist positions, the shoulder girdle was found to be generally protracted and elevated during sit-to-stand tasks. Shoulder girdle protraction and elevation would be expected when using the arms to reach forwards and facilitate the patient. Kneeling and standing positions showed only minor differences between left and right sides for elevation. Half-kneeling showed slight side differences for shoulder girdle protraction. When in standing these differences are likely related to the physiotherapist being positioned more often to the right of the patient. This could be related to the handedness of the physiotherapists, as most were right-hand dominant. When in kneeling, the physiotherapist was more often kneeling behind the patient, the minor differences may be related to individual variations in area of facilitation on the patient during the sit-to-stand tasks.

Shoulder movement

A similar pattern of task duration was spent in shoulder abduction for all physiotherapist positions. Peaks in task duration for kneeling, standing, and sitting positions were all spent between 11-20° shoulder abduction. Half-kneeling demonstrated a peak in time spent between neutral to 5° shoulder abduction. Overall, no physiotherapists went above 80°shoulder abduction during sit-to-stand tasks in this study. Full active abduction ROM is normally 180°, as discussed in Chapter 1. Therefore, the shoulder movement remained under half of the full available ROM during sit-to-stand tasks in all physiotherapist positions. Kneeling postures demonstrated a relatively even distribution of task time between internal and external shoulder rotation. Physiotherapists who were in half-kneeling, standing, and sitting positions spent more task time with the shoulder internally rotated. When the physiotherapists were reaching and facilitating at the patients' lower limbs and hips, internal rotation of the shoulder would be required. Minimal impact to the movement of the shoulder would be expected due to the physiotherapist's position and their position in relation to the patient.

Different patterns were visible for shoulder flexion depending on the physiotherapist's position during the task. When the physiotherapist was kneeling, three peaks in joint angle are visible between 6-10°, 41-50° and 81-85° flexion (Figure 5.32A). These positions could be related to the patients' position and the anatomical regions the physiotherapists were facilitating. Increased shoulder flexion could be related to reaching up or forwards to the patient when the physiotherapists were in a kneeling position. Shoulder position could be closer to neutral while also reaching to patients by flexing at the trunk or elbows. Standing and sitting positions demonstrated a more even spread of task duration spent in specific joint angles with a less clear single peak (Figure 5.32C, D). Standing showed less task duration spent in greater shoulder flexion than the sitting position. When in standing, most of the task duration was spent between neutral to 65° shoulder flexion. This is in contrast to sitting, where most of the task duration was spent between neutral to 100° shoulder flexion. This would be expected, as it was observed that the physiotherapists were standing close to the patient and less shoulder flexion would be required to reach towards the patient for facilitation. Half-kneeling shows a clear single peak in duration for the left shoulder between 26-30° flexion, with the right shoulder showing more of a spread of joint movement through range from 45° extension to 80° flexion (Figure 5.32B).

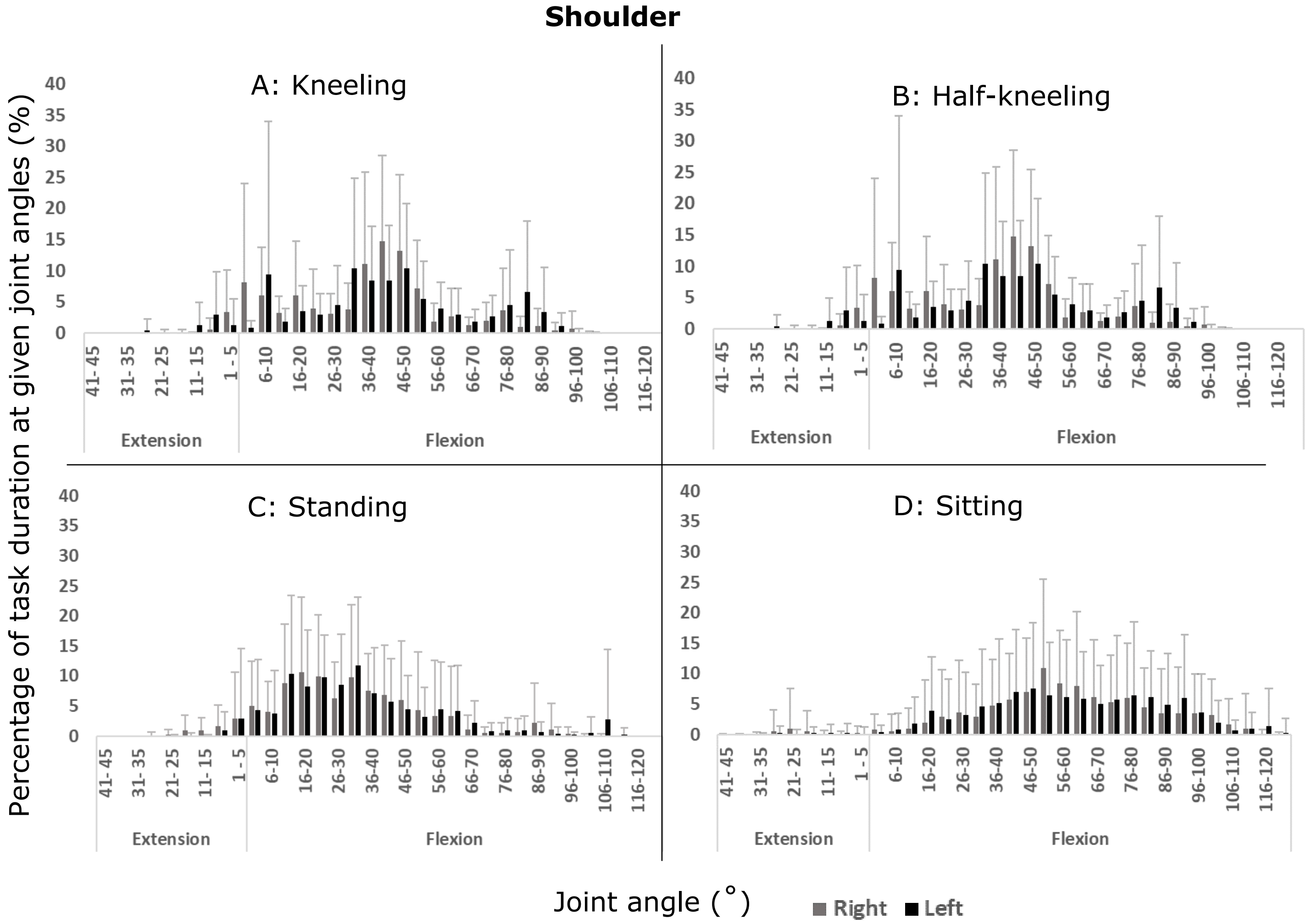


Figure 5.32: Sit-to-stand: Shoulder joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Hip movement

When the physiotherapists were in a kneeling position, the hip was slightly more abducted than other positions; especially at the left hip (Figure 5.33A). Half-kneeling illustrated a similar pattern for both left and right sides with two peaks in the task spent between neutral to 5° abduction and 11-15° hip abduction (Figure 5.33B). When the physiotherapists were standing, the right hip was closer to neutral, with the left more abducted (Figure 5.33C). This could be related to physiotherapist position in relation to the patient or plinth. More trials in standing were performed with the physiotherapists to the left of the patients (i.e., with the patient to the right of the physiotherapist when standing forwards). If the physiotherapists were to adopt a wider and more stable BoS, abduction at the left hip would be required, as the plinth would be close to the right lower limb. A large spread through joint range was found for sitting for hip adduction and abduction (Figure 5.33D). In terms of rotation at the hip, kneeling, standing, and sitting positions had a relatively even split of duration between internal and external rotation. Half-kneeling showed more range into internal rotation, with peaks in task duration between neutral to 10° external rotation and 16-20° internal rotation.

A large range of joint motion was found for hip flexion in kneeling, standing, and sitting positions. Half-kneeling showed less ROM measured during sit-to-stand tasks. This could suggest that when the physiotherapists were half-kneeling, their lower limbs moved less than in the other positions. Kneeling showed two peaks between 5° extension to 10° flexion, and 76° to 85° hip flexion (Figure 5.34A). This is related to the physiotherapists high and low kneeling behind the patient during the task. The physiotherapists who were standing showed generally lower flexion angles than in a sitting position (Figure 5.34C, D). This is expected as when seated the hips would be flexed to approximately 90°. Half-kneeling hip range illustrated two peaks in hip position at 11-15° flexion and 56-65° flexion (Figure 5.34B). This spread in joint angles could be due to variation in half-kneeling positions on the floor and on the plinth.

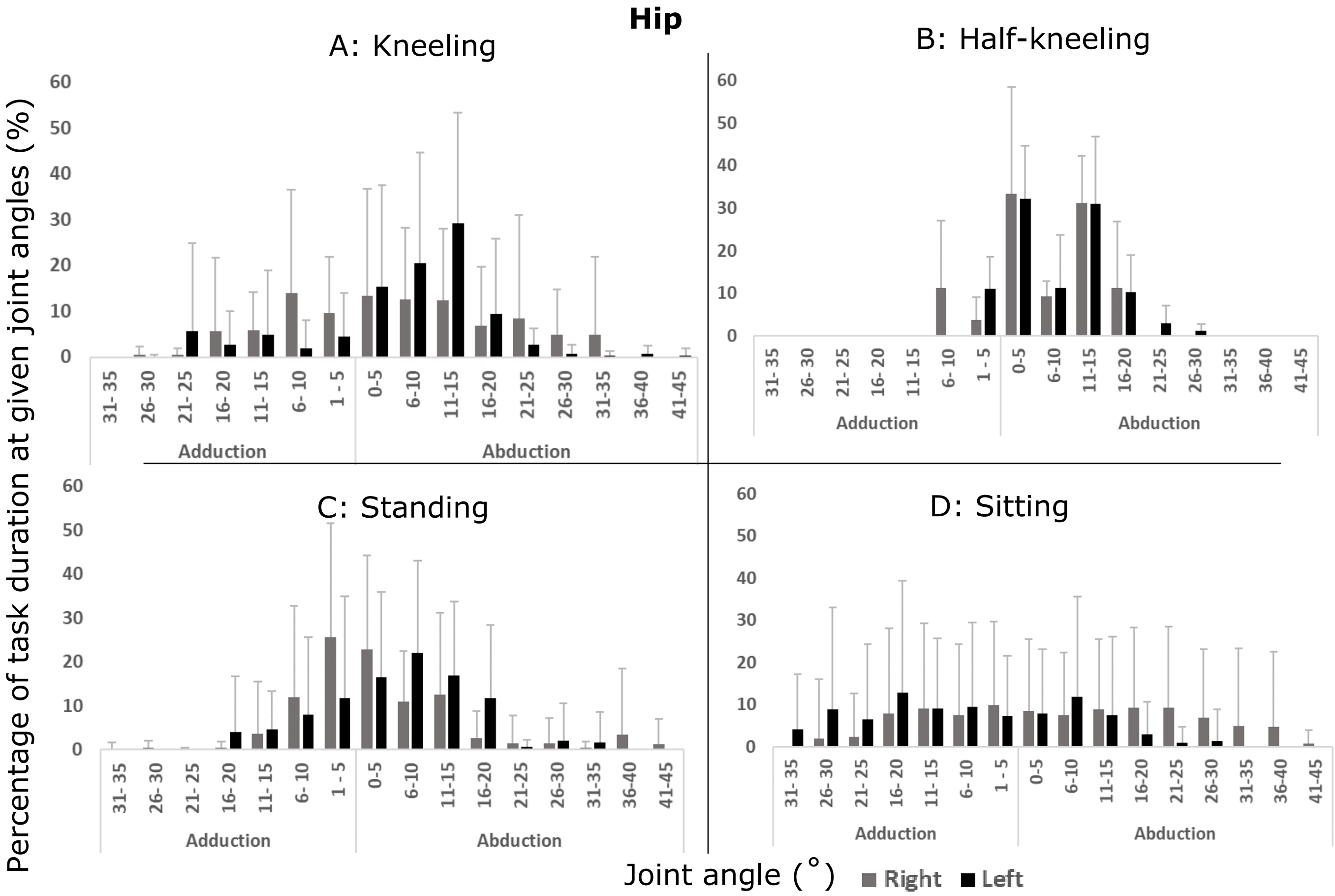


Figure 5.33: Sit-to-stand: Hip joint angle organised into physiotherapist position for adduction and abduction with data collected in contiguous 5-degree bins (+1SD)

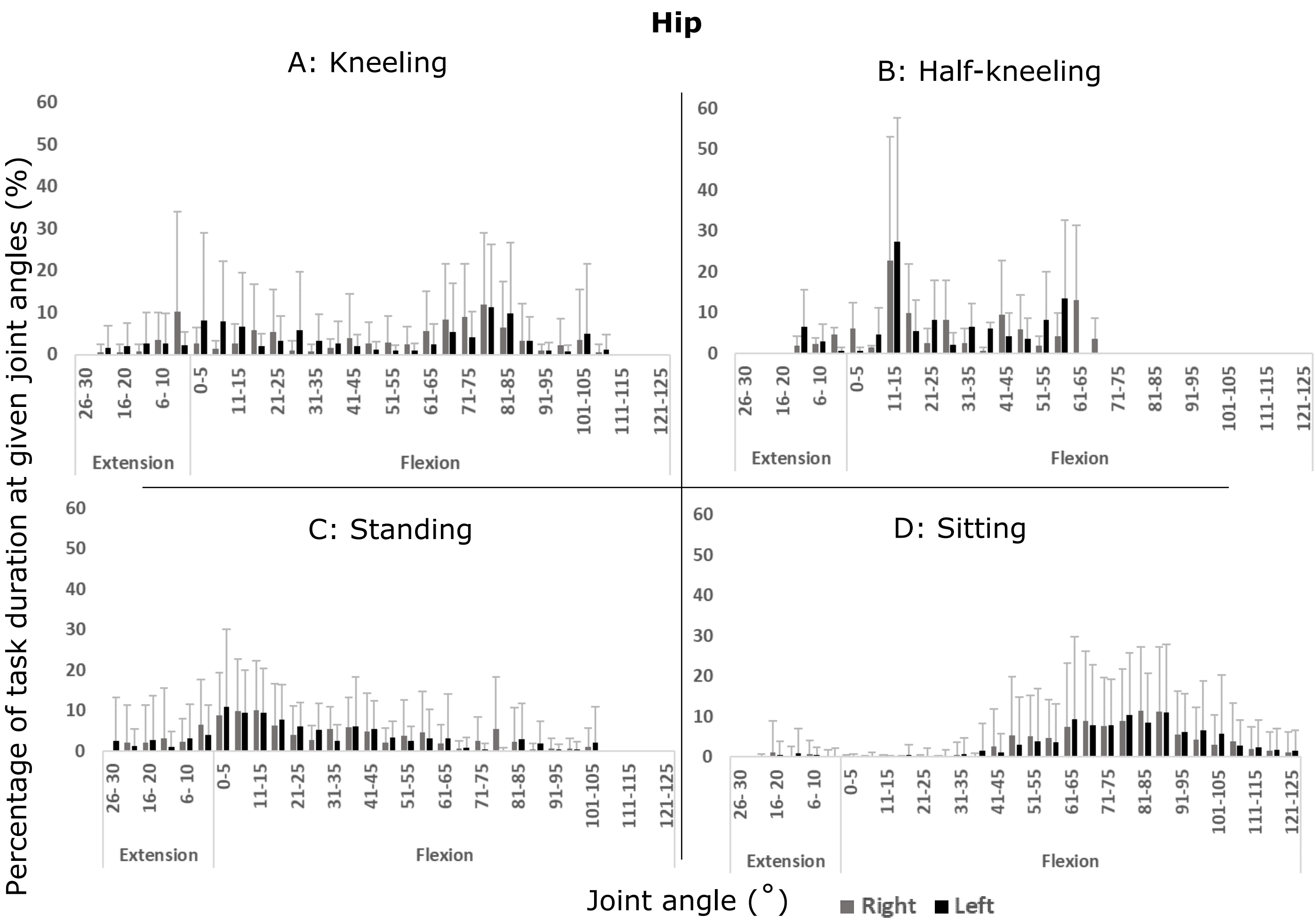


Figure 5.34: Sit-to-stand: Hip joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Knee movement

Knee movement during the sit-to-stand tasks when in kneeling, standing, and sitting positions fit with peaks and ranges of knee ROM that would be expected with each position. When kneeling, the knee was flexed towards end ROM, with a peak in task duration between 126-130° flexion. Standing showed a peak in task duration near neutral, and sitting showed a peak between 86-95° knee flexion (Figure 5.35C). These joint positions could be expected as standing requires a neutral, extended knee, whereas, sitting would require approximately 90° knee flexion. The variation found in knee flexion angles when in sitting are related to the variation in sitting on a fixed-height stool and also on a plinth, where the height could be changed. Half-kneeling showed two peaks in task duration between 11-20° flexion and 131-145° flexion (Figure 5.35B). When in half-kneeling the physiotherapist sometimes had one knee on the plinth with the other leg extended to the floor. This position would require one knee to be more extended and one flexed towards end ROM.

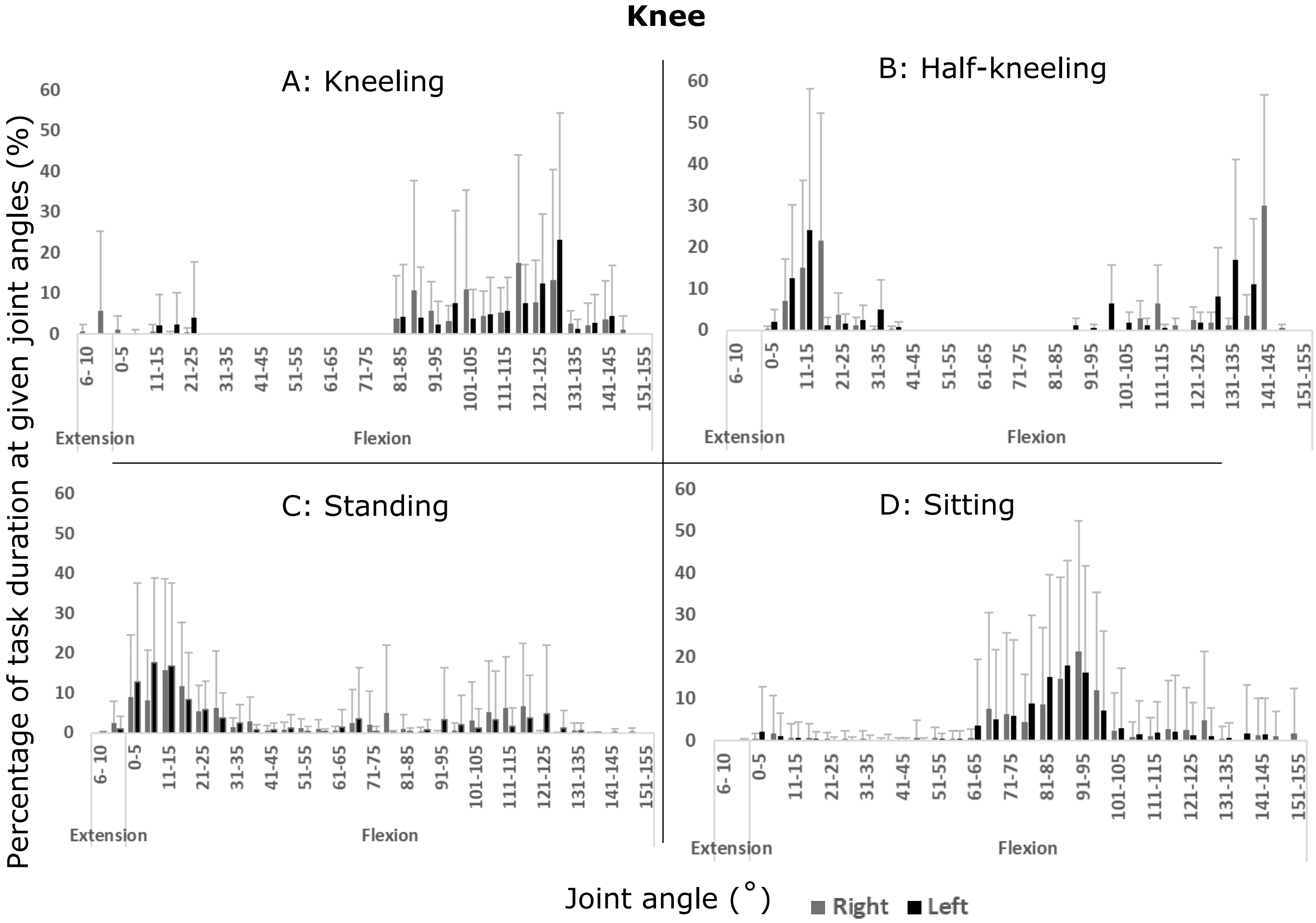


Figure 5.35: Sit-to-stand: Knee joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

5.7.2 Time Normalised Data

This data described how the physiotherapist moved over the duration of the sit-to-stand task in terms of joint angles for each category of physiotherapist position. The start of the task was when the patient was sitting, and the physiotherapist verbally instructed the start of the patient movement. The sit-to-stand task ended when the patient was in static standing. The joint angle data were time normalised for each recording to allow for comparison across all physiotherapists in each position during the sit-to-stand tasks. The time normalised data were presented as the average joint angles for each position used by the physiotherapists. As joint angle data from the physiotherapists' trunk and lower limbs showed little movement out of neutral for side bend and rotation, only the sagittal plane (flexion/extension) data is discussed.

When in a kneeling position, the cervicothoracic junction showed the physiotherapists, on average, moved from approximately 10° flexion to 15° flexion. The thoracolumbar and lumbosacral junctions maintain a steady flexion angle between neutral to 10° flexion for the duration of the task (Figure 5.36A). The physiotherapists' necks initially demonstrated 15° extension and steadily moved to 10° extension over the sit-to-stand task. The physiotherapists were more often kneeling behind the patient during the sit-to-stand tasks (n=7). The physiotherapists were kneeling on the plinth and a gradual extension movement was measured at the physiotherapists' lower limbs (Figure 5.37A), suggesting the patients raised up from low kneeling towards high kneeling. The neck may have become less extended as the physiotherapist moved to high kneeling, as the patient would move to be more similar in height to the physiotherapist. Hip flexion, in combination with cervicothoracic, thoracolumbar and lumbosacral flexion, suggested the physiotherapist was leaning forwards to the patient, with a rounded back.

Most of the sit-to-stand tasks recorded in a standing position were with the physiotherapist standing to the left of the patient (n=14). The physiotherapists would still be expected to flex at the trunk and hips to allow them to bend down or lean to the patient. Additionally, trunk and hip flexion would be expected if the patient was shorter in stature than the physiotherapist. When in standing, the physiotherapists' necks were found to maintain a more neutral position before slightly flexing at the end of the task. The cervicothoracic junction shows the highest flexion angle compared to the other positions, maintaining 15-20° flexion throughout the task. The thoracolumbar and lumbosacral junctions maintained a flexed position for the duration of the sit-to-stand tasks, with a slight increase in flexion angle measured over the first half of the task (Figure 5.36C). The physiotherapists lower limbs showed similar movement for left and right sides. The hips and knees were slightly flexed with a slight increase in flexion over the first half of the task (Figure 5.37C). This increase in hip and knee flexion could be due to the physiotherapist leaning forward to the patient, or from a slight softening of the knees which is taught in moving and handling training (NHS 2021). The physiotherapists likely lowered themselves to the height of the patient with a combination of slight lower limb flexion and cervicothoracic, thoracolumbar and lumbosacral flexion.

When in a half-kneeling position, the neck and cervicothoracic junction showed extension over the middle portion, before flexing at the end of the sit-to-stand task. Half-kneeling positions demonstrated initial lumbosacral flexion before maintaining that flexion angle for the remainder of the sit-to-stand task. Half-kneeling showed the highest angle of flexion maintained at the lumbosacral junction during sit-to-stand tasks (15-20° flexion) (Figure 5.36B). The physiotherapists' lower limbs illustrated a pattern of extension over the duration of the sit-to-stand task when the physiotherapists were half-kneeling (Figure 5.37B). The physiotherapists left and right lower limbs follow a similar pattern of movement. The physiotherapists were observed to be half kneeling, with one knee, and the other foot on the floor. The slight hip flexion and lumbosacral flexion are related to the physiotherapist leaning forwards towards the patient in this position.

When the physiotherapist was assisting sit-to-stand from a sitting position, little movement was seen at all joints analysed. The cervicothoracic, thoracolumbar and lumbosacral junctions maintained a relatively static flexed position throughout the duration of the sit-to-stand task (Figure 5.36D). The lower limbs also maintained hip and knee flexion angles as would be expected with a seated position (Figure 5.37D). This could suggest most of the task was performed by the upper limbs when the physiotherapists were sitting. As shown in Figure 5.25 (Page 155), most of the physiotherapists were sitting in front of the patients (n=22). When sitting in front of the patient, the physiotherapists would have to flex forwards at the trunk and hips to lean towards the patient. The physiotherapists' shoulders would also flex to reach up to the patient and the physiotherapists' lower limbs would remain generally static.

Overall, differences in patterns of movement can be seen between the different physiotherapist positions. Sitting showed the least movement during the task, potentially due to the limited movement available when sitting in front of the patient and 'blocking' the patient's affected knee with their own knees. Half-kneeling and sitting show the highest flexion angles at the lumbosacral junction, potentially due to the physiotherapist leaning and reaching towards the patient. Physiotherapists assisting sit-to-stand from a half-kneeling position also showed an increase in hip flexion, lumbosacral flexion and neck extension.

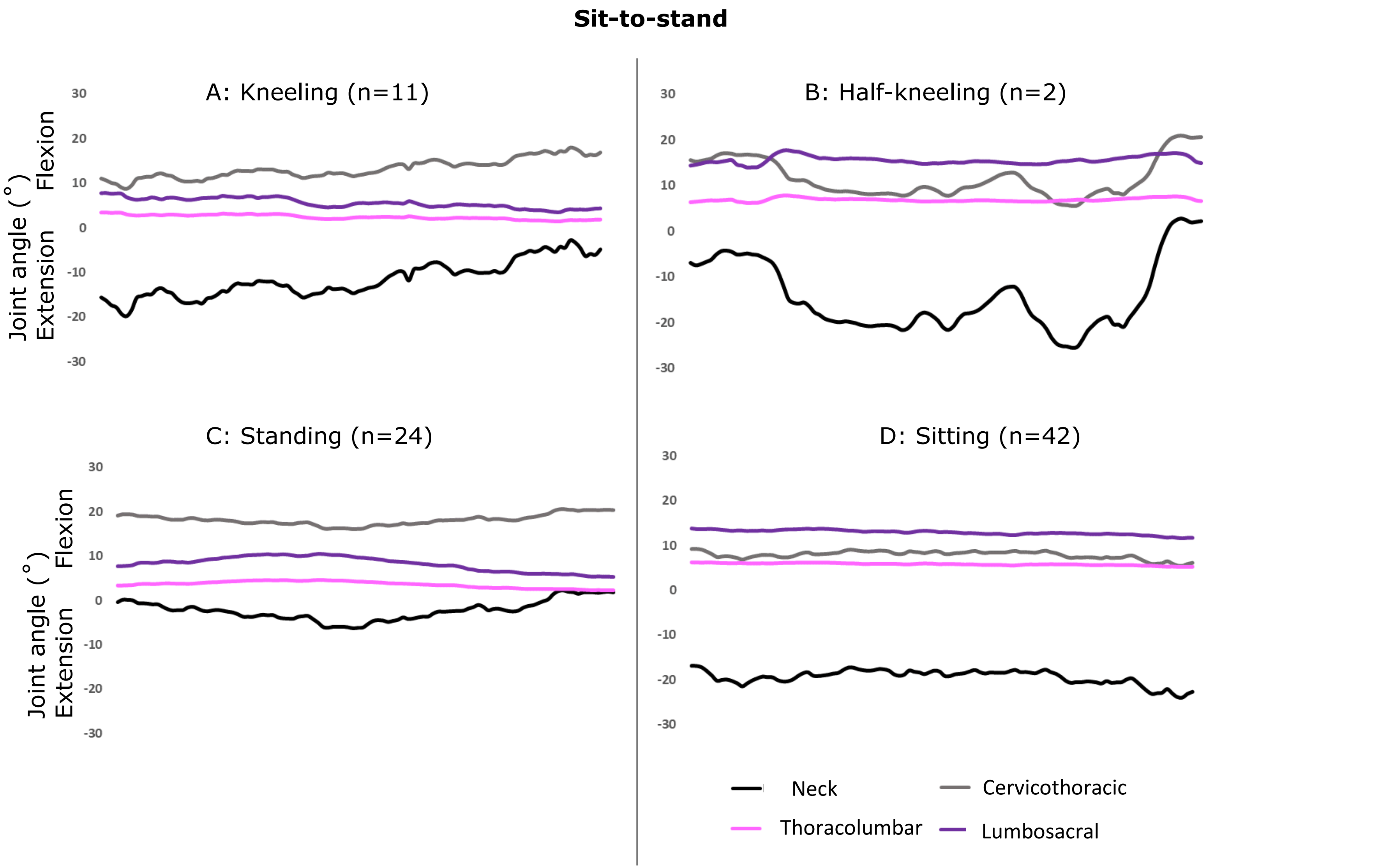


Figure 5.36: Sit-to-stand: Time normalised average joint angle for trunk movement organised by physiotherapist position. A: Kneeling, B: Half-kneeling, C: Sitting, D: Standing (n=79)

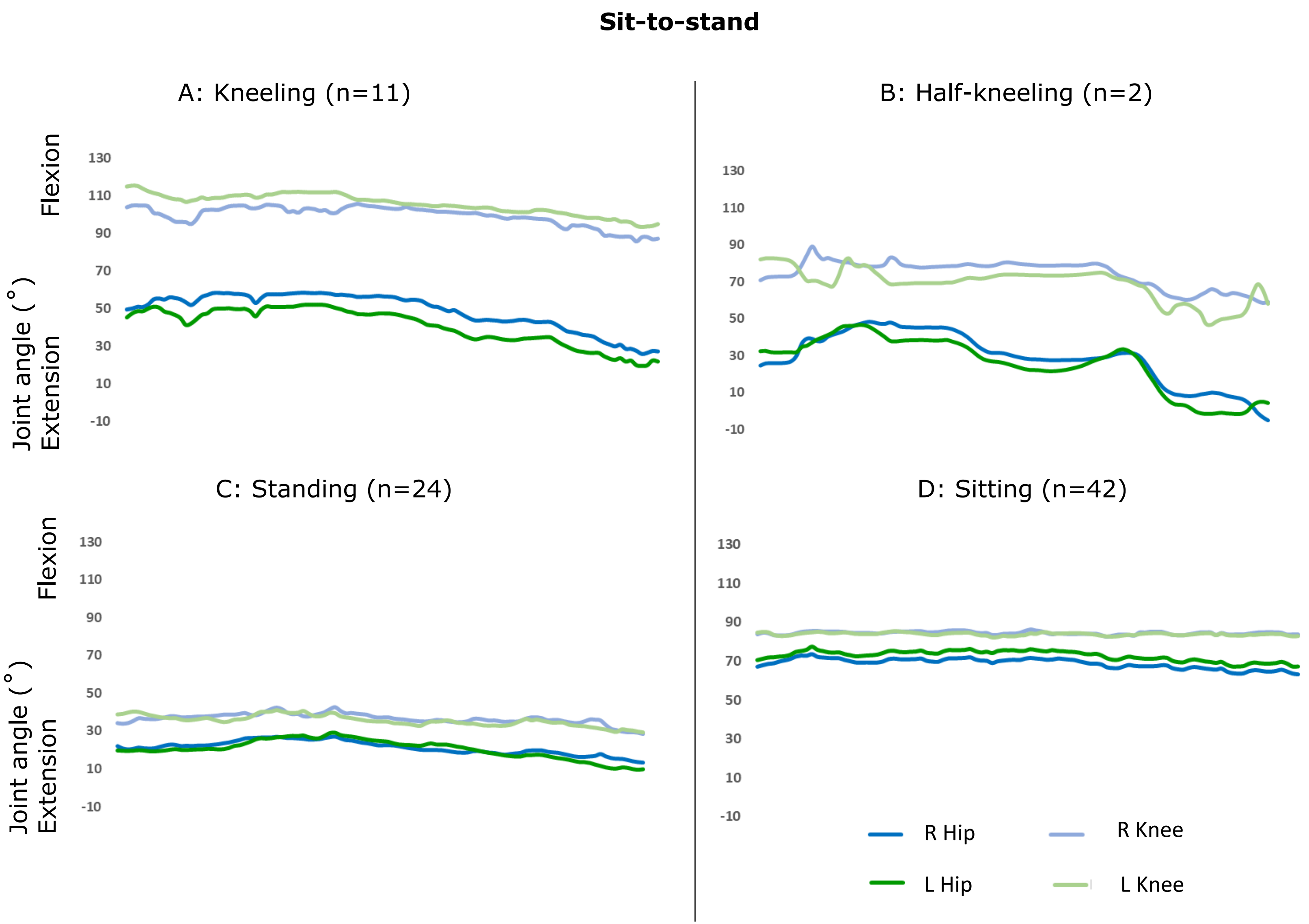


Figure 5.37: Sit-to-stand: Time normalised average joint angle for lower limb movement organised by physiotherapist position. A: Kneeling, B: Half-kneeling, C: Sitting, D: Standing (n=79)

5.7.3 Sit-to-stand Summary

Physiotherapist position during facilitation of sit-to-stand has been quantified and described both in terms of percentage duration of task in joint angles and with time normalised data. Physiotherapists' recordings were organised into four positions (kneeling, half-kneeling, standing and sitting) to aid with quantification and description of joints during the task.

Overall, the trunk and head were generally near a neutral position for lateral bend and rotation for all positions, with little movement at the thoracolumbar junction found. An exception to the neutral position was seen when the physiotherapists were half-kneeling, which showed slight right bend and rotation at the head and lumbosacral junction. This could be due to a combination of position in relation to the patient and an asymmetrical BoS. Facilitating sit-to-stand from a half-kneeling position was performed from the left of the patient (n=1) and from behind the patient (n=1). The head rotation could be from the physiotherapist turning their head to communicate round the patient or to another physiotherapist or support worker.

Differences in physiotherapists' joint angles were seen especially for flexion and extension movements at each joint analysed. When the physiotherapists were in a kneeling position, lumbosacral movement was found to remain closer to neutral than half-kneeling positions, which demonstrated lumbosacral flexion. Differences were also seen at the physiotherapists' lower limbs between kneeling and half-kneeling positions. Half-kneeling was sometimes on the floor, which would require increased flexion angles at the hips and knees, or on the plinth which would require one hip and knee to be more flexed with the other side more extended to reach the floor. It was not observed than any physiotherapists half-kneeled with both lower limbs on the plinth. Half-kneeling with one knee on the plinth and the other extended to the floor would explain the two peaks seen for hip and knee ROM.

When the physiotherapists were kneeling, the knees were found to maintain flexion towards end ROM for most of the task duration as would be expected with the position. The spread of joint angles measured at the physiotherapists' hips, which suggested the physiotherapists' hips did not stay stationary during facilitation of sit-to-stand from a kneeling position. Sometimes the physiotherapists would move from low kneeling (sitting back onto the lower legs) to high kneeling (hips extended). This would explain the spread of joint angles measured during the task. The physiotherapists were often kneeling on the plinth and would move to high kneeling as the patient moved to standing. The plinth would provide some cushioning under the physiotherapists knees but maintaining end range knee flexion with the addition of the physiotherapist's body weight could cause discomfort. Shoulder movement was generally similar for kneeling and half-kneeling positions.

When the physiotherapists were seated, higher neck extension was measured for the task than the other physiotherapist positions. This is combined with trunk flexion at all three joints measured and could be an uncomfortable position if maintained for a prolonged period of time. The shoulders were also found to be flexed to a higher angle than other positions, as the physiotherapist would have to reach up to the patient once they have performed the sit-to-stand. However, little task duration was spent over 90° shoulder flexion.

When the physiotherapist was standing, the neck was found to be more neutral however, the cervicothoracic junction was more flexed than other positions. This could be due to the physiotherapist reaching or stooping down to the patient to facilitate at the patients' hips or trunk. Differences in upper limb and lower limbs would be expected. Standing to sitting positions place the physiotherapist in a different position in relation to the patient. When in a standing position the physiotherapist placed themselves close to the patient. Standing close to the patient could explain the smaller hip and lumbosacral flexion angles measured as the physiotherapist would be required to lean towards the patient less. However, the physiotherapists would potentially have to stoop down if the patient were shorter in height or to reach down to the patient's hips. The cervicothoracic junction was flexed during sit-to-stand tasks from a standing position, which could describe the physiotherapist stooping down. The other three physiotherapist positions may place the physiotherapist further away from the patient and therefore could require further trunk flexion and upper limb from reaching forwards to the patient. Variations in physiotherapist movement were measured, suggesting a large range of physiotherapist movements and positions during sit-to-stand tasks.

Most of the physiotherapists were sitting when assisting the patient up to standing. This seated position is potentially quite specific to neurological physiotherapy settings, as moving and handling trains staff to facilitate sit-to-stand from a standing position next to the patient. To therapeutically treat the patient, more specific handling and facilitation of the patients' lower limbs is required, which would not be more difficult if the physiotherapists were standing.

5.8 Upper Limb Facilitation

The data presented in this section describes the physiotherapist movement while treating and assisting the patients' upper limb. Patients can experience significant upper limb weakness and altered coordination of movement after a stroke or brain injury. Treatment aims to improve movement through targeting specific muscle groups, movements or functional tasks. To improve independence with upper limb tasks, physiotherapists work on improving sensation, global muscle activation and fine motor control tasks (Pollock et al. 2014). Examples of tasks performed are muscle stretches, sensation, strengthening and functional tasks such as reaching (Table 5.2 on Page 122). The range of positions used by the physiotherapists is outlined below in Figure 5.38. The most common position used by physiotherapists was sitting (41 of 97 trials), standing positions were the second most held position (34 of 97 trials). It was observed that more patients presented with a left-sided weakness in this study; this would account for the larger number of recordings with the physiotherapist positioned to the left of the patient. When the physiotherapists were sitting it was either on the plinth beside the patient or on a stool. The average duration of upper limb treatment was 116.5 seconds (SD 70.9).

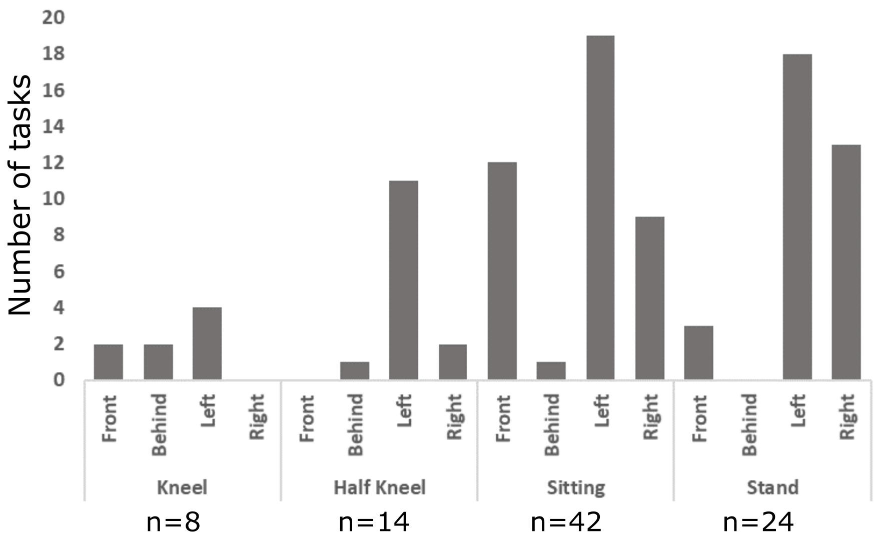


Figure 5.38: Physiotherapist position in relation to patient during patient upper limb treatments (n= number of physiotherapists)

5.8.1 Proportion and Joint Angle Data During Upper Limb Facilitation

Neck movement (Head/C1)

The neck was generally within 5° of neutral posture for both side bend and rotation in kneeling, standing and sitting positions. A greater duration was spent in slight right bend when the physiotherapists were half-kneeling. If the physiotherapist was half-kneeling on the plinth, it was observed that they often faced the patient. This positioned the patients left side to the right of the physiotherapist and could describe the slight preference to right bend found. The neck was more extended in kneeling and sitting positions compared with half-kneeling and standing positions. Kneeling showed a peak between 16-20° neck extension (Figure 5.39A) and sitting between 6-10° neck extension (Figure 5.39D). The neck was more neutral when the physiotherapists were in standing positions (Figure 5.39C).

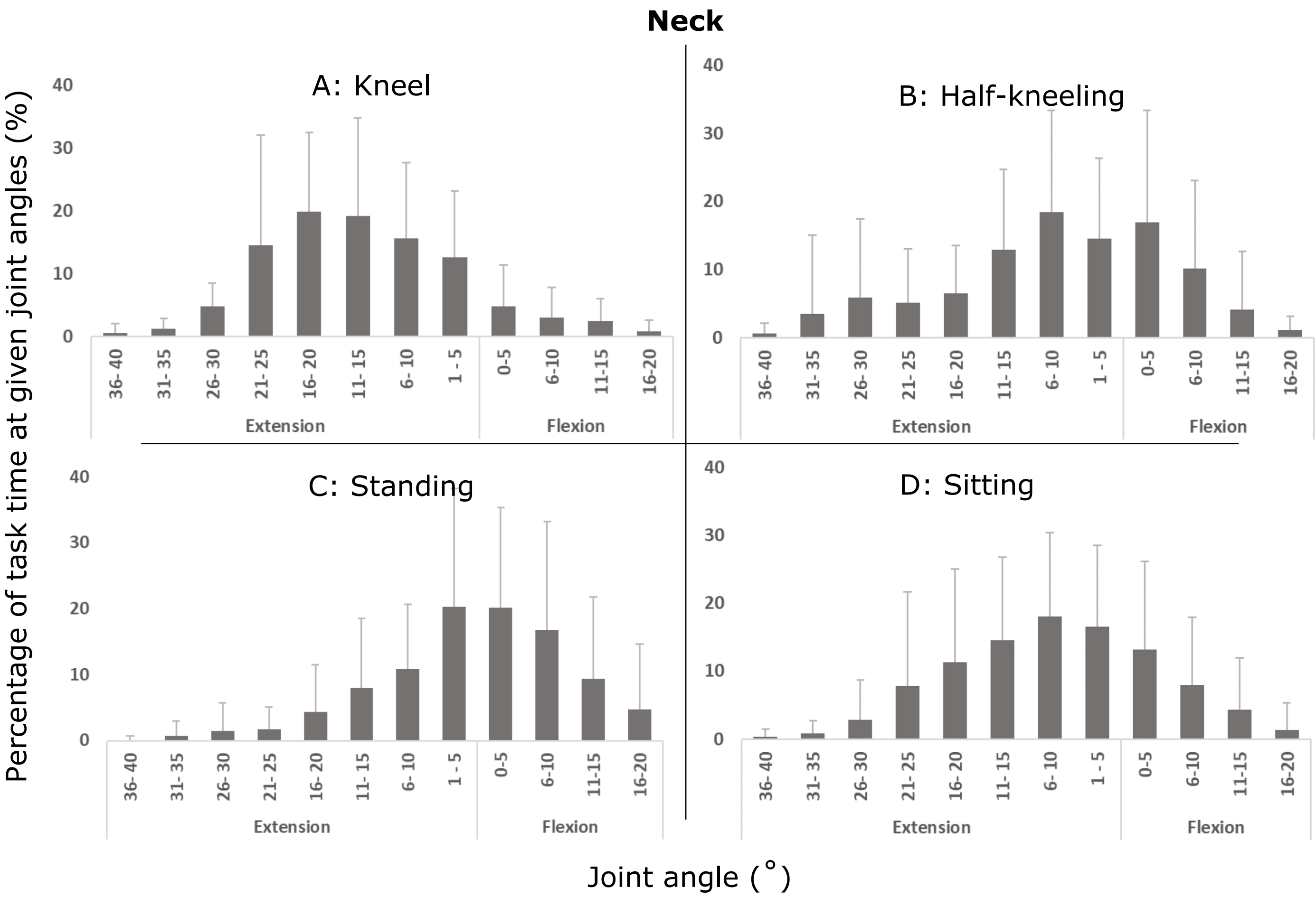


Figure 5.39: Upper Limb: Neck joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Cervicothoracic movement (C7/T1)

The cervicothoracic junction was mostly within 5° of neutral posture for side bend in kneeling, standing and sitting positions. Slight right bend was found when the physiotherapists were in half-kneeling, with a peak in task duration between neutral to 10° right side bend. Similar to the neck, the slight preference to right bend is likely related to the recordings where the patient is to the right of the physiotherapist. The slight preference to the right side could also be related to the greater proportion of participants being right-hand dominant or due to the layout of the plinths in the gym space. The cervicothoracic junction was mostly within 5° of neutral rotation for all physiotherapist positions. The cervicothoracic junction was flexed for all physiotherapist positions, a similar pattern of duration in joint ranges is demonstrated and a peak in task duration was spent between 11-25° cervicothoracic flexion (Figure 5.40A-D). Cervicothoracic flexion could describe the physiotherapists rounding at their upper back during upper limb facilitations independent of position.

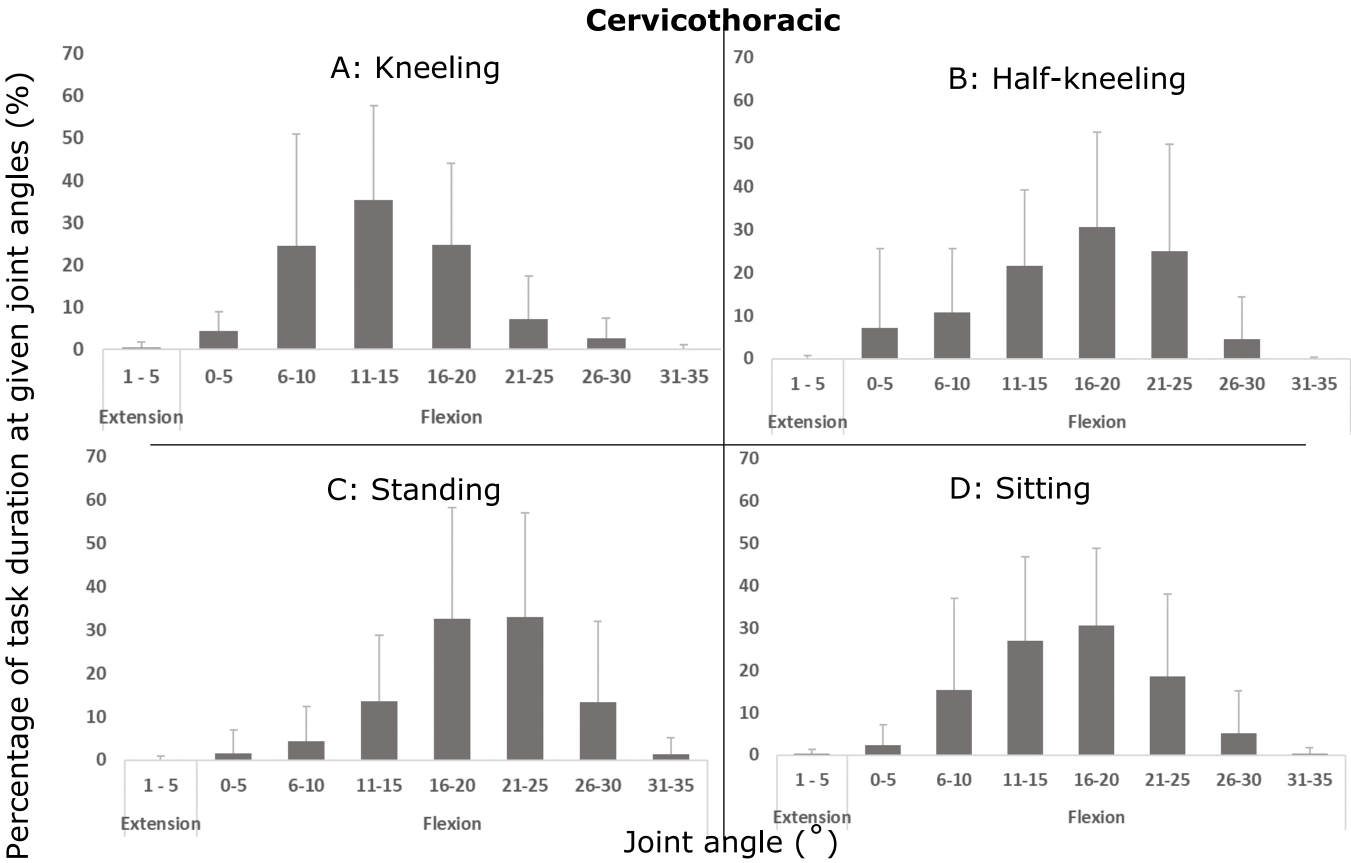


Figure 5.40: Upper Limb: Cervicothoracic joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Thoracolumbar movement (T12/L1 Joint)

Little ROM was seen at this joint for all physiotherapist positions and planes of motion. The thoracolumbar junction was mostly within 5° of neutral for side bend and rotation for all physiotherapist positions. A similar pattern of thoracolumbar flexion and extension in all positions was found; a peak in task duration between neutral to 5° thoracolumbar flexion. During upper limb facilitations the thoracolumbar junction remained relatively static and near neutral posture for all physiotherapist positions. If the physiotherapist was performing sensation work or mobilising joints in the patient's hand, little overall movement was required except at the physiotherapists' upper limbs.

Lumbosacral movement (L5/S1 Joint)

The lumbosacral junction was generally within 5° of neutral posture for side bend and rotation for all physiotherapist positions. When sitting, more left rotation was found than in the other positions. Sitting to the left of the patient was the most commonly used sitting position during upper limb tasks which could be associated with the preference towards left rotation. However, the peak in task duration was spent between 5° right to 5° left lumbosacral rotation. Kneeling showed a larger spread of ROM measured at the lumbosacral junction (10° extension to 30° flexion) (Figure 5.41A). Half-kneeling, standing and sitting positions showed most of the task was spent in lumbosacral flexion (Figure 5.41B-D). Physiotherapists facilitating upper limb tasks from a half-kneeling position showed a peak in task duration (34.3% of the task) between 11-15° flexion (Figure 5.41B). The physiotherapists' trunks were flexed at the cervicothoracic and lumbosacral junctions and remained closer to neutral at the thoracolumbar junction in all positions.

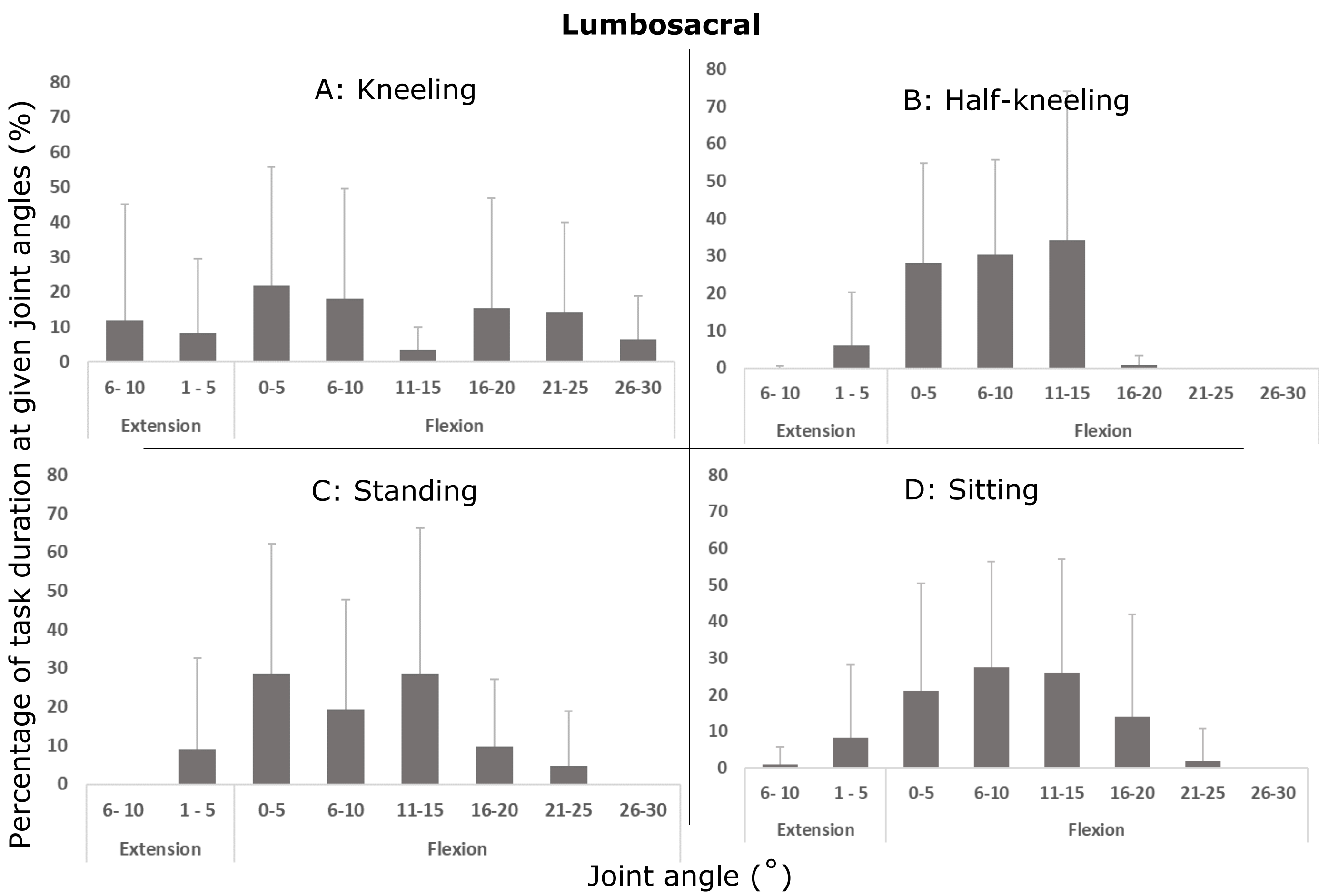


Figure 5.41: Upper Limb: Lumbosacral joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Shoulder girdle movement (T4/Shoulder Joint)

The shoulder girdle was mostly elevated and protracted for all movements and positions. The left and right sides illustrated similar patterns of movement for all positions. The physiotherapist was positioned to the left of the patient more often in the sessions. From observation, the physiotherapist used both upper limbs during the tasks and positioned themselves near the patient’s affected upper limb. Positioning themselves this way in relation to the patient may have minimised the impact of being positioned to one side of the patient.

Shoulder movement

A similar pattern of shoulder joint angles was seen for all positions, with peaks in task duration ranging between 6-20° abduction. All positions showed more duration of the tasks were internally rotated. The patterns of duration in joint ranges for shoulder flexion are similar for all positions (Figure 5.42A-D), suggesting physiotherapist overall position has minimal impact on shoulder ROM. Shoulder flexion was found to range from neutral to approximately 90° flexion for all physiotherapist positions. The physiotherapists' shoulders were rarely flexed over 90° during facilitation of the patients' upper limbs.

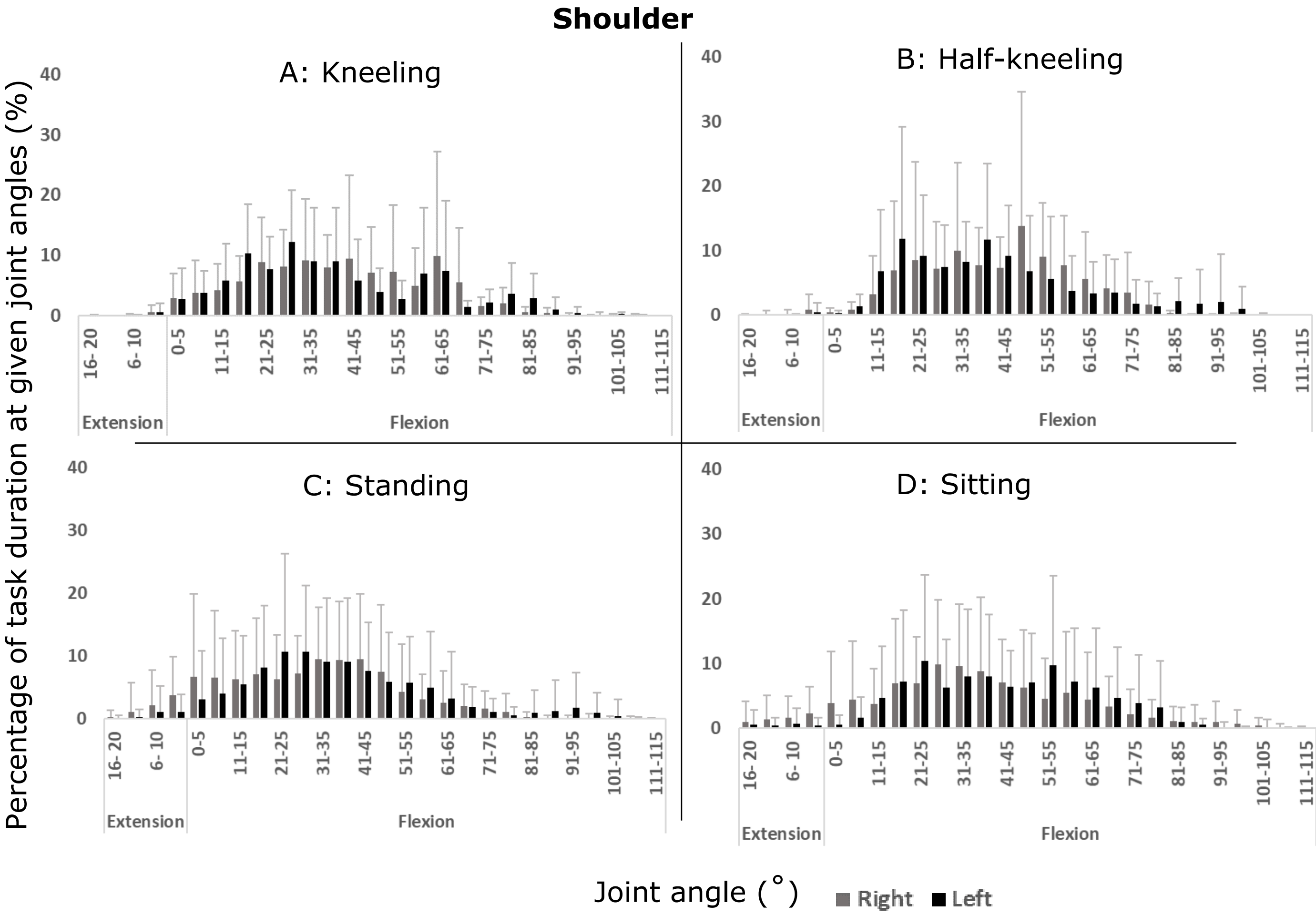


Figure 5.42: Upper Limb: Shoulder joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Hip movement

Kneeling and sitting positions showed a larger range of hip abduction and adduction joint angles. All physiotherapist positions showed a relatively even split of time between hip abduction and adduction. A similar pattern of hip rotation was seen for all positions, with standing showing a smaller range measured during upper limb tasks. Kneeling showed peaks in task time between 10° hip extension to 5° hip flexion for both left and right sides, 61-65° hip flexion for left and 76-80° hip flexion for right (Figure 5.43A). Half-kneeling and sitting positions showed a wide spread of hip flexion measured during upper limb facilitations (Figure 5.43B, D). The spread of joint angles measured in all positions are potentially due to variations and adjustments made by the physiotherapists during upper limb tasks. Standing showed a peak from 10° hip extension to 15° hip flexion (Figure 5.43C). The range in hip position found when standing could be due to the physiotherapists standing with their legs offset, which would have one hip more extended than the other. The physiotherapists were standing at the edge of the plinth and may have offset their feet to allow them to keep close to the patient’s upper limb.

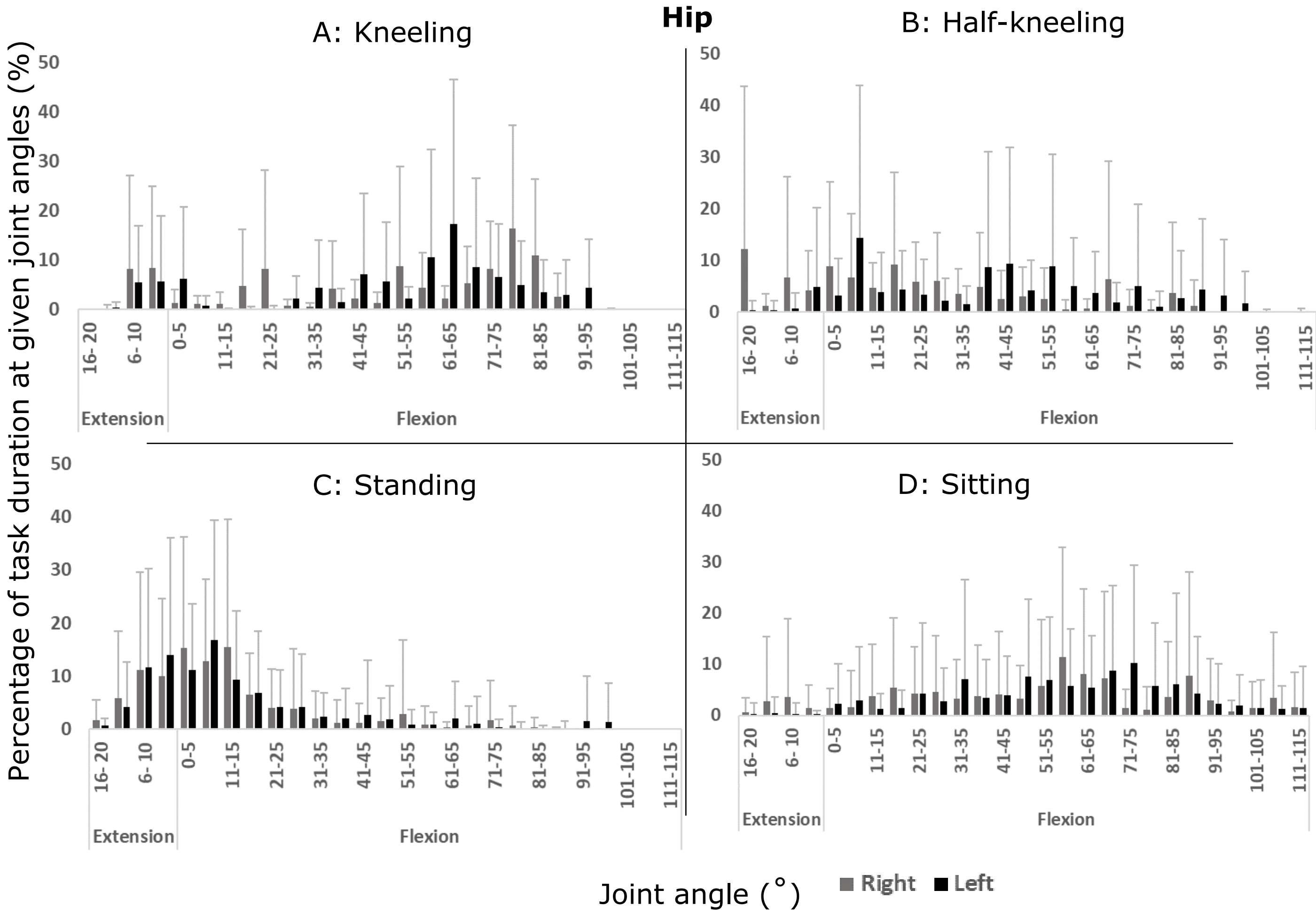


Figure 5.43: Upper Limb: Hip joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Knee movement

When the physiotherapists were in kneeling, the knee was generally near end range flexion, with a small amount of task duration near neutral extension (Figure 5.44A). Despite taking care to remove data where knee angles were affected after the motion trackers were knocked or moved, some erroneous data may have remained. The greater knee extension angles, especially when kneeling and half-kneeling could be a result of remaining affected data. Half-kneeling showed two clear peaks in task duration spent between neutral to 15° knee flexion and 121-125° knee flexion (Figure 5.44B). The two peaks in knee flexion could be due to the physiotherapists half-kneeling on the plinth with one leg on the floor with the other flexed on the plinth. Physiotherapists facilitating the patient's upper limb in standing showed a peak between neutral to 10° knee flexion; this would be expected in standing as minimal knee flexion is required to stand upright (Figure 5.44C). Physiotherapists in a sitting position showed a wide spread of joint angles measured with a small peak seen between 71-85° flexion (Figure 5.44D). The range measured when in sitting could be from short movements into standing or from variations in plinth height changing the degree of knee flexion required.

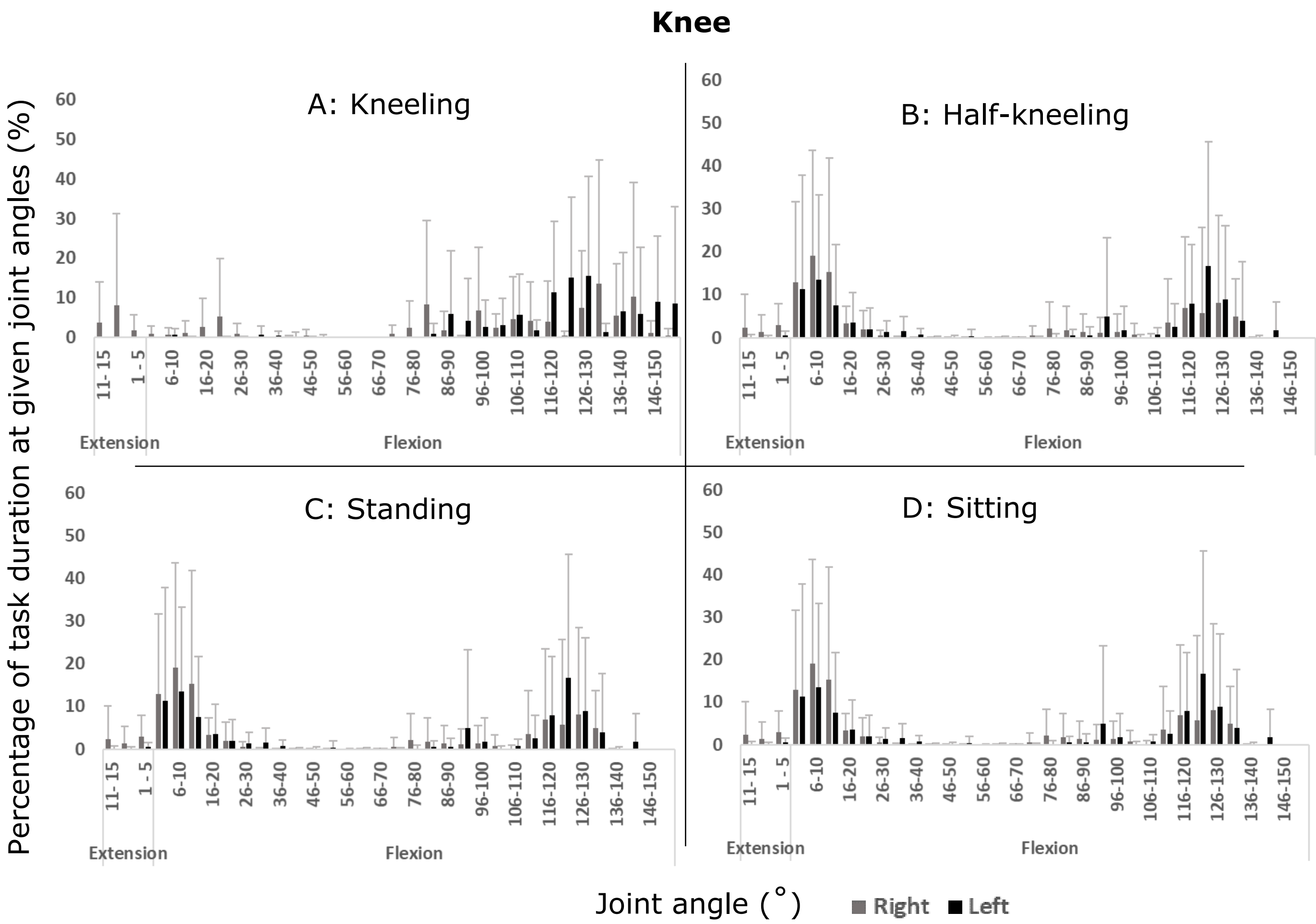


Figure 5.44: Upper Limb: Knee joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

5.8.2 Upper Limb Facilitation Summary

When facilitating the patients' upper limbs, the physiotherapists were more often in a sitting position (41 of 97 trials). Overall, consistency was demonstrated for physiotherapist neck, trunk and upper limb movement between the physiotherapist positions. Facilitating upper limb tasks from a kneeling position showed slightly more range of lumbosacral junction movement and a small portion of the task was spent in an extended position. The physiotherapists may have extended at the lumbosacral junction when in kneeling as a result of facilitating the patient to reach forwards.

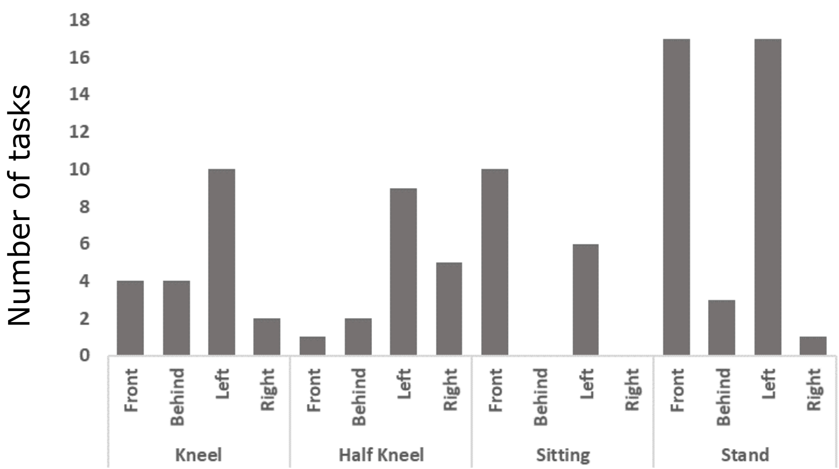
Physiotherapists facilitating upper limb tasks from half-kneeling positions showed slightly more right bend and rotation at the neck, and right bend at the cervicothoracic junction. Most physiotherapists were half-kneeling to the left of the patient. From observation, the physiotherapists were often facing towards the foot of the plinth, placing the patient to their right-hand side. Therefore, some right bend and rotation may be a result of turning towards the patient for the treatment.

Movements at the physiotherapists' upper limbs showed little difference between each position. Similar patterns of time spent in joint positions were identified. A large spread of shoulder flexion angles were measured for all physiotherapist positions. From observation, the physiotherapists' upper limbs performed most of the patient's upper limb task movements. The physiotherapists' lower limbs remained relatively static during the facilitation of upper limb tasks. The physiotherapists' lower limbs illustrated joint angles related to their position. The patient remained in sitting or lying throughout the duration of upper limb facilitations. Patient's upper limbs would be relatively light and are often used for functional and fine motor tasks rather than large and powerful movements. However, if facilitating a significantly weakened upper limb or repeating a movement for a prolonged period, there is potential for increased physical demand for the physiotherapist. The patients often performed functional reaching or grasping tasks with the physiotherapist facilitating muscle activity or guiding the movement. From the joint angle data found, the physiotherapists were found to spend a prolonged time towards end range knee flexion.

5.9 Lower Limb Facilitation

This section describes physiotherapist movement while performing treatments specifically for the patients' lower limbs. Some of the treatments performed were stretching, facilitating active movement, stability and control tasks. A full list of treatments is available in Table 5.2 (Page 122). The lower limbs require sufficient power and stability to maintain the weight of the body in standing (Lee 2019). Patient's lower limb control and function is improved through sensation, proprioception and global strengthening tasks (Lee 2019). A lower limb can form approximately 17.06% of the weight of the human body (Durkin and Dowling 2003). The weight of the lower limbs combined with potential muscle weakness following a brain injury or stroke could become physically demanding for physiotherapists during therapeutic handling.

The physiotherapists performed 91 lower limb treatments during the patient sessions. The average duration of treatment was 108.5 seconds (SD 70.2). The physiotherapists were generally in a standing position for this task (38 of 91 trials). From observation, the patients were often in lying on the plinth, and the physiotherapist was standing at the side or foot of the plinth. Sitting was the least used position during lower limb facilitations (16 of 91 trials). Similar to upper limb facilitations, more patients presented with left-sided weakness of their lower limbs. The physiotherapists were more often positioned to the left of the patient closer to the affected limb. The distribution of positions is displayed in Figure 5.45.



n=20 n=17 n=16 n=38

Figure 5.45: Physiotherapist positioning in relation to patient during lower limb treatments (n= number of physiotherapists)

5.9.1 Proportion and Joint Angle Data During Lower Limb Facilitation

Neck movement (Head/C1)

The neck was found to be mostly within 5° of neutral posture for side bend and rotation for all positions during patient lower limb treatments. The neck was mostly extended with neck extension up to 40° measured for all physiotherapist positions. Physiotherapists in kneeling and half-kneeling positions showed a peak in task time spent between 11-15° neck extension (Figure 5.46A, B). When the physiotherapists were sitting, neck movement ranged from 55° extension to 15° flexion. When in sitting, two peaks in task time between neutral to 5° neck extension and 26-30° neck extension were found (Figure 5.46D). These two peaks in sitting could be due to the physiotherapist looking up to the patient, and also from looking to the area of facilitation.

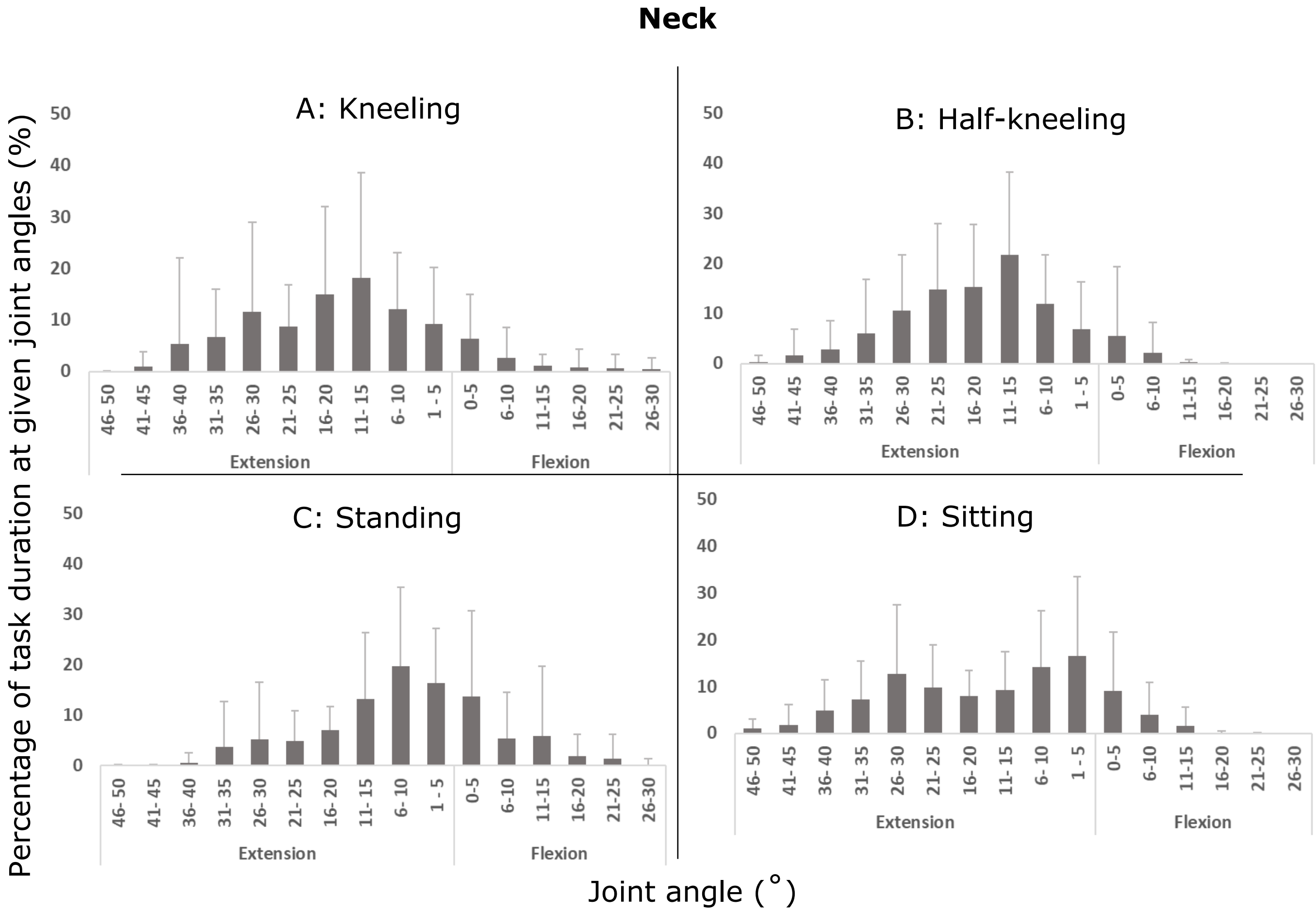


Figure 5.46: Upper Limb: Neck joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Cervicothoracic movement (C7/T1 Joint)

The cervicothoracic junction was mostly within 5° of neutral posture for side bend and rotation for all positions. Kneeling, half-kneeling and standing positions illustrated a similar pattern of time spent in cervicothoracic flexion. Kneeling and half-kneeling positions showed a peak of task time spent between 11-15° cervicothoracic flexion (Figure 5.47A, B) Standing demonstrated the peak time in cervicothoracic flexion was spent between 16-20° (Figure 5.47C). Kneeling, half-kneeling and standing positions showed a bell-shaped distribution of time spent in cervicothoracic flexion. Physiotherapists facilitating lower limb tasks from sitting did not show this same bell shape, and demonstrated a peak in task time was spent between 16-20° flexion (Figure 5.47D).

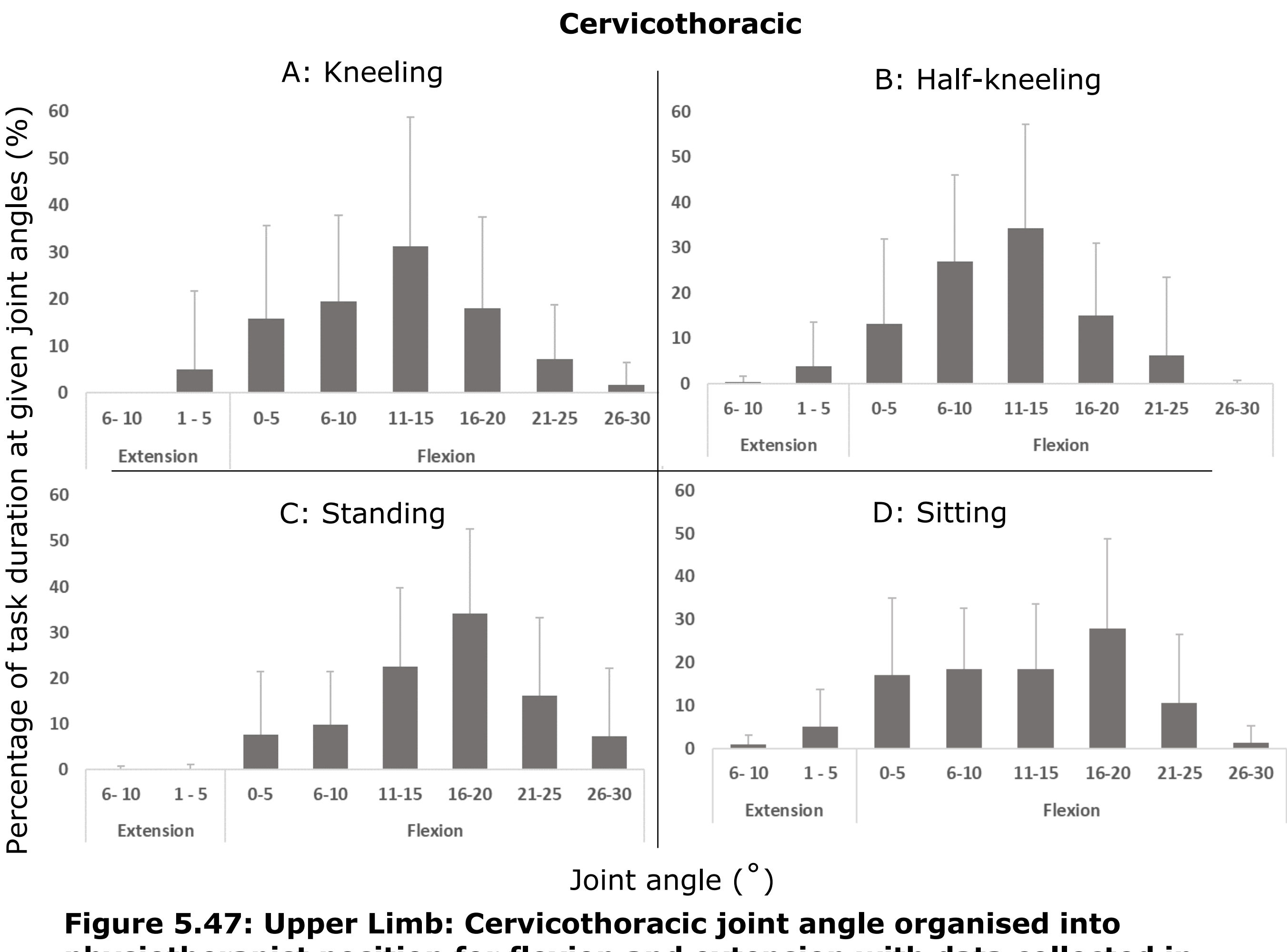


Figure 5.47: Upper Limb: Cervicothoracic joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Thoracolumbar movement (T12/L1 Joint)

Overall little ROM was found at the thoracolumbar junction and most of task duration was spent within 5° of neutral for side bend and rotation for all physiotherapist positions. Kneeling and sitting positions showed more spread in joint angles during the task, both illustrated peaks of task time was spent between 6-10° thoracolumbar flexion.

Lumbosacral movement (L5/S1 Joint)

The lumbosacral junction was also found to be mostly within 5° of neutral for side bend for all physiotherapist positions. Kneeling, half-kneeling and standing positions showed the lumbosacral junction was mostly within 5° of neutral rotation. Sitting showed a larger spread of joint angles during the task, with most of the task time spent within 10° of neutral rotation. Lower limb facilitations were performed either in front of the patient (n=10) or sitting to the left of the patient (n=6). The increased range of rotation found could be from twisting towards the patient when in sitting.

Kneeling, half-kneeling and sitting positions showed similar patterns in time of task spent in lumbosacral flexion. These three physiotherapist positions were mostly flexed and illustrated smaller portions of task were spent in lumbosacral extension (Figure 5.48A, B, D). Standing showed less time spent in extension than the other physiotherapist positions. From observation, when the physiotherapists were facilitating the patient's lower limb through full range flexion and extension, they flexed and extended at the trunk following the patients ROM. There were also tasks observed where the patient was pushing into the hip of the physiotherapist. The physiotherapist was resisting the movement, and this could have caused slight extension at the hips and lumbosacral junction as a result of providing resistance to the patient. A peak in task time was found between 6-10° flexion (48.5% of task) when facilitating lower limb tasks from standing (Figure 5.48C). The physiotherapists were more often standing to the front or the left of the patient (n=17 each). The slight lumbosacral flexion, both in front and to the left, could be from the physiotherapist leaning towards the patient.

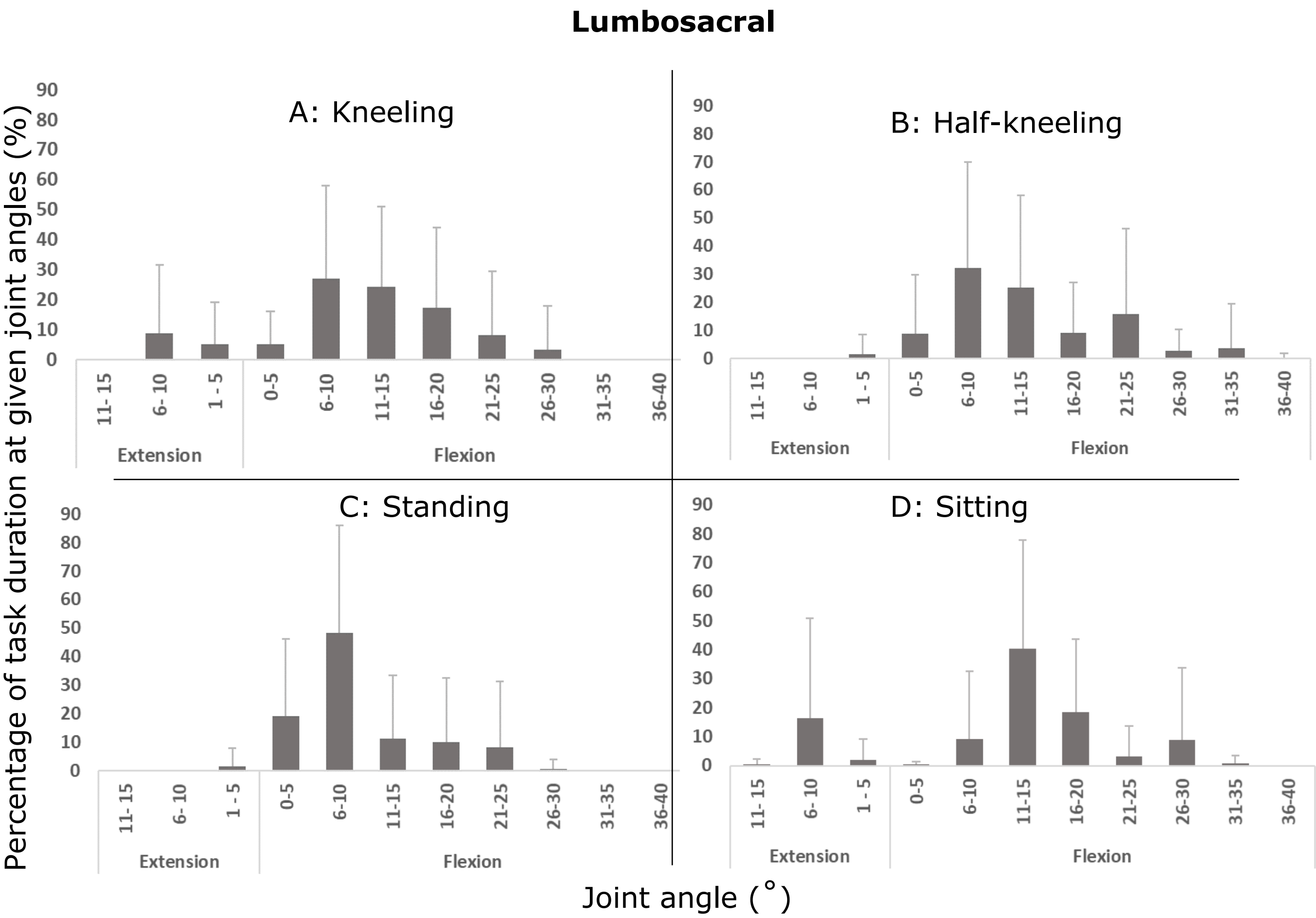


Figure 5.48: Upper Limb: Lumbosacral joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Shoulder girdle movement (T4/Shoulder Joint)

The shoulder girdle showed that most lower limb facilitation tasks were spent in an elevated and protracted posture. Left and right sided movement was generally similar for all positions. From observation, both upper limbs were involved in facilitating lower limb tasks which could account for the similar left and right movement found.

Shoulder movement

Kneeling, standing and sitting positions showed a similar trend in time spent in shoulder abduction angles, with peaks in time illustrated between 11-20˚ abduction. Half-kneeling showed a slightly larger spread in shoulder abduction with a wider peak in task time spent between 6-25˚ abduction. The shoulder was mostly internally rotated for all physiotherapist positions during lower limb facilitation tasks. The physiotherapists' shoulders were mostly flexed in all positions. Standing showed more task time at lower degrees of shoulder flexion than the other physiotherapist positions (Figure 5.49C). When the patient was lying on the plinth, they would be lower than the physiotherapist and the physiotherapists upper limbs would be reaching down which would require less shoulder flexion. Other physiotherapist positions would position them more similar to the height of the patient's lower limb, and to reach forwards to the patient, higher flexion angles would be required than the standing position. Kneeling and half-kneeling positions showed a less clear peak in time during the task (Figure 5.49A, B). The physiotherapists were moving their upper limbs throughout the lower limb tasks and could account for the large range in shoulder flexion measured.

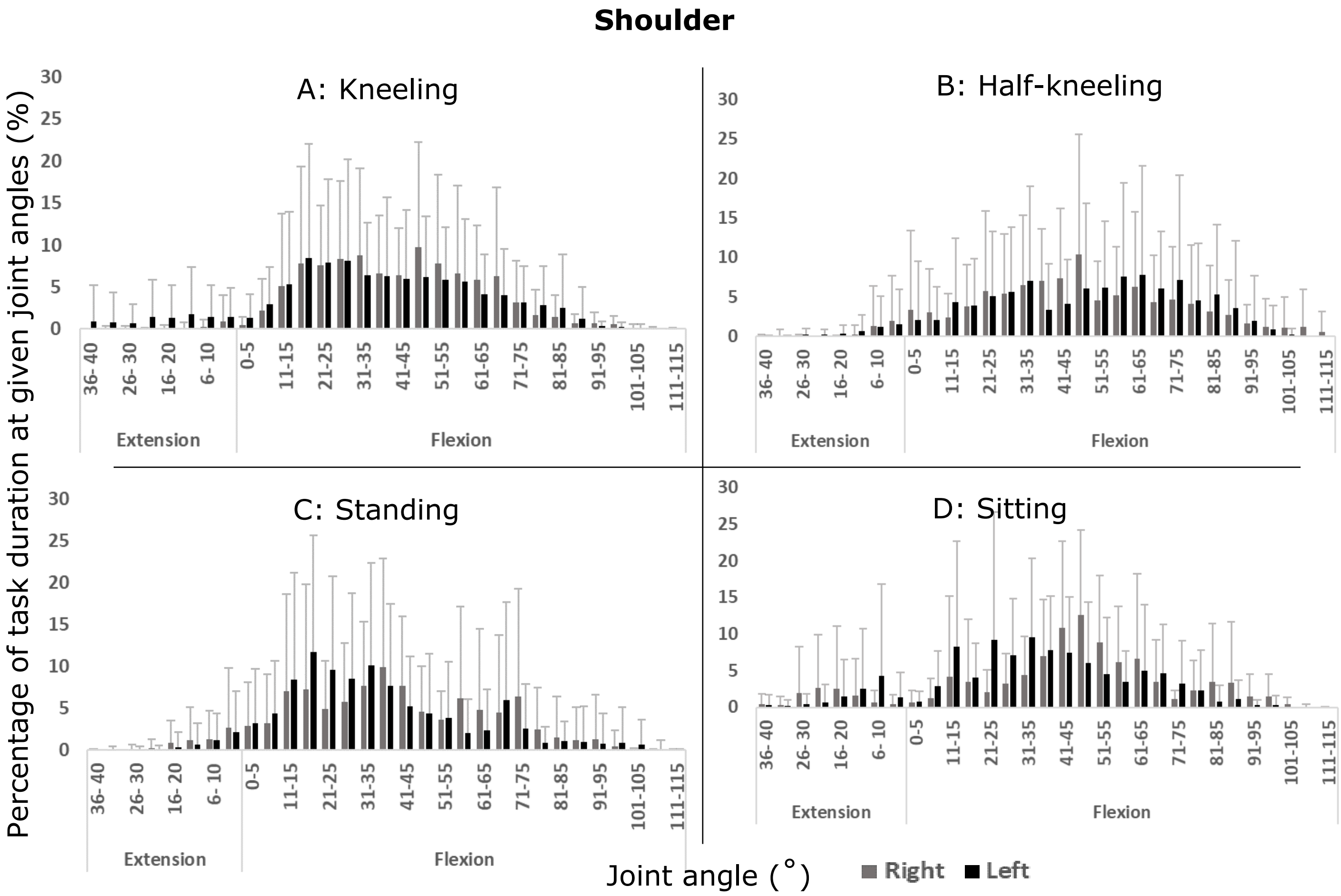


Figure 5.49: Upper Limb: Shoulder joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Hip movement

Standing showed an even split in task duration spent between hip abduction and adduction, with a smaller range of hip motion compared to the other physiotherapist positions (Figure 5.50C). Kneeling and sitting positions demonstrated a large spread of hip adduction and abduction angles during lower limb tasks with differences between left and right sides found (Figure 5.50A, D). The differences between sides when in sitting could be due to perch sitting observed during sessions. The physiotherapists were sitting to the left of the patient at the edge of the plinth diagonally, to allow them to face towards the patient. This sitting position could require one hip to be more abducted than the other side. When the physiotherapists were kneeling, more of the task was spent with the hips internally rotated. The physiotherapists demonstrated a wide variation in kneeling positions as highlighted by the range of hip abduction and adduction found. Half-kneeling, standing and sitting showed more of an even split in time between internal and external rotation.

Kneeling showed a peak in task time between 56-60° hip flexion and little of the task duration was spent under 40° hip flexion (Figure 5.51A). Standing illustrated a range of hip angles measured from 30° extension to 45° flexion with more clustering around the neutral position found (Figure 5.51C). The range in hip motion when standing could be due to the physiotherapist adjusting their posture or bending forwards towards the patient. Half-kneeling and sitting positions showed a wide spread of flexion angles during the lower limb facilitation tasks with no clear peak in duration in one position or joint range (Figure 5.51B, D). The spread in angles measured when in half-kneeling may be due to the physiotherapist having one leg on the plinth and the other on the floor. It was also observed that there was more short changes in position of the physiotherapists during lower limb tasks when half-kneeling and sitting.

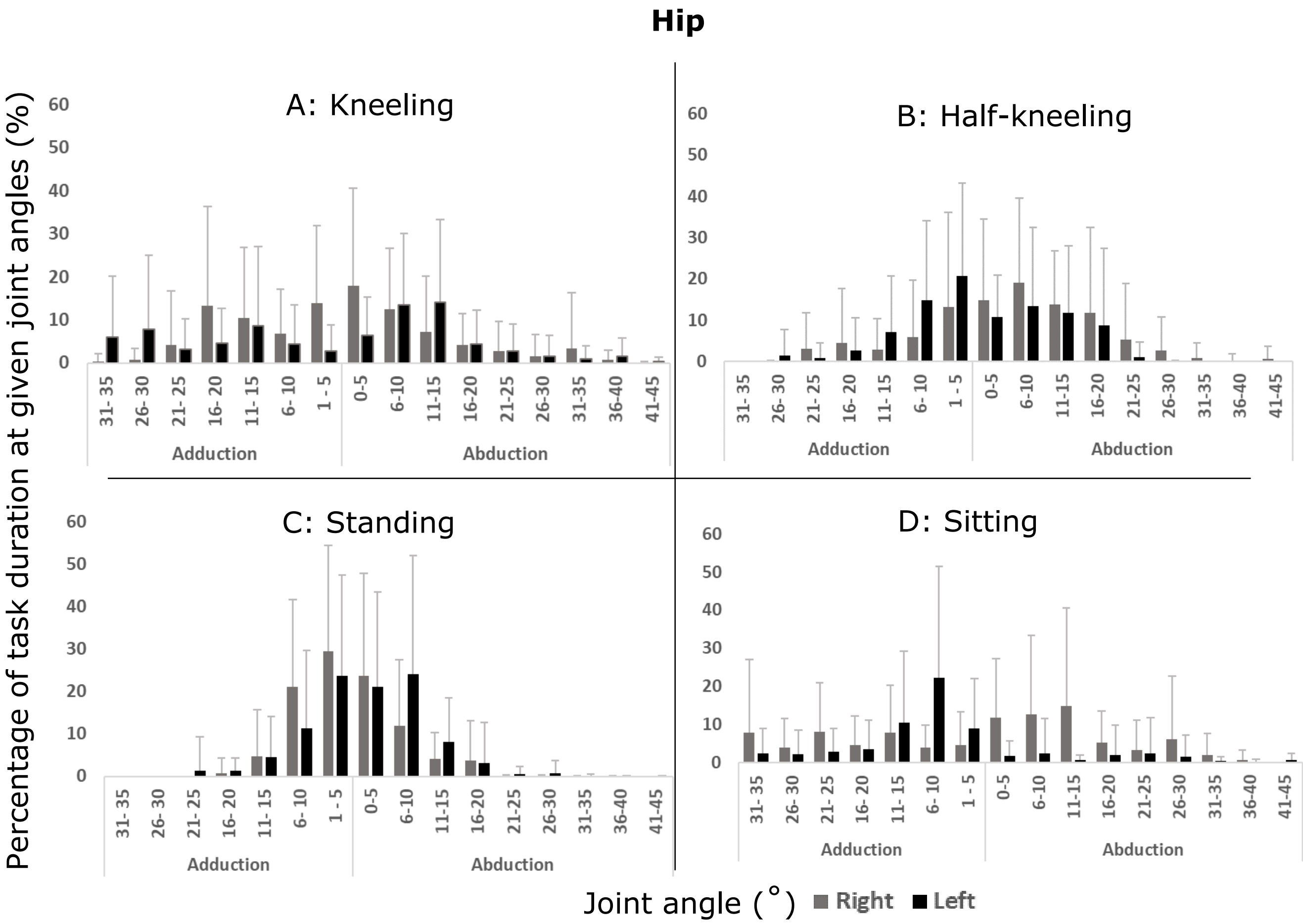


Figure 5.50: Upper Limb: Hip joint angle organised into physiotherapist position for adduction and abduction with data collected in contiguous 5-degree bins (+1SD)

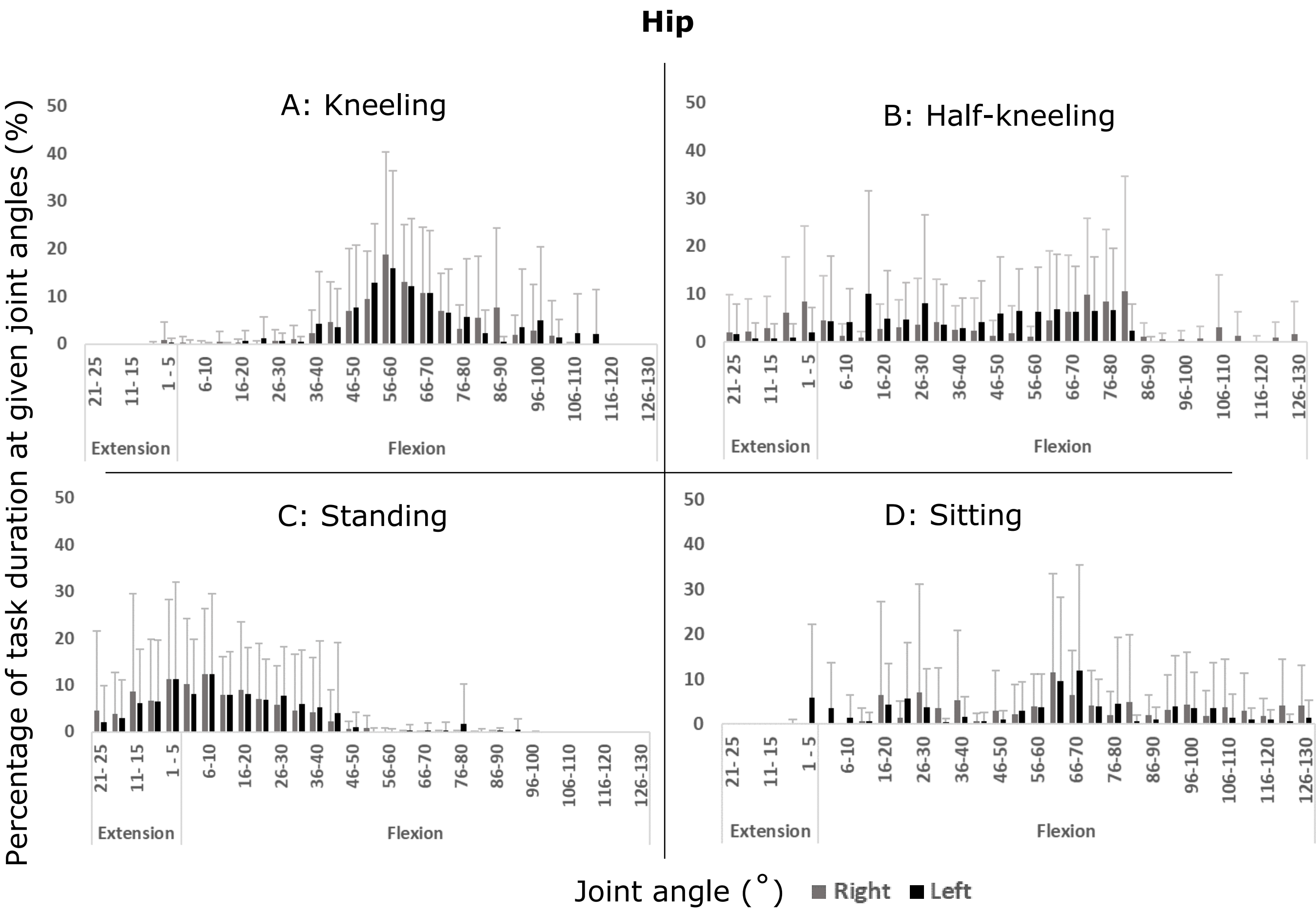


Figure 5.51: Upper Limb: Hip joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Knee movement

When the physiotherapists were kneeling, as expected, their knees maintained end range knee flexion for the duration of the task (Figure 5.52A). Standing also showed the expected posture with the knees between neutral to slight flexion (Figure 5.52C). Half-kneeling and sitting positions illustrated more variation in joint angles found within the physiotherapists positioning. Half-kneeling was often with one knee up on the plinth and the other extended to the floor, which would fit with the two peaks visible at neutral and between 126-130° knee flexion (Figure 5.52B). The variation in knee joint angles when sitting (Figure 5.52D) could be due to the physiotherapist’s perch sitting on the plinth and also sitting on a stool. When perch sitting on the plinth, the height of the plinth can be changed and, if positioned higher, could reduce hip and knee flexion angles.

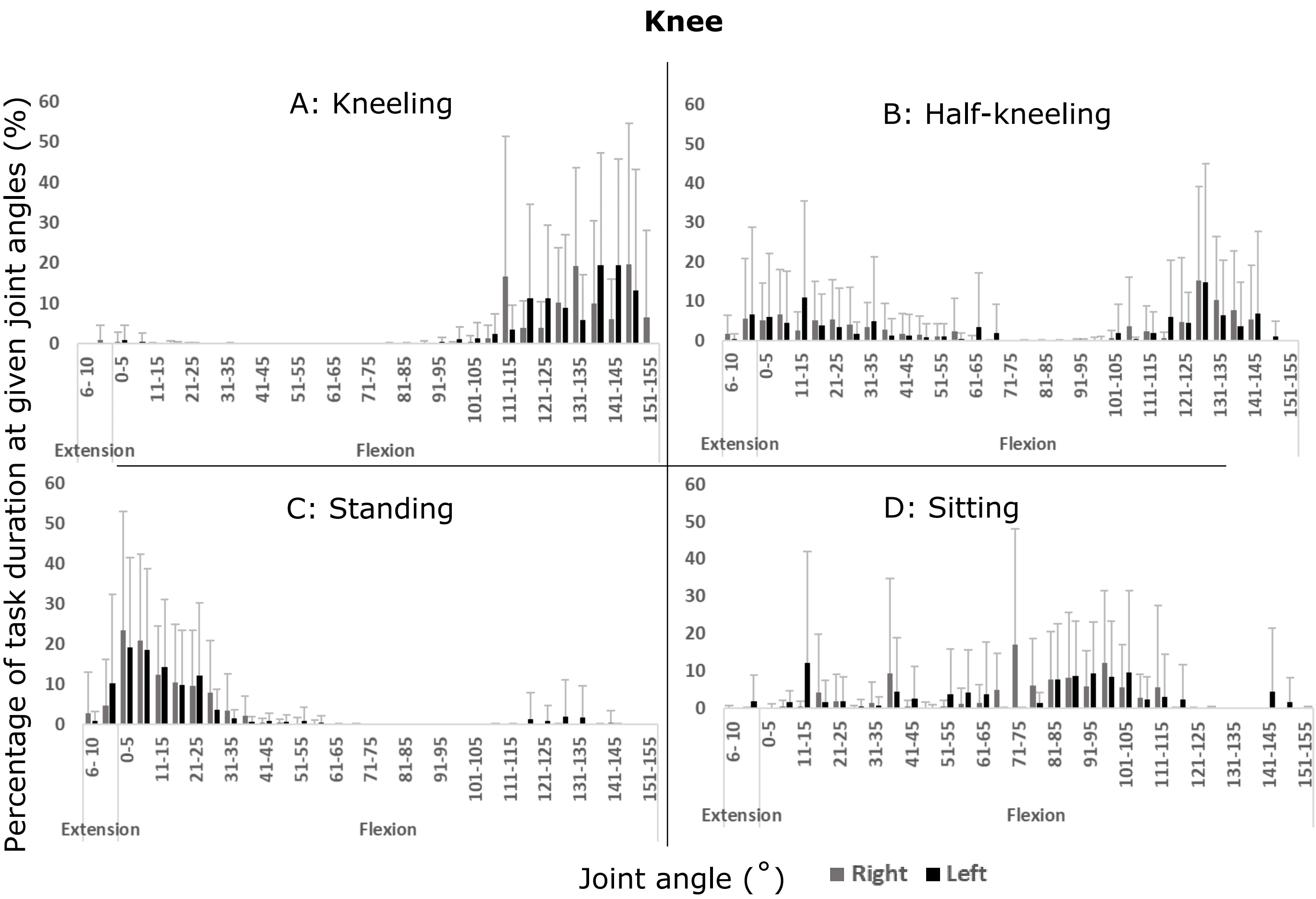


Figure 5.52: Upper Limb: Knee joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

5.9.2 Lower Limb Facilitation Summary

Most of the included physiotherapists performed lower limb facilitations in standing positions (n=38). The number of treatments performed in kneeling, half-kneeling and sitting were relatively equal (n= 20, 17, and 16 respectively). The neck and trunk movements were generally neutral for side bend and rotation for all positions, with patterns of task time spent in joint angles often found to be similar. Standing and sitting showed the highest flexion angles at the cervicothoracic junction (16-20° flexion). The lumbosacral junction showed a larger ROM measured when seated with joint movement measured into both extension and flexion. Standing showed less lumbosacral movement and remained closer to neutral during lower limb facilitation, likely due to raising the height of the plinth.

Slight differences in shoulder flexion movements were identified, with more shoulder flexion measured when in half-kneeling than the other physiotherapist positions. The increased shoulder flexion could be due to the physiotherapist having to reach further to the patient which would require increased shoulder flexion angles. No position spent a significant duration of lower limb facilitation tasks over 90° shoulder flexion. Overall, the hips showed the least spread in joint ROM measured when in standing, with more variation in joint angles found in half-kneeling and sitting positions.

The wide range in joint angles measured when the physiotherapist was sitting could be related to the physiotherapists generally perch sitting which places them in a higher seated position than that of a chair, in addition the knees are more extended than a more standard sitting position (~90° knee flexion). When the physiotherapist was kneeling, the lumbosacral junction showed a portion of the task spent in a slight extended position with the hips and knees in a flexed position. This suggests the back, in combination with the upper limbs, possibly was involved more in the movement of the patients' lower limbs. As the hips remained flexed throughout, there was potentially less compensatory movement at the hips when the back extended. Moving and treating patients' lower limbs has potential to be a heavier task for physiotherapists depending on the treatment and level of weakness at the lower limb.

5.10 Trunk Facilitation

This section describes physiotherapist movement during treating patients' trunk movement, control and strength. Trunk strength and co-ordination is essential for upright standing, walking and improving upper limb functionality (Gillen 2016). Treatments at the trunk included muscle stretching, sitting balance and trunk muscle strengthening (Table 5.2 on Page 122) and were performed 55 times by physiotherapists with the average duration of treatment 109.6 seconds (SD 79.1). The most common position used by the physiotherapists was kneeling (26 of 55), in particular kneeling behind the patient who was sitting on the plinth (20 of 55) (Figure 5.53). Kneeling behind the patient is illustrated in Figure 5.54. This position was observed when patients had altered trunk control or strength. The physiotherapists were positioned behind and placed their hands on the patient's trunk. This position also allowed the patient to lean back onto the physiotherapist during rest periods. In contrast to upper and lower limb facilitation tasks, there was more of an even split between the physiotherapists positioning themselves to the left and right sides of the patient.

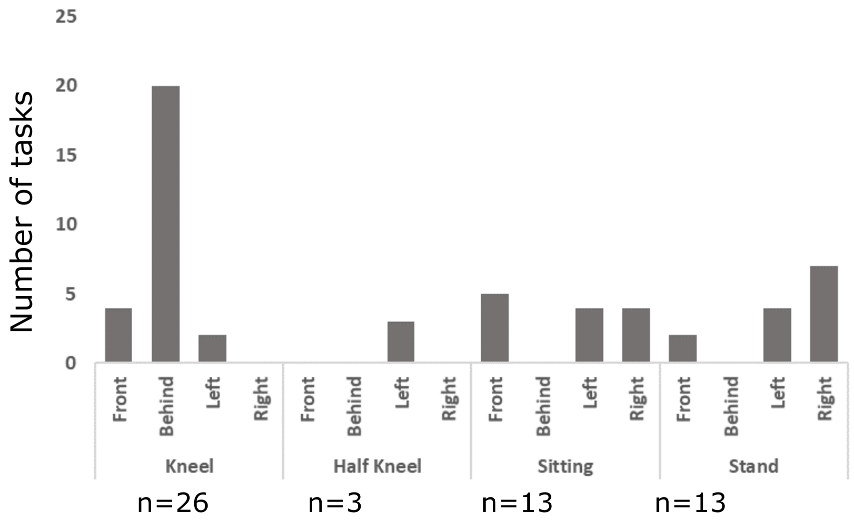


Figure 5.53: Physiotherapist positioning in relation to patient during trunk treatments (n= number of physiotherapists)

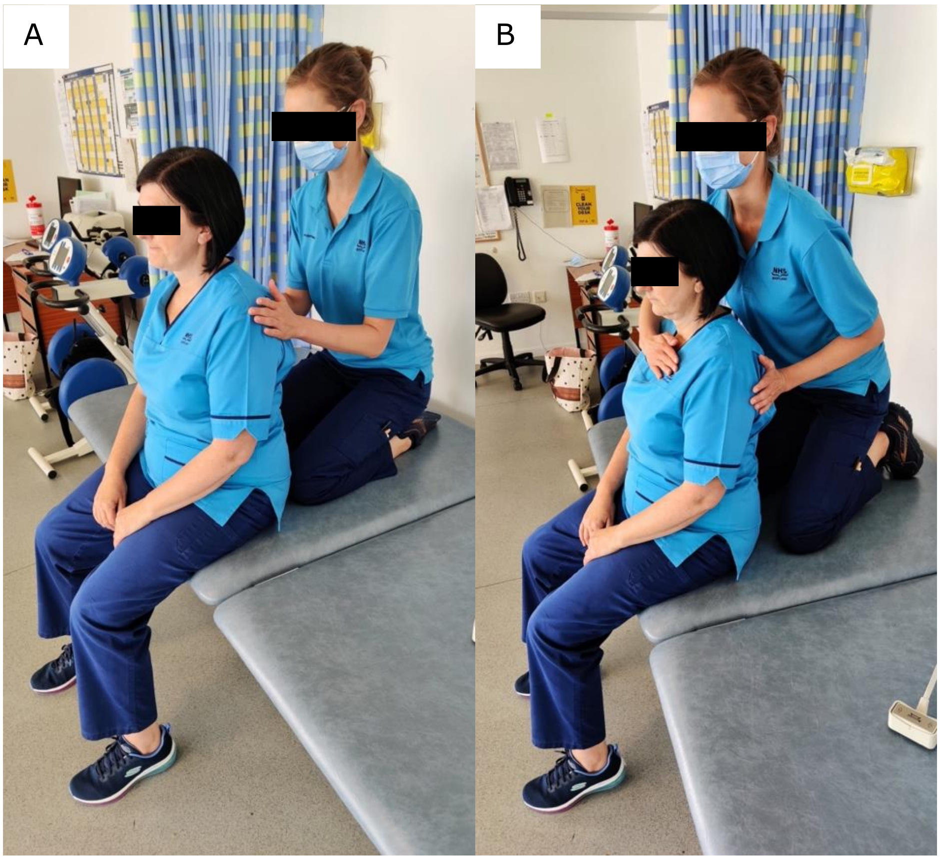


Figure 5.54: Physiotherapist kneeling behind patient in A: low kneeling, B: moving to high kneeling

5.10.1 Proportion and Joint Angle Data During Trunk Facilitation

Neck movement (Head/C1)

The neck was mostly within 5° of neutral side bend in kneeling, standing and sitting positions. Half-kneeling showed a more even spread of time in joint angles between 15° left bend to 20° right bend at the neck. All physiotherapist positions showed a bell-shaped curve centred around neutral to 10° left rotation (Figure 5.55A-D). The neck was mostly extended during lower limb facilitation tasks in kneeling, half-kneeling and sitting positions, ranging from neutral to 40° neck extension (Figure 5.56A, B, D), with a slight decrease in extension range found in standing (up to 30° extension). However, the peak in task time was closer to the neutral posture in both half-kneeling and sitting positions. Kneeling demonstrated a peak in task time was spent between 11-15° neck extension. From observation of the sessions, when the physiotherapist was kneeling behind the patient, they were bending forwards at the trunk. This trunk flexion then required the physiotherapist to extend their neck to speak with the other staff member that was positioned in front of the patient. Standing showed a peak in task time was spent between neutral to 5° flexion (Figure 5.56C).

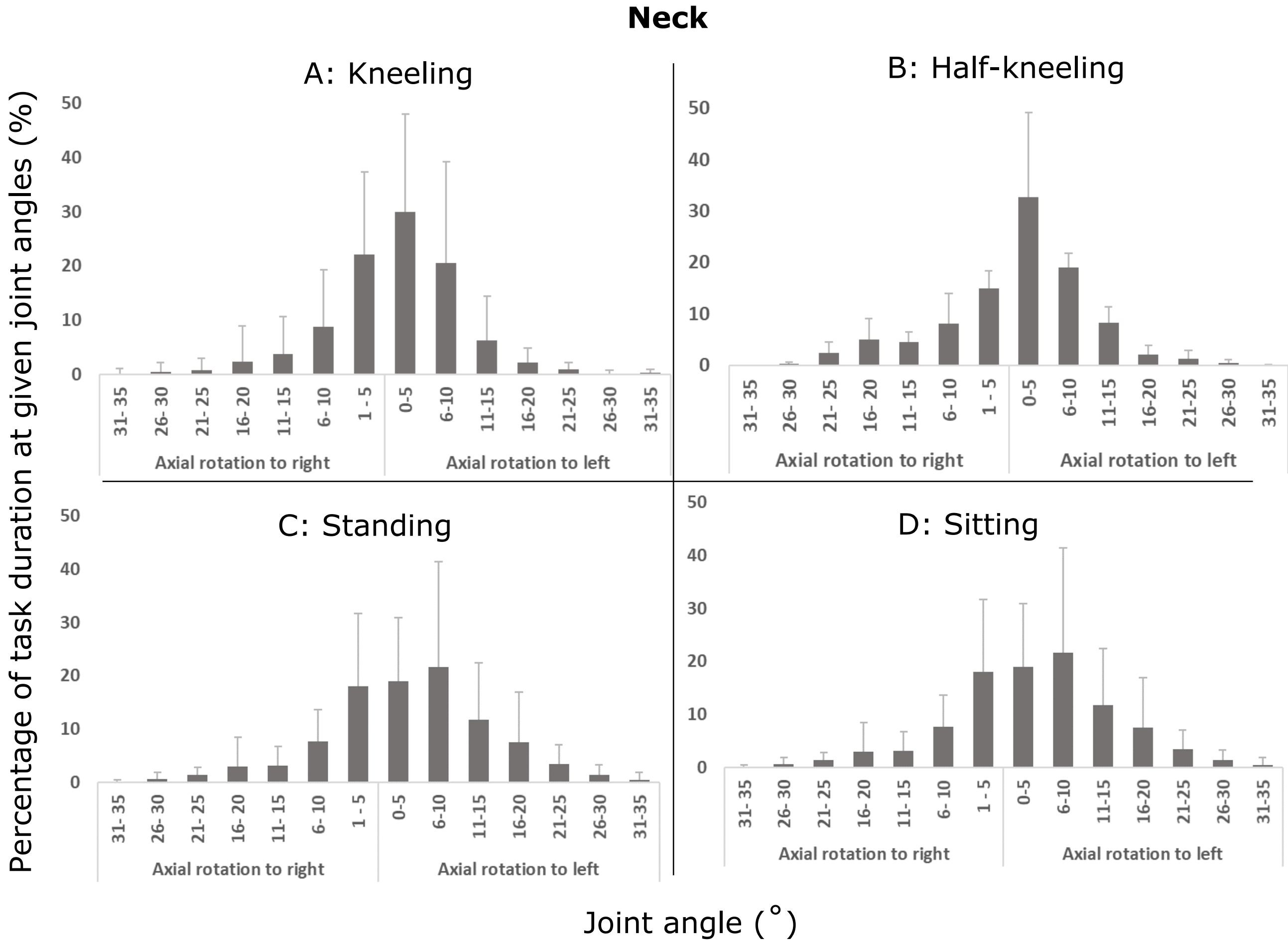


Figure 5.55: Trunk facilitation: Neck joint angle organised into physiotherapist position for axial rotation with data collected in contiguous 5-degree bins (+1SD)

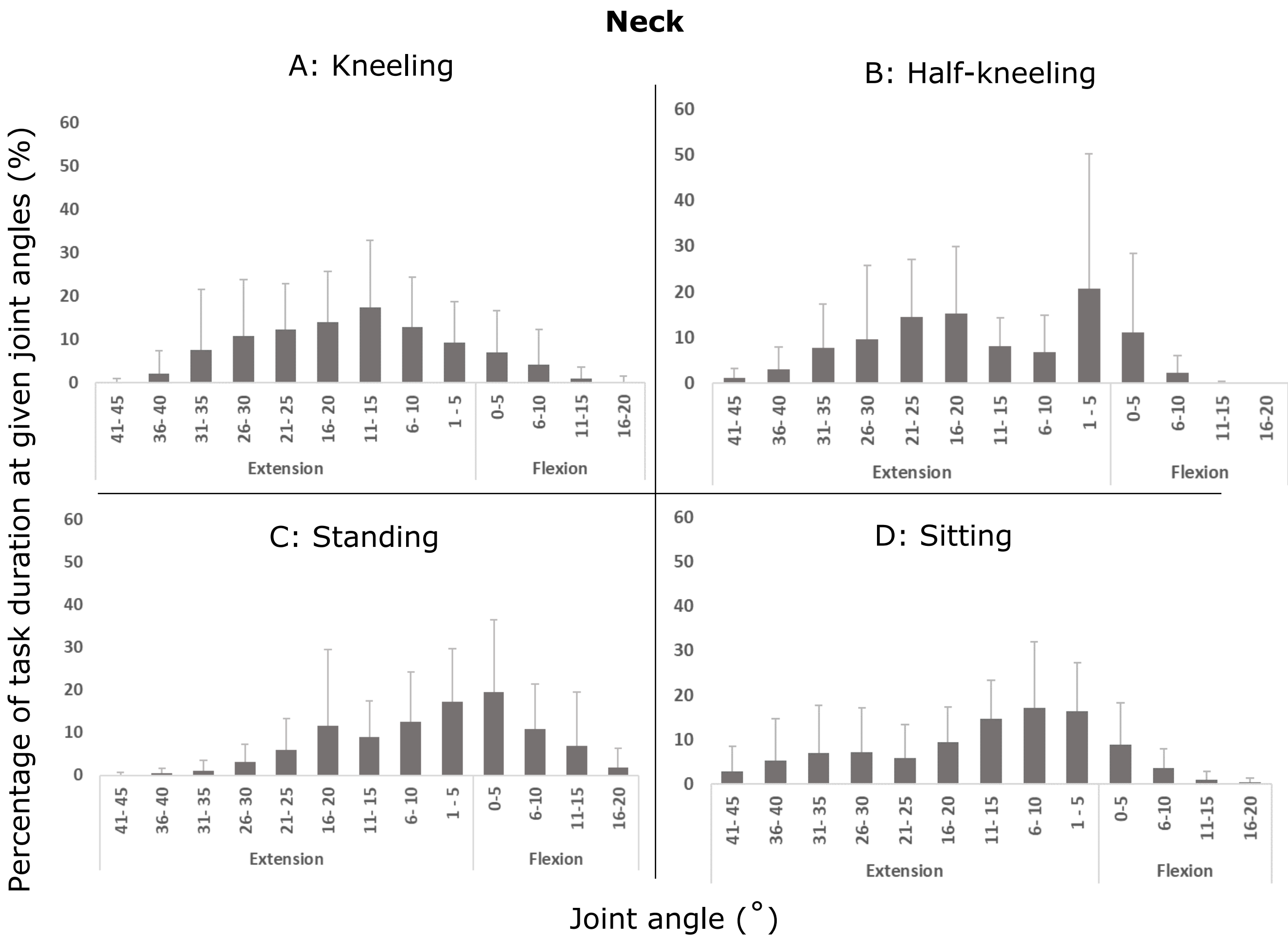


Figure 5.56: Trunk facilitation: Neck joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Cervicothoracic movement (C7/T1 Joint)

Kneeling, standing and sitting positions were mostly within 5° of neutral for side bend during trunk facilitation tasks. Similar to movement found at the neck, half-kneeling showed more of an even spread of task time spent between 10° left bend to 10° right bend. All physiotherapist positions were found to be mostly within 5° of neutral for cervicothoracic rotation. A similar pattern of cervicothoracic flexion for all physiotherapist positions was found. Half-kneeling, standing and sitting positions showed a peak in task time spent between 16-20° cervicothoracic flexion (Figure 5.57B, C, D). Kneeling showed a peak in task time between 11-15° flexion (Figure 5.57A).

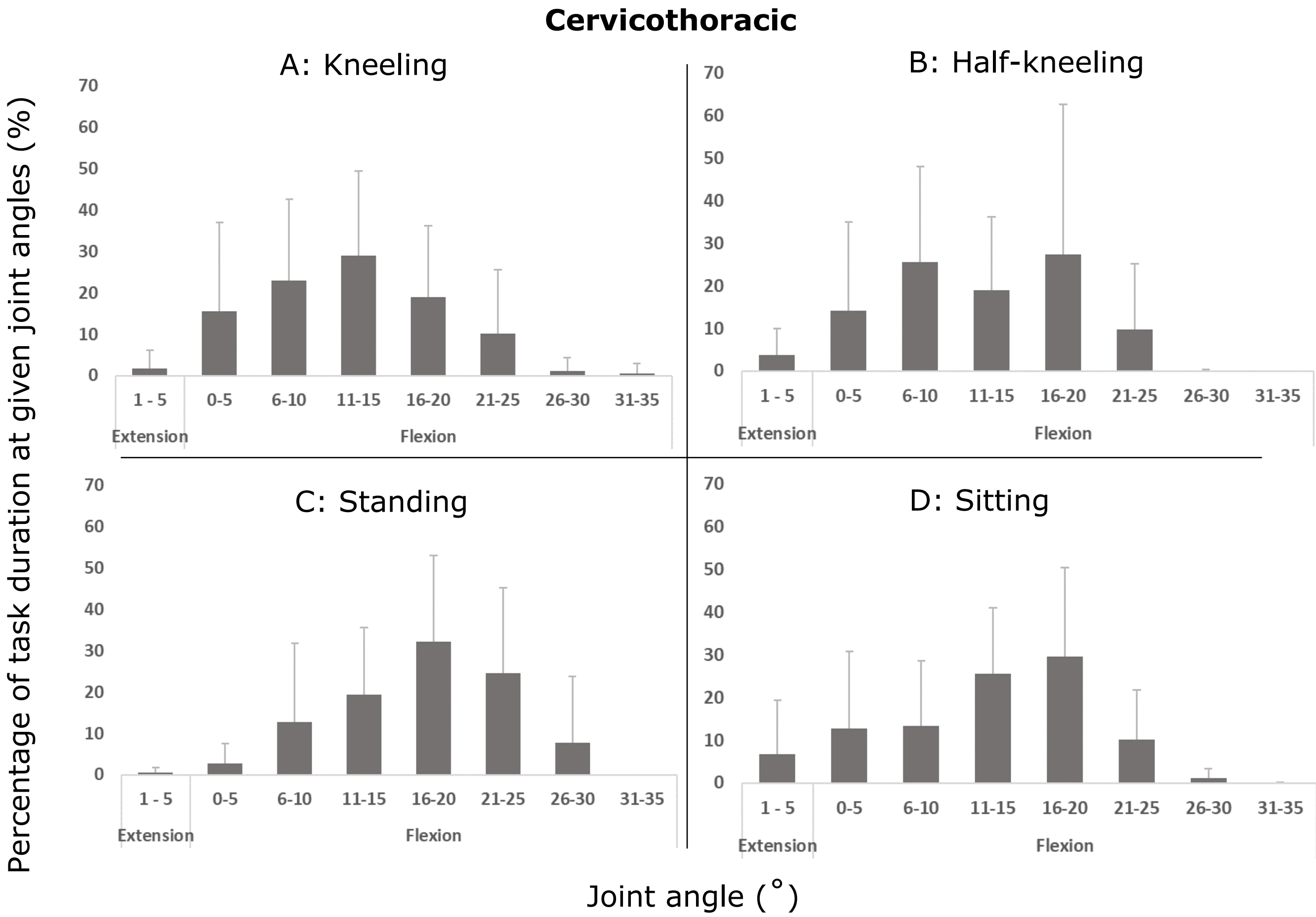


Figure 5.57: Trunk facilitation: Cervicothoracic joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Thoracolumbar movement (T12/L1 Joint)

Similar to other patient facilitation tasks, the thoracolumbar junction showed little ROM measured for all directions of movement. All positions showed most of the task duration was spent within 5° of neutral for thoracolumbar side bend and rotation. Kneeling and half-kneeling positions showed higher thoracolumbar flexion to standing and sitting positions. Most of the task duration was spent between 6-10° thoracolumbar flexion in kneeling and half-kneeling positions. The range of thoracolumbar joint angles measured ranged from 5° extension to 15° flexion when in kneeling, and neutral to 15° flexion in half-kneeling. Standing and sitting positions spent most of trunk facilitation tasks within 5° of neutral thoracolumbar posture.

Lumbosacral movement (L5/S1 Joint)

Kneeling, half-kneeling and standing positions showed most of the task time was spent within 5° of neutral for lumbosacral rotation and side bend. Sitting showed more of the task was spent in right bend, however, the peak in task duration remains between neutral to 5° right bend. Rotation at the lumbosacral junction is generally within 5° of neutral for all physiotherapist positions. The lumbosacral junction was mostly flexed in all physiotherapist positions, with kneeling and half-kneeling positions demonstrating increased flexion with peaks in task time between 11-15° lumbosacral flexion (Figure 5.58A, B). When in kneeling and half-kneeling positions, cervicothoracic, thoracolumbar and lumbosacral flexion was found which describes a forward flexed and rounded trunk posture. Standing showed a peak in task time closest to neutral of all physiotherapist positions (Figure 5.58C). It was observed that the physiotherapists were standing they were facilitating at the patient's core or trunk during exercises in crook lie. The patients were lying on the plinth, the physiotherapists could raise the height of the plinth which reduced the amount of lumbosacral flexion required.

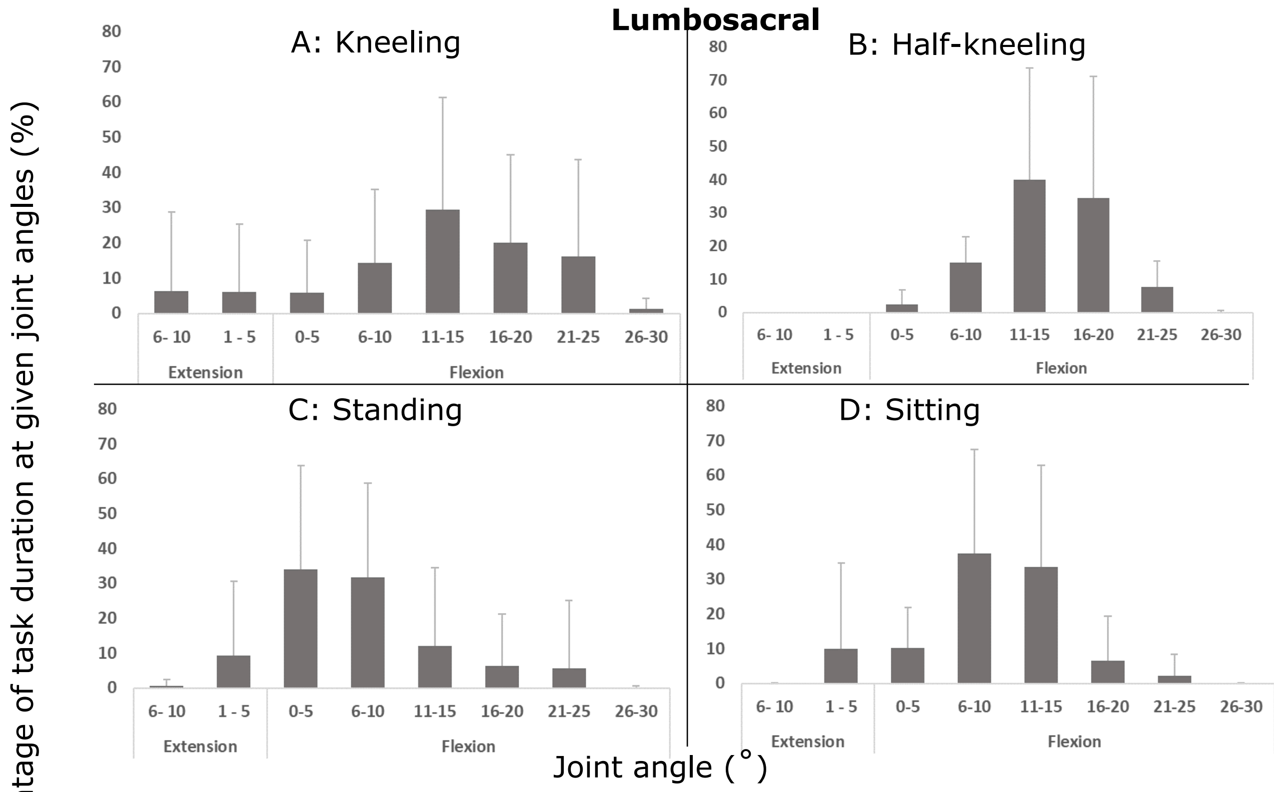


Figure 5.58: Trunk facilitation: Lumbosacral joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Shoulder Girdle movement (T4/Shoulder Joint)

The shoulder girdle was mostly elevated and protracted for all positions. Half-kneeling and sitting showed more differences between left and right side movement. The differences between left and right sided movement may be due to the physiotherapist reaching further with one arm round or over the patient's trunk which would require different shoulder postures.

Shoulder movement

All physiotherapist positions showed a similar pattern and range of shoulder abduction measured during trunk facilitation tasks. Kneeling, half-kneeling and standing positions demonstrated a peak in task time spent between 11-25° shoulder abduction. Sitting showed a wider spread of shoulder abduction range, with less time of the task spent in one shoulder posture. All physiotherapist positions illustrated the shoulders were more internally rotated during trunk facilitation tasks. Kneeling and half-kneeling positions showed less range of shoulder rotation measured than in standing and sitting positions. Additionally, more differences between left and right sided movements were found in kneeling and half-kneeling compared to standing and sitting positions.

Half-kneeling showed a peak in task time was spent between 31-35° shoulder flexion (Figure 5.59B). Sitting illustrated a wide range of shoulder motion measured from 50° extension to 120° flexion, with increased clustering of task time spent between neutral to 55° shoulder flexion (Figure 5.59D). Kneeling and standing positions demonstrated a similar range of shoulder ROM between 10° extension to 100° flexion (Figure 5.59A, C). The shoulder flexion measured during trunk facilitation tasks from kneeling could be related to the physiotherapist reaching around or over the patient's trunk. When in standing, the physiotherapists were found to have less lumbosacral flexion than other positions, likely due to the plinth being raised. To reach towards the patient in standing, increased shoulder flexion could be required as a result of the reduced forward trunk flexion.

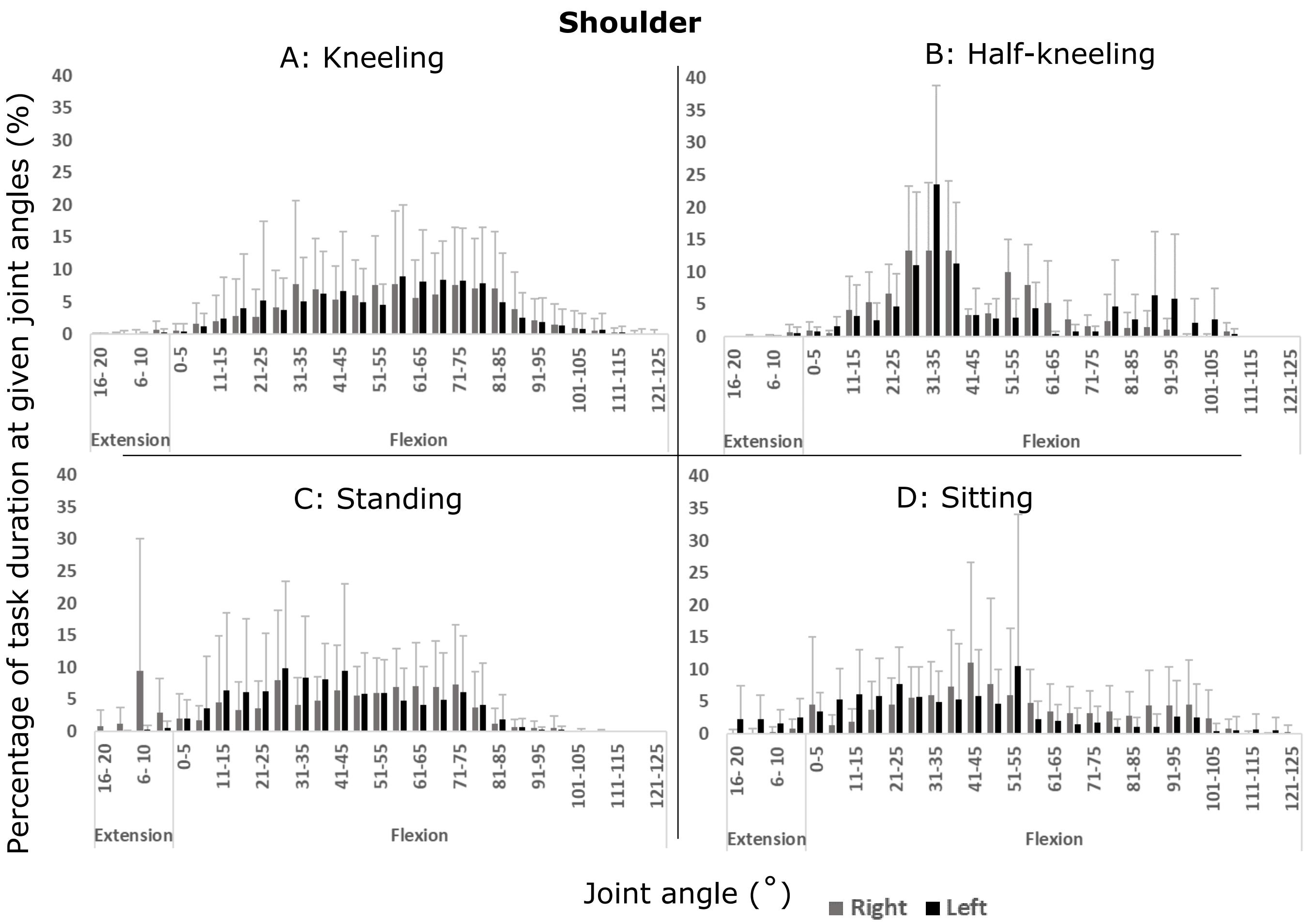


Figure 5.59: Trunk facilitation: Shoulder joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Hip movement

Kneeling and standing positions showed a large variation in hip adduction and abduction ROM measured during the task (Figure 5.60A, C). In standing, the left hip was adducted and the right hips abducted. When facilitating the trunk in standing, the physiotherapist was more often standing to the side of the patient (left n=4, right n=7) than in front (n=2). When standing at the side of the patient, the physiotherapist was positioned against the plinth which would 'block' one lower limb and reduce available movement. The physiotherapist was more often facing up to the patient with their right side closest to the patient. The increased adduction angles measured at the right hip could be from the physiotherapist leaning into the plinth and the increased abduction at the left hip from stepping wider to increase their BoS. Half-kneeling showed both the left and right hips were abducted, and sitting showed a smaller spread of joint angles measured during the task with most of the task spent within 10° of neutral for both left and right sides (Figure 5.60B, D). The hips were mostly internally rotated when the physiotherapist was kneeling, especially at the left hip. There was a more even split in task duration spent in internal and external rotation at the hip when half-kneeling and sitting. When standing, the right hip was found to be more externally rotated.

A wide spread in flexion ROM was measured when the physiotherapists were kneeling, indicating time in both low and high kneeling positions (Figure 5.61A). It was observed that the physiotherapists were in low kneeling when the patients were reclined sitting, the physiotherapists then moved to high-kneeling when the patient moved to upright sitting. The physiotherapists would often maintain high-kneeling and provide trunk support with their hands while the patient was in upright sitting. Half-kneeling showed a smaller joint ROM measured and a peak in task duration was found between 36-45° hip flexion (Figure 5.61B). Standing was mostly around neutral, which would be expected as standing upright requires minimal hip flexion (Figure 5.61C). The plinth was also raised which required les forward lean from the physiotherapists to reach the patients. Sitting showed a more even distribution of hip angles measured during trunk facilitation tasks. Most of the task time was spent between 30-100° hip flexion (Figure 5.61D). This suggests more continual movement during the task rather than remaining more static.

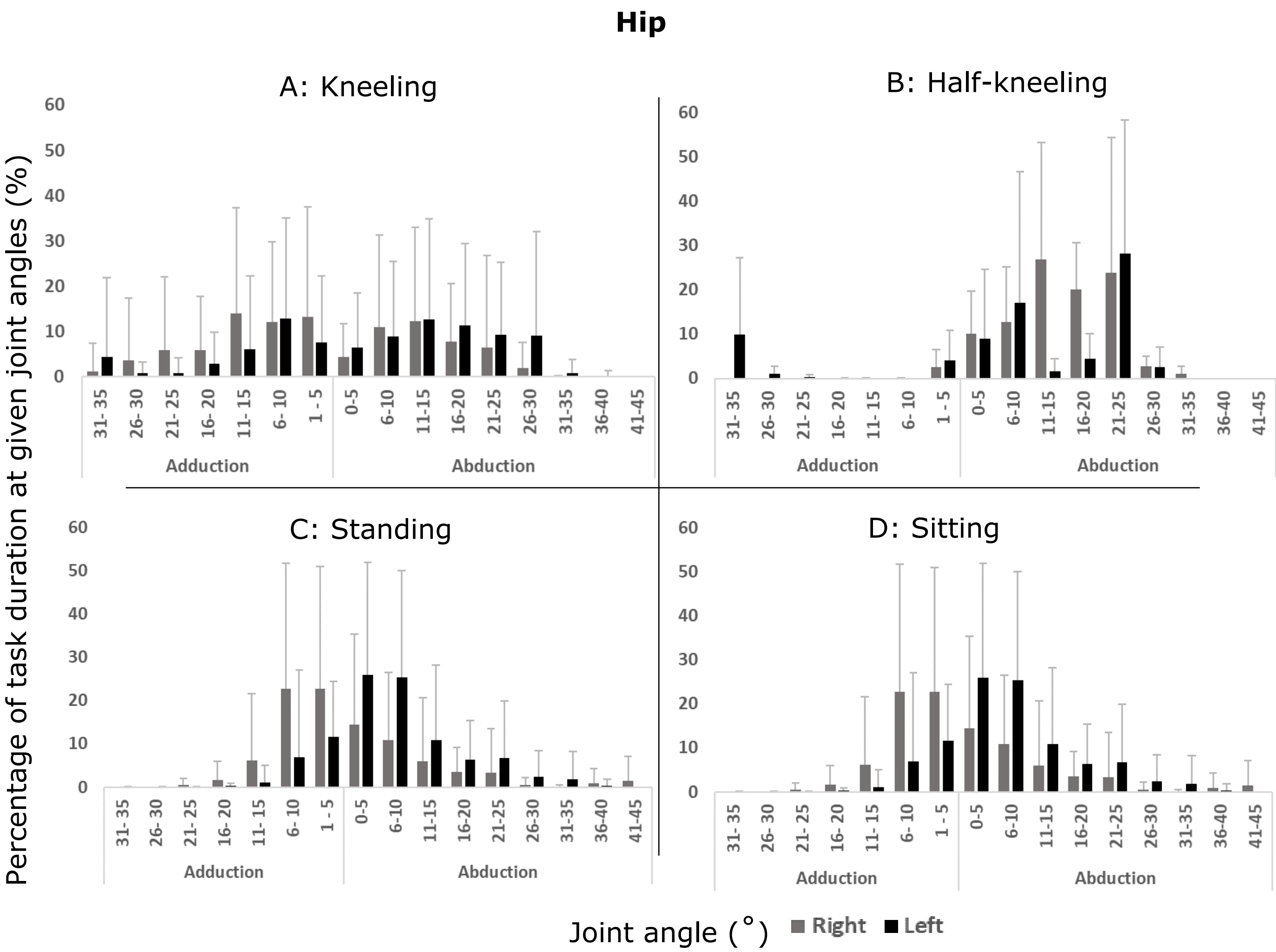


Figure 5.60: Trunk facilitation: Hip joint angle organised into physiotherapist position for adduction and abduction with data collected in contiguous 5-degree bins (+1SD)

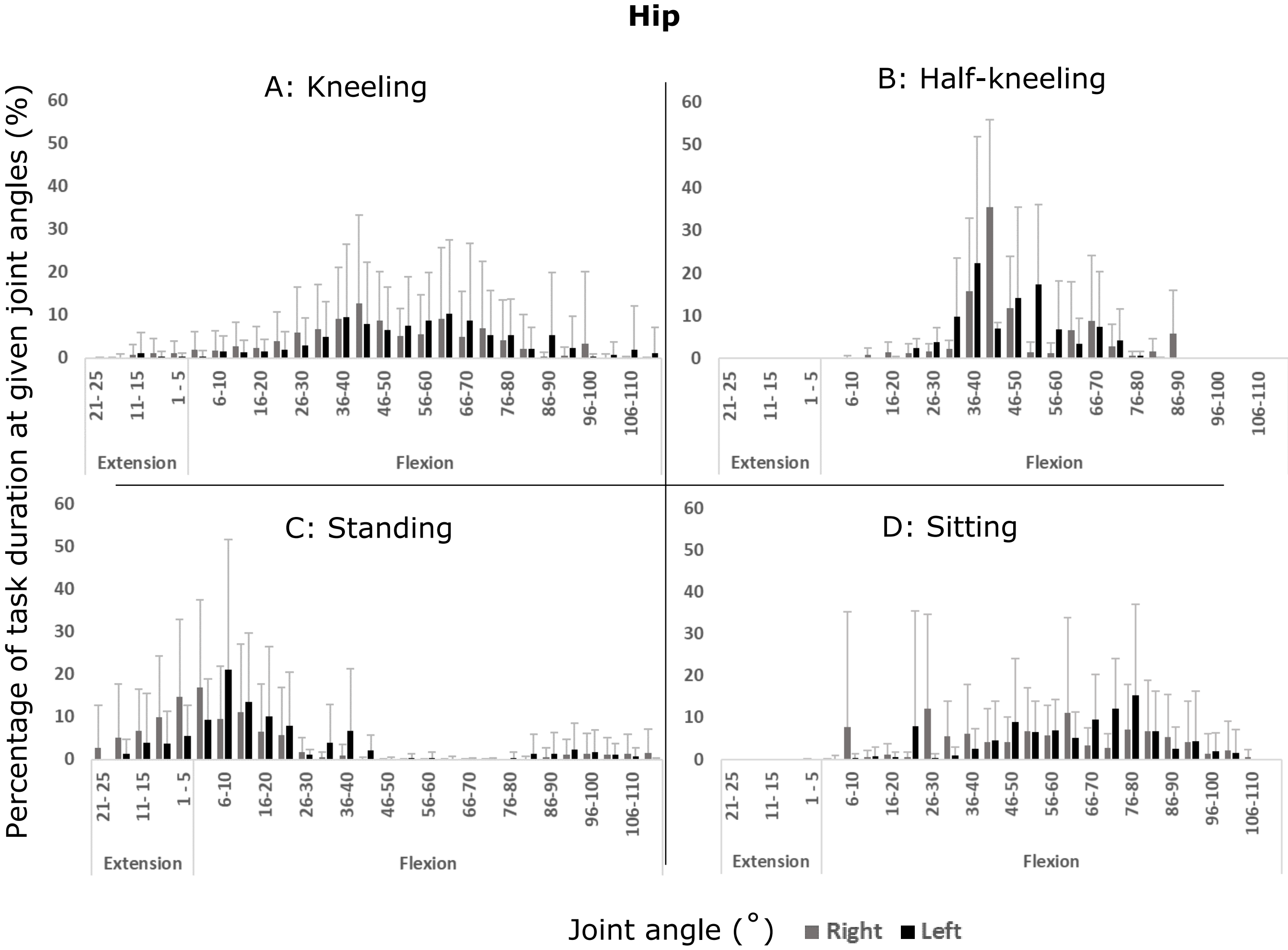


Figure 5.61: Trunk facilitation: Hip joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Knee movement

When kneeling, the knee was found to be flexed towards end range flexion, with a peak in task time spent between 141-145° flexion (Figure 5.62A). Standing showed a peak in task time spent near neutral, a small portion of the task was spent in increased flexion angles (Figure 5.62C). The small amount of time in increased knee flexion could be due to the physiotherapists making short adjustments into sitting, kneeling or squatting depending on facilitation the patient required. Sitting showed a larger portion of trunk facilitation tasks were spent between 71-100° knee flexion (Figure 5.62D). This knee flexion would fit with the expected joint position when sitting. Other joint angles measured during the task could be due to variations in sitting position (e.g., stool vs raised plinth) or short movements into standing to assist the patient. Half-kneeling showed a large portion of the task duration was near end range knee flexion, with the left knee showing a peak in task duration between 36-40° flexion (Figure 5.62B). It was not documented in this study which knee was on the floor or plinth. However, the data suggest the physiotherapist could have had their left leg forward when half-kneeling, this could require less knee flexion.

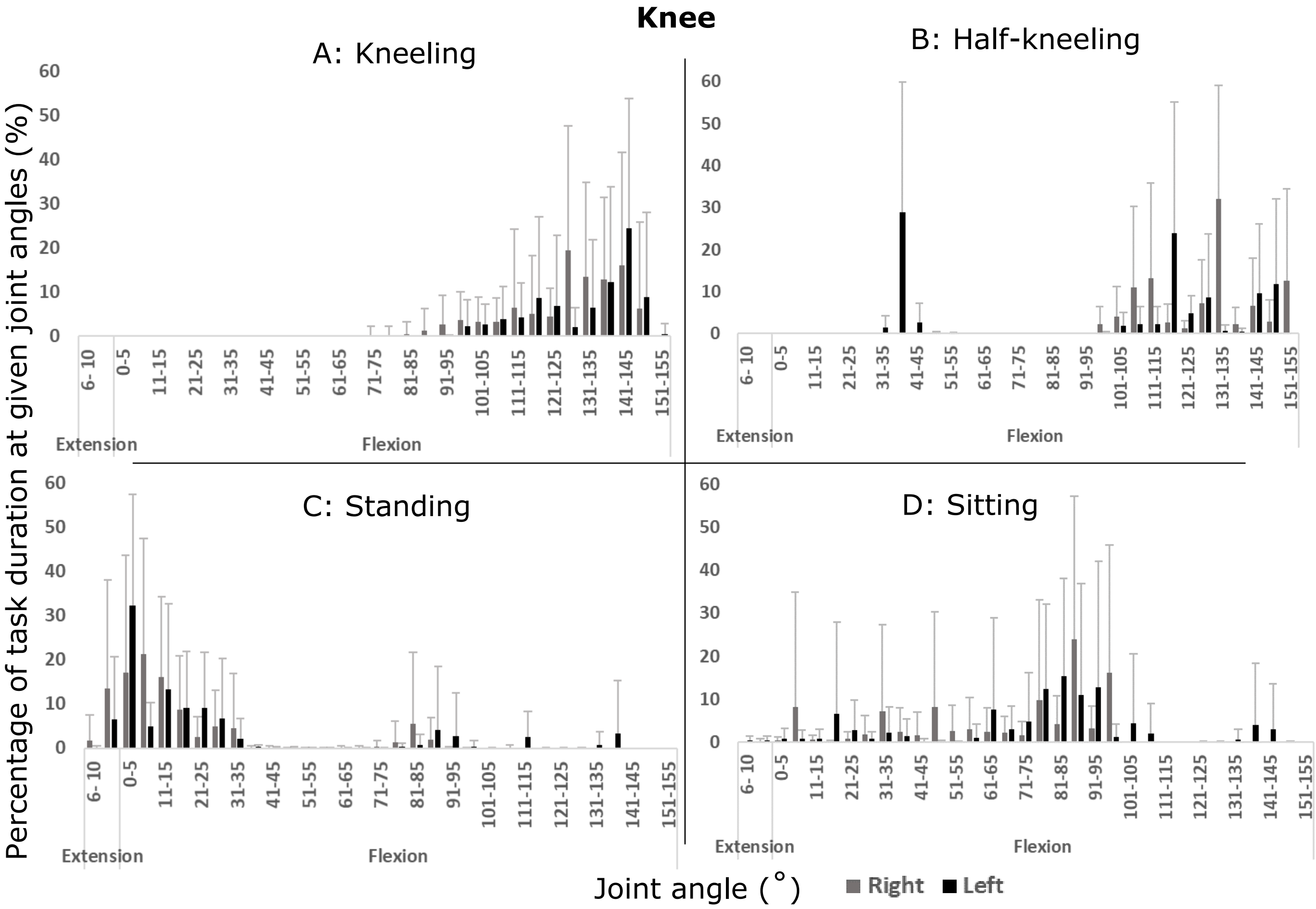


Figure 5.62: Trunk facilitation: Knee joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

5.10.2 Trunk Facilitation Summary

Patterns of movement at the head, trunk and shoulder girdles were generally similar between physiotherapist positions. Kneeling and half-kneeling showed a more extended head position than standing and sitting positions. For all physiotherapist positions, the cervicothoracic junction was flexed. Kneeling, half-kneeling and sitting positions demonstrated more lumbosacral flexion than standing positions during trunk facilitation tasks. Slight differences in shoulder rotation and flexion were measured between physiotherapist positions, with increased shoulder flexion angles found when the physiotherapist was kneeling. More notable differences were found at the physiotherapists' lower limbs; standing showed joint positions near neutral to slight flexion, as would be expected in standing. Kneeling and sitting positions demonstrated a larger range in hip flexion measured, suggesting the hips moved consistently during trunk facilitation tasks. When in kneeling and half-kneeling positions, the physiotherapists were mostly over 116° knee flexion. Half-kneeling showed a smaller spread of joint angles measured during trunk facilitation tasks, suggesting the trunk remained more stationary with more task time spent in joint positions. From observation, when the physiotherapists were kneeling behind the patients, they often supported the patient's trunk when in reclined and upright sitting. The physiotherapists also provided facilitation to aid the patient from reclined to upright sit (e.g., modified sit up). The physiotherapist extending their hips would likely provide the power to assist the patient into upright sitting. Depending on the weight of the patient and level of weakness the task could be manually intensive. The patients were sitting over the edge of the plinth with no support behind in all sessions observed. The physiotherapist kneeling behind would also provide the patient support so they could rest back between treatment exercises.

5.11 Standing Facilitation

This section describes physiotherapist movement during treatments with the patient in static standing. Patients will need to maintain upright standing to allow for gait (Bassile and Hayes, 2016; Kane and Buckley, 2016; Lee, 2019). Assistance was provided to the patients by the physiotherapists, plinths or other equipment (e.g., foam cubes or stand aids). Examples of tasks included in these treatments were static balance, dynamic balance and weight transference, these are outlined in Table 5.2 (Page 122). Standing treatments were performed 76 durations during the data collection sessions with the average duration 170.4 seconds (SD 101.6). Sitting was the most common position used by the physiotherapists (40 of 76), in particular sitting in front of the patient (20 of 76) (Figure 5.63). This position is the same as when assisting sit-to-stand, with the physiotherapist on a stool in front of the patient. This position was often used to allow for facilitation of the patients' hips and knees when the patient was standing.

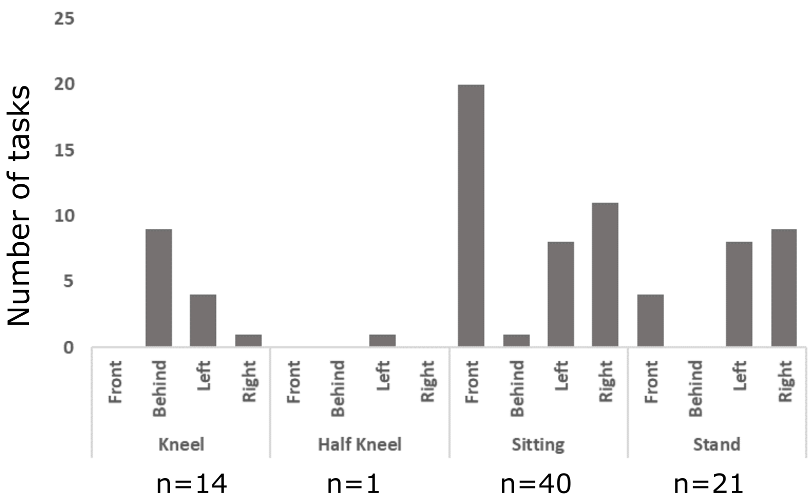


Figure 5.63: Physiotherapist positioning in relation to patient during standing treatments (n= number of physiotherapists)

5.11.1 Proportion and Joint Angle Data During Standing Facilitation

Neck movement (Head/C1)

Kneeling, standing and sitting positions showed the physiotherapists were generally within 5° of neutral posture for side bend. Half-kneeling showed a peak in task time was spent between 6-10° left bend at the neck, however, there was only one recording of physiotherapists facilitating standing half-kneeling. The physiotherapist was half-kneeling to the left and slightly in-front of the patient, the physiotherapist likely rotated their neck to look towards the patient. All physiotherapist positions demonstrated a bell-shaped curve around neutral neck rotation. The neck was generally extended in kneeling and sitting positions during facilitation of standing (Figure 5.64A, D), with half-kneeling and standing closer to neutral (Figure 5.64B, C). Kneeling and sitting positions placed the physiotherapist lower than the patient, which would require increased neck extension to look up and communicate with the patient. It was observed that the physiotherapist was half-kneeling on the plinth to the left of the patient. The plinth had been raised prior to the standing task to assist the patient during sit-to-stand, which then positioned the physiotherapist higher up. This could explain the neck posture closer to neutral than compared with kneeling.

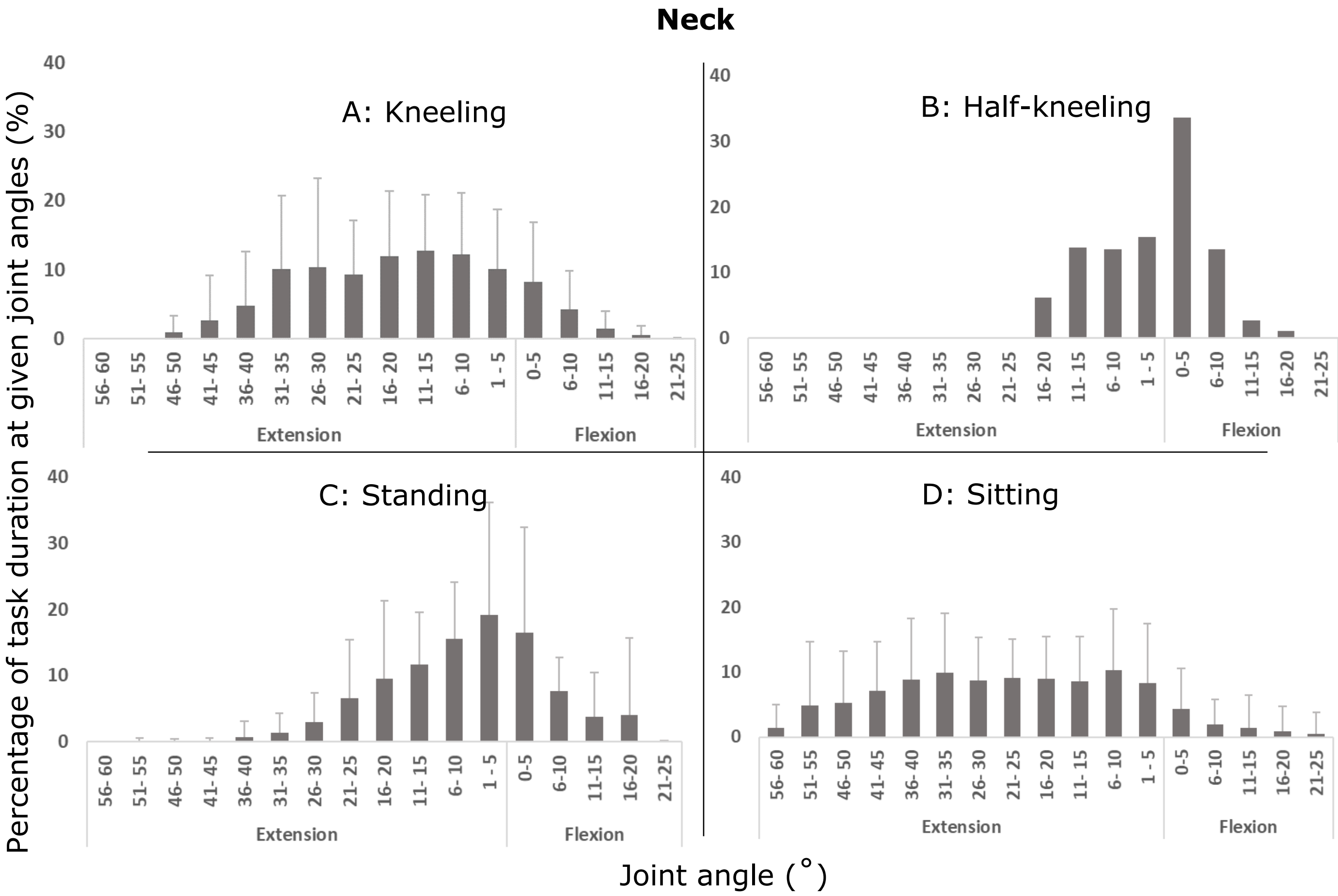


Figure 5.64: Standing: Neck joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Cervicothoracic movement (C7/T1 Joint)

The cervicothoracic junction was generally within 5° of neutral posture for both side bend and rotation in all physiotherapist positions. Most of the standing facilitation tasks were spent in cervicothoracic flexion for all the physiotherapist positions. Half-kneeling showed a peak in task time was spent between 21-25° cervicothoracic flexion (Figure 5.65B). Standing illustrated a bell-shaped curve around 16-20° cervicothoracic flexion (Figure 5.65C). Kneeling and sitting illustrated a larger spread of cervicothoracic motion from 10° extension to 25° flexion (Figure 5.65A, D), which suggests more even distribution of time spent in joint angles.

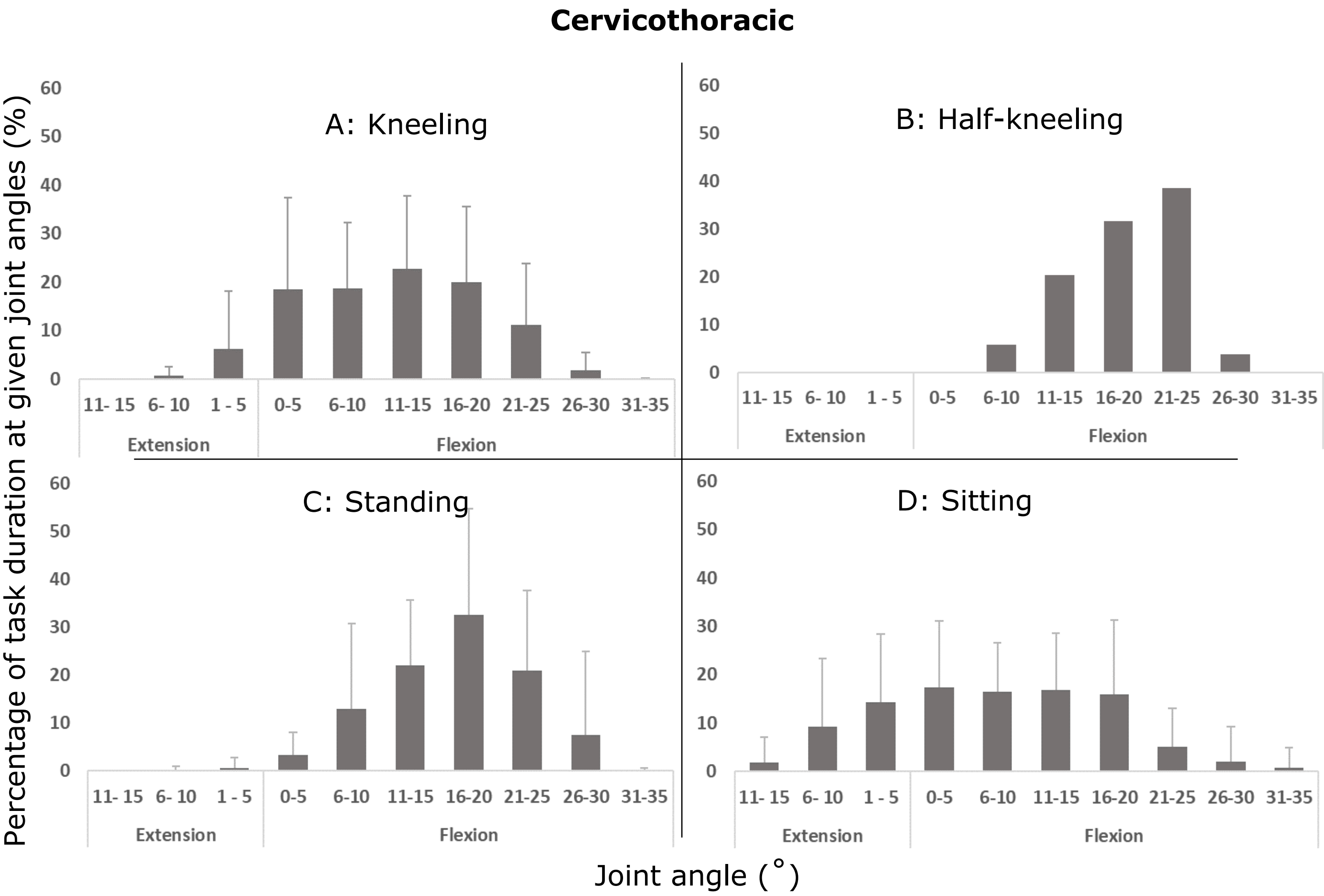


Figure 5.65: Standing: Cervicothoracic joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Thoracolumbar movement (T12/L1 Joint)

A small ROM was measured at the thoracolumbar junction for all directions of movement and physiotherapist positions. Most of the task duration was spent within 5° of neutral posture for side bend and rotation for all physiotherapist positions. The thoracolumbar junction was mostly flexed with half-kneeling and sitting showing a peak in task duration between 6-10° flexion.

Lumbosacral movement (L5/S1 Joint)

The lumbosacral junction was generally within 5° of neutral posture for side bend and rotation for all physiotherapist positions during standing facilitation tasks. Standing and sitting positions showed a range in lumbosacral movement from 6° extension to 25° flexion. However, the peak in task time in standing was spent between neutral to 5° lumbosacral flexion (Figure 5.66C), and sitting was between 11-15° lumbosacral flexion (Figure 5.66D). Kneeling demonstrated a larger spread of lumbosacral movement measured during standing facilitation tasks from 10° extension to 30° flexion, with a peak in task time spent between 11-15° flexion (Figure 5.66A). This larger spread in kneeling is in contrast to half-kneeling, where 83% of the standing facilitation task was spent between 11-15° flexion (Figure 5.66B).

Half-kneeling and sitting positions were found to be flexed at the cervicothoracic, thoracolumbar and lumbosacral junctions, suggesting the trunk was flexed and also rounded during standing facilitation tasks in these positions. Facilitating standing tasks from a standing positions described the physiotherapist flexed at the cervicothoracic junction with a more neutral trunk position at the thoracolumbar and lumbosacral junctions.

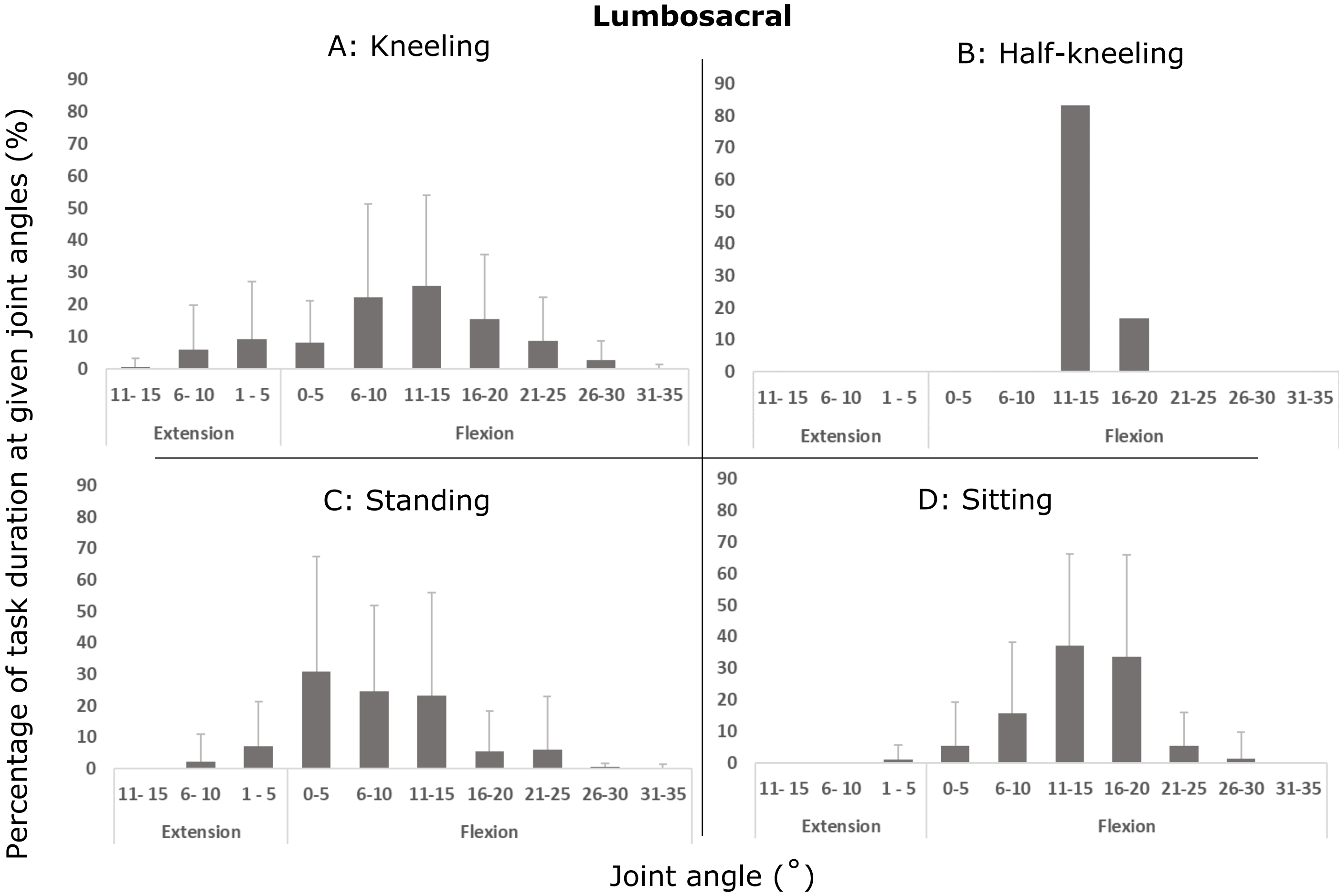


Figure 5.66: Standing: Lumbosacral joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Shoulder girdle movement (T4/Shoulder Joint)

The shoulder girdle was found to be elevated and protracted for all physiotherapist positions with little difference between the left and right upper limbs measured. The physiotherapist's position in relation to the patient varied during trunk facilitation tasks. Physiotherapist position in relation to the patient potentially makes minimal difference to the physiotherapist's shoulder girdle movement.

Shoulder movement

Half-kneeling showed the most abducted position during the task with a peak in task duration between 66-80° shoulder abduction. Kneeling, standing and sitting positions showed a wider spread of time during standing facilitation tasks; a peak in task time was spent between 6-30° shoulder abduction. Half-kneeling and standing positions showed an even split of task time spent between internal and external rotation; with kneeling and sitting illustrating more internal rotation.

When the physiotherapists were sitting, shoulder movement was found to mostly range from 20° flexion to 100° shoulder flexion (Figure 5.67D). This could be related to the physiotherapists reaching up to the patients' hips when sitting in front of the patients. Kneeling, half-kneeling, and standing positions showed a similar pattern of shoulder flexion during the tasks, with movement mostly ranging from 20° shoulder extension to 85° shoulder flexion (Figure 5.67A, B C). For all physiotherapist positions, although maximum flexion reached 125°, very little task duration was spent over 90° flexion.

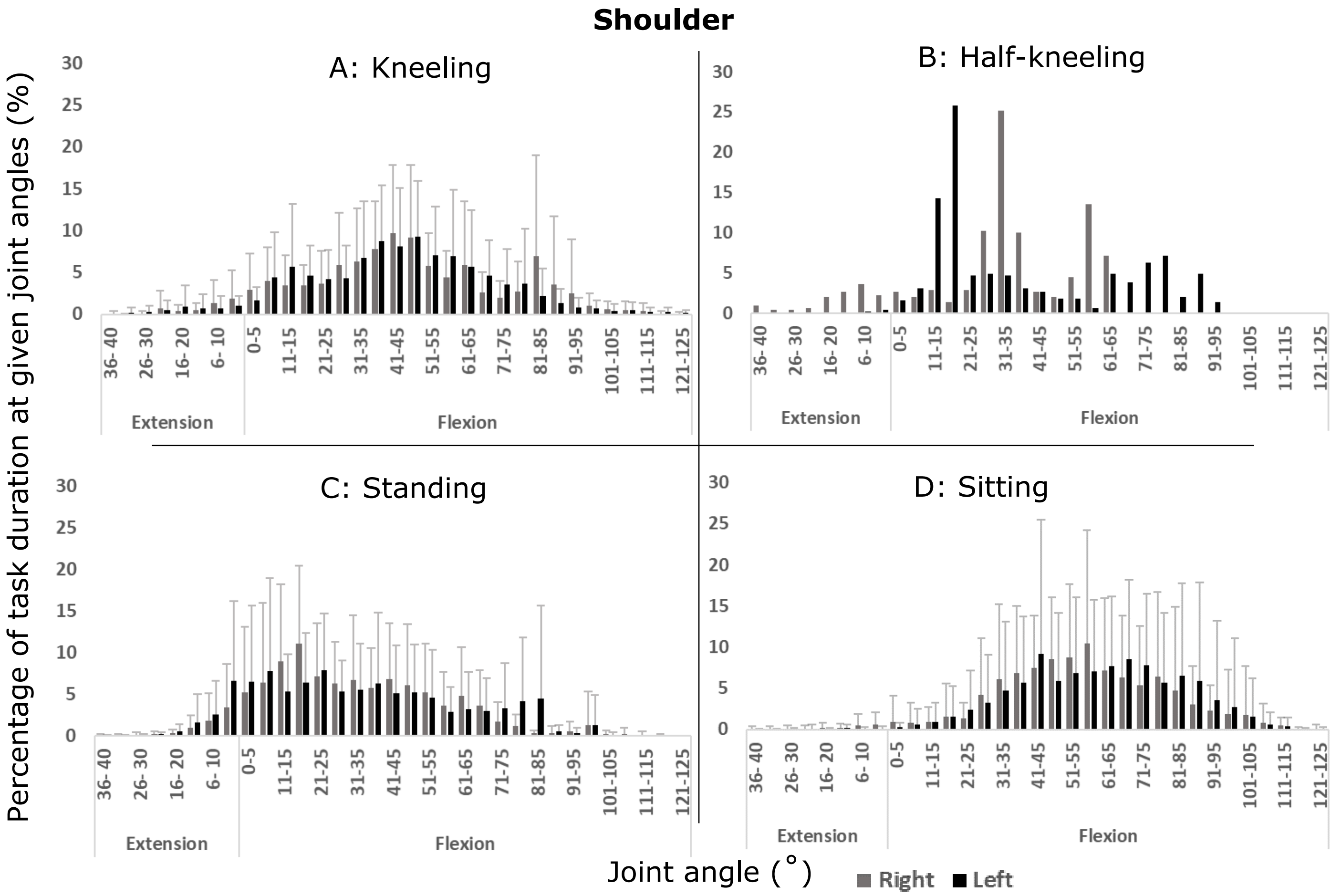


Figure 5.67: Standing: Shoulder joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Hip movement

Differences between left and right sided movement for adduction and abduction were seen in all physiotherapist positions (Figure 5.68A-D). Standing and half-kneeling showed the least variation in joint angles measured with kneeling and sitting showing the most variation. Standing showed most of the task time was spent within 10° of neutral hip posture. The spread of hip abduction and adduction measured when in kneeling and sitting could be due to the physiotherapist positioning themselves in different positions in relation to the patient. Sitting to the left of the patient would require a different hip position to sitting to the right of the patient. Sitting illustrated an equal split of task time spent between internal and external hip rotation. Kneeling showed more of the task time was spent in an internally rotated hip position. Half-kneeling and standing showed more of the task time was spent in an externally rotated position.

Kneeling and half-kneeling positions showed a large spread of task time in hip flexion angles (Figure 5.69A, B). The spread of joint angles measured in kneeling and half-kneeling suggest the hips moved consistently during standing facilitation tasks. Joint motion was measured through the full range of hip motion for standing and sitting positions; standing showed a cluster of task time was spent between 30° hip extension to 20° hip flexion (Figure 5.69C), and sitting between 61-90° hip flexion (Figure 5.69D).

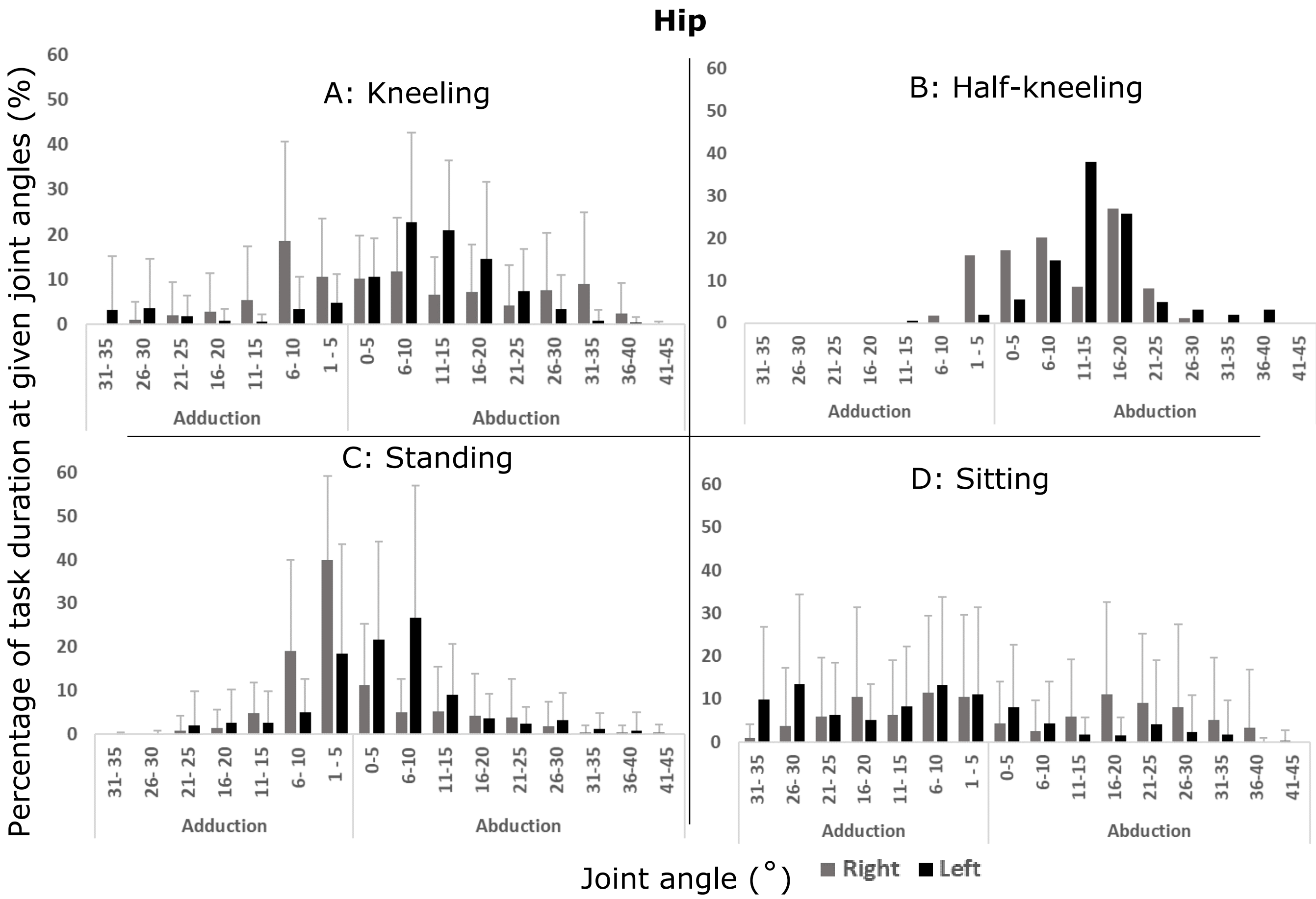


Figure 5.68: Standing: Hip joint angle organised into physiotherapist position for adduction and abduction with data collected in contiguous 5-degree bins (+1SD)

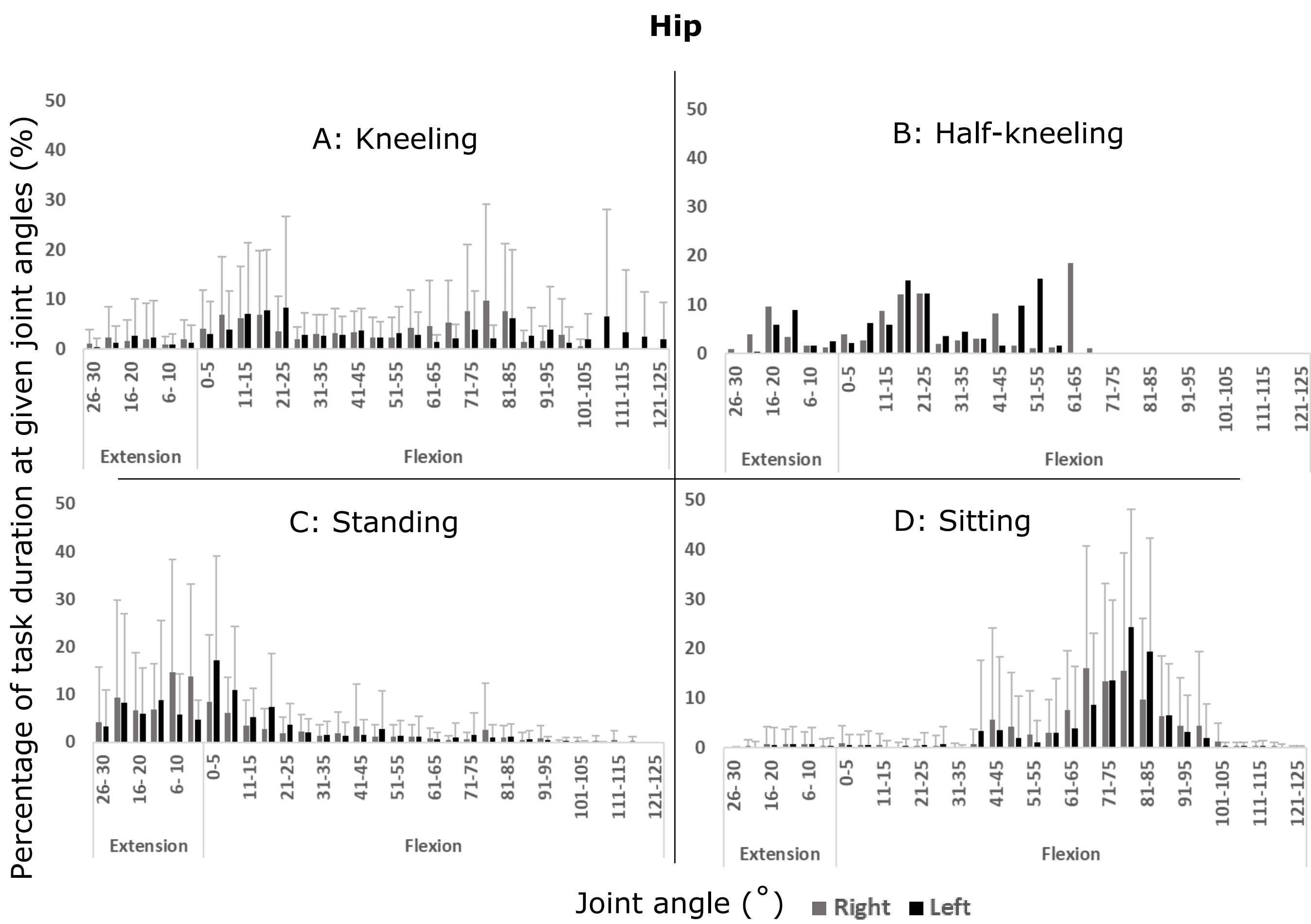


Figure 5.69: Standing: Hip joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Knee movement

Kneeling showed most of the task time was spent between 81-155° knee flexion (Figure 5.70A). This increased flexion angle reflects the physiotherapist position as kneeling requires more knee flexion than the other positions. Standing showed most of the task time was spent between neutral to 25° knee flexion; standing upright would require the knee to be towards a neutral position. The slight flexion found when standing during facilitation of standing tasks could be due to the physiotherapists maintaining a soft knee (Figure 5.70C). Sitting illustrated a spread in knee flexion angles measured with a peak in task time spent between 61-100° knee flexion (Figure 5.70D). Variations in sitting positions and plinth heights could affect the amount of physiotherapist's knee flexion during standing facilitation tasks. Half-kneeling showed the physiotherapist's left knee was flexed between 20-25° for most of the task time, the right knee showed flexion between 126-140° flexion (Figure 5.70B). The physiotherapist was half-kneeling to the left of the patient, so the physiotherapist's right knee was kneeling on the plinth, with the left leg extended to the floor.

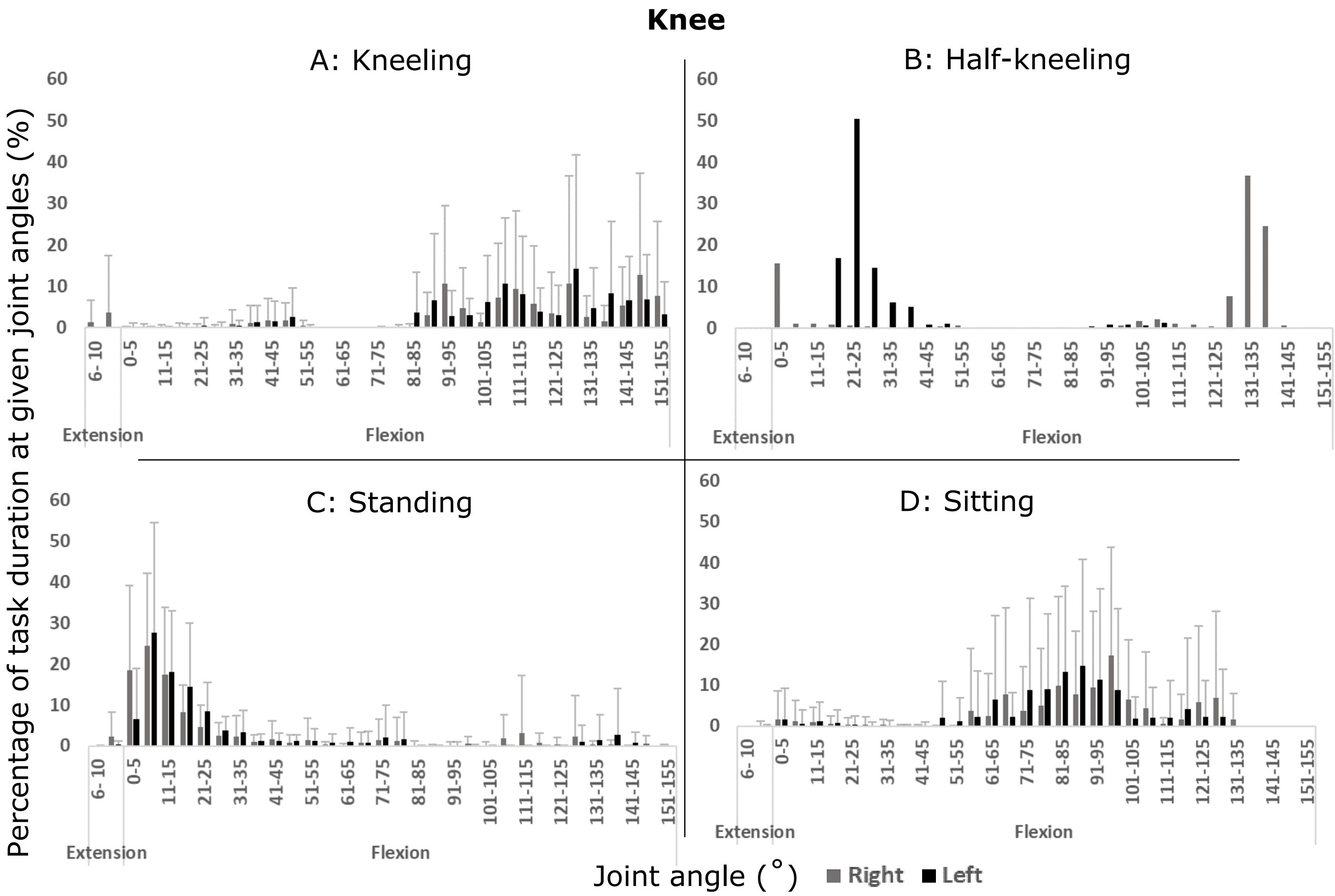


Figure 5.70: Standing: Knee joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

5.11.2 Standing Facilitation Summary

Sitting was the most common position used by the physiotherapists during standing treatments. The physiotherapists were often seated in front of the patient on a small, wheeled stool. Sitting and kneeling positions showed a similar pattern of time spent in joint angles for the neck, trunk and shoulders. When sitting and kneeling, the neck was more extended and the cervicothoracic, thoracolumbar and lumbosacral junctions were flexed. Both positions demonstrated shoulder flexion, likely due to the physiotherapist reaching up towards the patient. Sitting showed slightly greater shoulder flexion angles than kneeling. Sitting and kneeling positions both described cervicothoracic, thoracolumbar and lumbosacral flexion, which suggests the physiotherapist’s trunk was flexed and rounded forwards. This trunk posture, in combination with neck extension, hip and shoulder flexion could become uncomfortable for physiotherapists if maintained for a prolonged period. Kneeling would add the additional discomfort of maintaining end range knee flexion to the previously described physiotherapist position. There is potential the physiotherapists would have been kneeling repetitively through the day or for a prolonged period which could become uncomfortable for the physiotherapists. Standing showed a more neutral neck, thoracolumbar and lumbosacral junction position. However, the cervicothoracic junction was flexed, potentially due to them slightly stooping down to reach the patient.

5.12 Walking Facilitation

This section describes physiotherapist movement during treatments aimed to improve the patients walking. Treatments ranged from stepping on the spot to full walking depending on the patient's ability. Examples of walking treatments are outlined in Table 5.2 (Page 122). Successful and safe walking requires the patient to maintain dynamic balance and stability of the hip and lower limb during weight bearing (Bassile and Hayes, 2016; Kane and Buckley, 2016; Lee, 2019). Equipment and walking aids can assist patients, however, it was observed that the physiotherapists manually facilitated patient movement in addition to equipment. The trunk, lower limb and standing exercises all combine together to improve aspects of the patient's strength, balance and control with the aim to improve functional ability and safety for walking (Bassile and Hayes, 2016; Kane and Buckley, 2016; Lee, 2019).

Walking treatments were performed 75 times during the recorded sessions, with an average duration 101.8 seconds (SD 72.9). The most common position used by the physiotherapists was standing (44 of 75 trials), in particular standing behind the patient (22 of 75 trials) (Figure 5.71). A large number of patients were assisted during walking with the physiotherapist in a sitting position. When sitting, the physiotherapists were observed to facilitate with moving and placing the patients' feet. The physiotherapists were sitting on a stool which had wheels, allowing them to move with the patient.

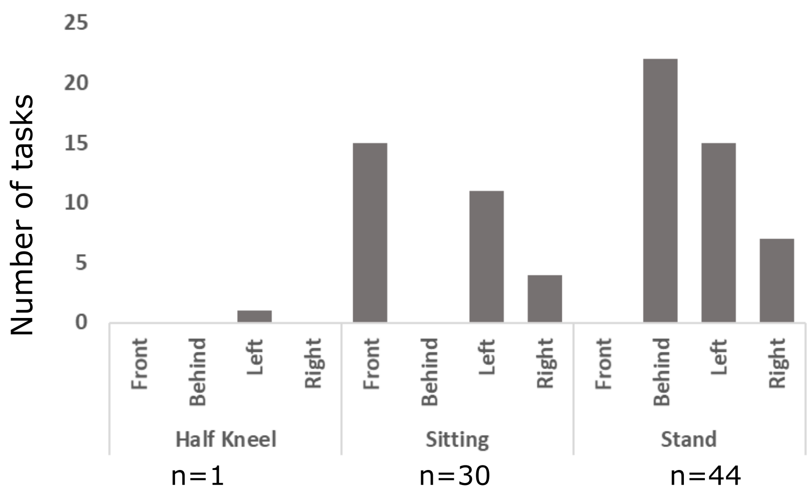


Figure 5.71: Physiotherapist positioning in relation to patient during walking treatments (n= number of physiotherapists)

5.12.1 Proportion and Joint Angle Data During Walking Facilitation

Neck movement (Head/C1)

The neck was mostly within 5° of neutral posture for side bend and rotation in standing and sitting positions. Half-kneeling showed more time of the task was in slight right bend, and a peak in task time was spent between 6-10° right bend at the neck. Half-kneeling also illustrated more task time in right rotation, a peak in task duration was found between 6-10° right rotation at the neck. The physiotherapist was positioned to the left of the patient. This position placed the patient to the right-hand side of the physiotherapist, therefore requiring right bend and rotation of the neck to turn towards the patient.

Standing showed neck angles measured during facilitation of walking ranged from 50 ° neck extension to 30 ° neck flexion; a peak in task time was spent between 6-10° neck flexion (Figure 5.72B). Sitting and half-kneeling positions demonstrated most of the task time was spent in an extended position, and a peak in task time was spent between 6-10 ° neck extension Figure 5.72A, C). Half-kneeling showed a second peak in task time was spent between 16-20° neck extension (Figure 5.72A). Neck posture closer to neutral was found during walking facilitation than other patient tasks. From observation, the physiotherapists looked up to the patient less when in sitting and half-kneeling than other tasks. The physiotherapists instead, looked at the areas of manual facilitation on the patient with short periods of increased neck extension to communicate with the patient and other staff member involved in the treatment.

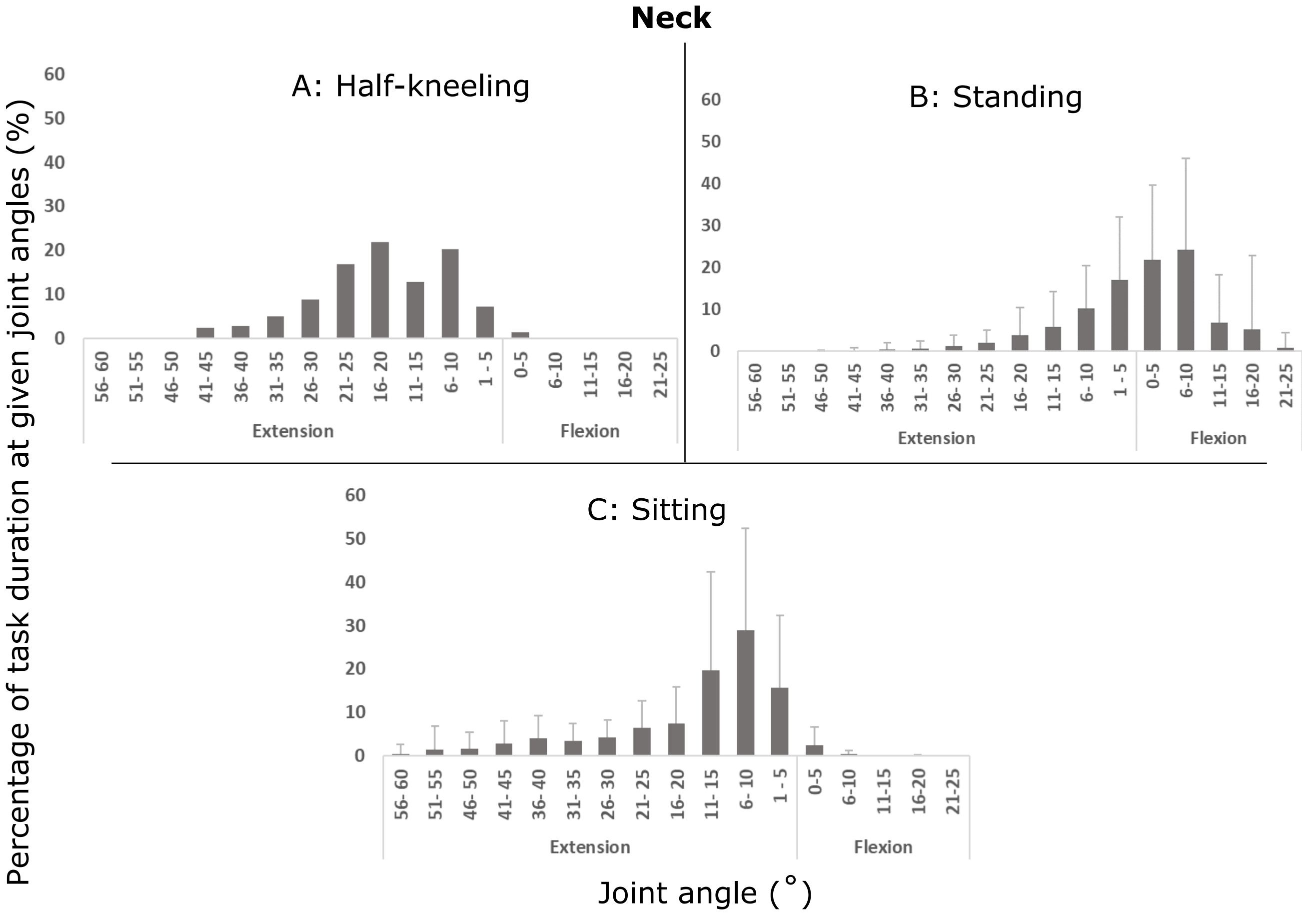


Figure 5.72: Walking: Neck joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Cervicothoracic movement (C7/T1 Joint)

The cervicothoracic junction was generally within 5° of neutral posture for side bend in all physiotherapist positions. Standing and sitting positions were also generally within 5° of neutral posture for cervicothoracic rotation. Half-kneeling showed a peak in task time was spent between 6-10° right cervicothoracic rotation. This right side bend and rotation at the cervicothoracic junction, similar to the neck, is likely due to the physiotherapist looking to the patient.

All physiotherapist positions showed cervicothoracic flexion. Standing illustrated a peak in task time spent between 21-25° flexion cervicothoracic (Figure 5.73B). Sitting and half-kneeling demonstrated a peak in task time spent between 16-20° flexion (Figure 5.73C) and 11-15 ° flexion (Figure 5.73A) respectively. The physiotherapists were potentially rounding at their upper backs in all positions during facilitation of walking.

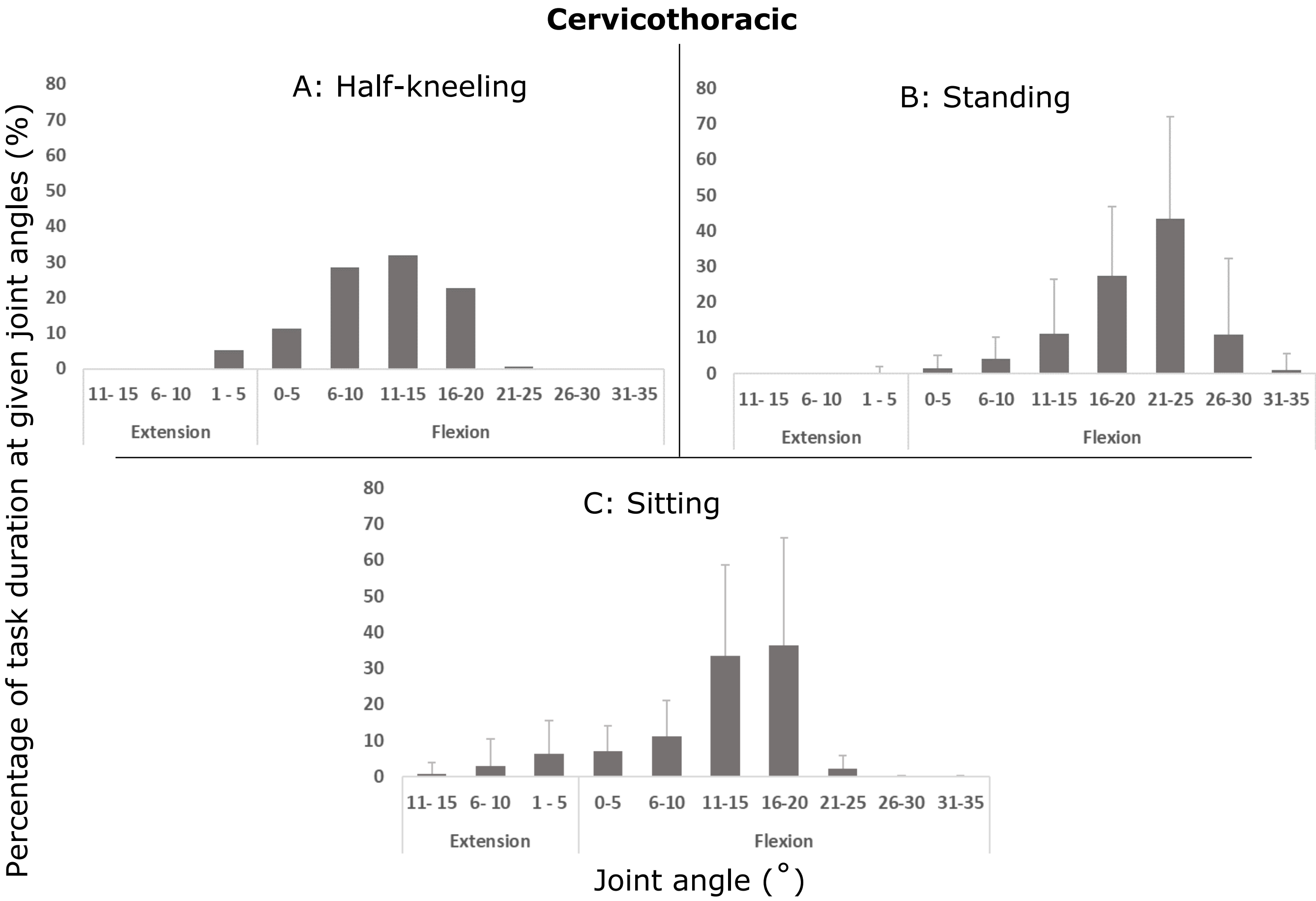


Figure 5.73: Walking: Cervicothoracic joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Thoracolumbar movement (T12/L1 Joint)

A small ROM was measured at the thoracolumbar junction for all directions of movement and positions. Most of the task was spent within 5° of neutral for side bend and rotation for all positions. Half-kneeling showed little ROM during the task with most of task duration between 6-10° flexion. Sitting showed equal duration of the task between neutral to 5° extension and 6-10° thoracolumbar flexion.

Lumbosacral movement (L5/S1 Joint)

The lumbosacral junction was mostly within 5° of neutral for side bend and rotation for all positions. Half-kneeling showed the most flexed position with a peak in task duration between 16-20° flexion (Figure 5.74A). Sitting showed the most range of joint angles measured, with a peak in task duration between 6-10° extension and 11-15° flexion (Figure 5.74C). This could indicate the lumbosacral junction moved more when the physiotherapists were seated.

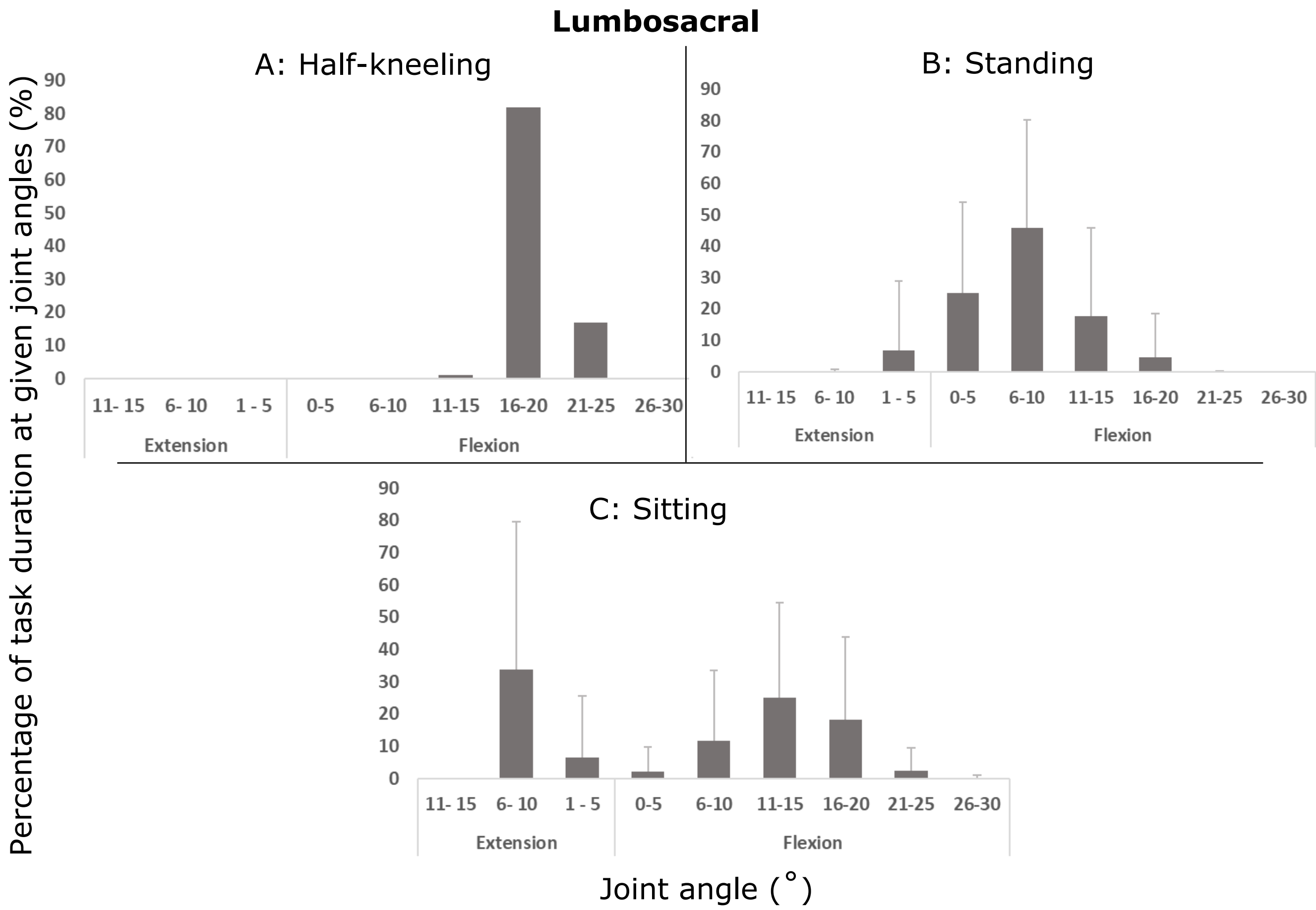


Figure 5.74: Walking: Lumbosacral joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Shoulder girdle movement (T4/Shoulder Joint)

The shoulder girdle was mostly elevated and protracted for all positions during walking tasks. Left and right upper limbs followed a similar pattern of task duration. The physiotherapists were positioned in a variation of positions in relation to the patient. When facilitation of walking tasks was observed, both of the physiotherapists' upper limbs were involved in facilitation of walking. The similarities between physiotherapist position and position in relation to the patient showed minimal impact on shoulder girdle movement.

Shoulder movement

Half-kneeling showed the most abducted shoulder position with a peak in task duration between 46-55°. Standing and sitting positions both showed a peak in task time was spent between 11-20° shoulder abduction, however, there was a large spread of joint angles measured in standing (25° shoulder adduction to 130° shoulder abduction). When in a half-kneeling position, the physiotherapist's left arm was externally rotated with the right arm internally rotated. The patient was to the physiotherapists right hand side, however, the physiotherapists were observed to be reaching over to the patient which may explain the shoulder position measured. Standing showed a larger ROM was measured during facilitation of walking, however, an even split of task time was spent between internal and external shoulder rotation. Sitting showed more task time was spent in an internally rotated position. When facilitating walking from a sitting position, the physiotherapists were reaching towards the patient with both upper limbs placing the shoulders in a more internally rotated position.

Half-kneeling showed differences in postures between the left and right shoulders, the right shoulder showed a peak in task time was spent between 56-60° flexion and the left shoulder was between 76-80° flexion (Figure 5.75A). Similar to the rotation found at the shoulders, standing showed a wide spread of joint angles measured during walking facilitations (Figure 5.75B). Sitting showed a spread of shoulder motion was measured between 11° to 110° shoulder flexion, however, a cluster of shoulder flexion was found between 46-60° (Figure 5.75C). Sitting would be expected to show increased shoulder flexion than standing as the physiotherapists could be reaching forward and up to the patient from sitting.

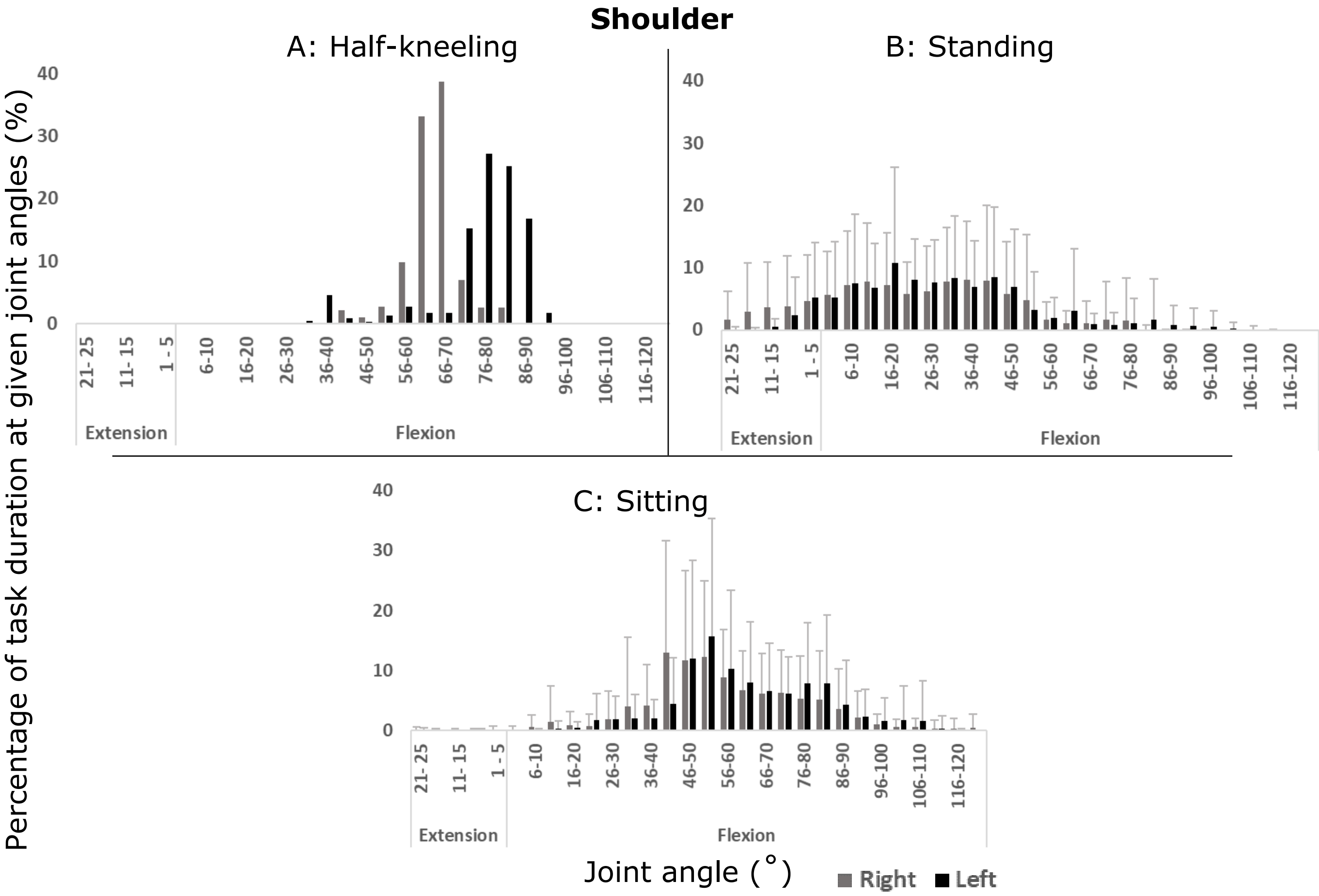


Figure 5.75: Walking: Shoulder joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Hip movement

Half-kneeling showed clear differences between left and right sided movement, with the left hip adducted and the right hip abducted. Sitting showed a larger spread in joint abduction and adduction ROM measured during facilitation of walking tasks. Standing showed a peak in task time was spent between 5° hip adduction to 5° hip abduction and also 5° external to 5° internal hip rotation.

Half-kneeling showed the left hip was flexed between 16-20° with the right hip between 61-65° flexion (Figure 5.76A). The physiotherapist had their right knee and their left foot on the floor. This position would place the physiotherapists right hip closer to neutral with the left hip flexed. Standing illustrated motion was measured between hip extension to slight hip flexion, which would be expected when walking (Figure 5.76B). Sitting showed most of the task time was spent between 61-120° flexion (Figure 5.76C). This flexion angle is more than measured when sitting for other patient handling tasks and could describe more of a lean forward to the patient during facilitation of walking.

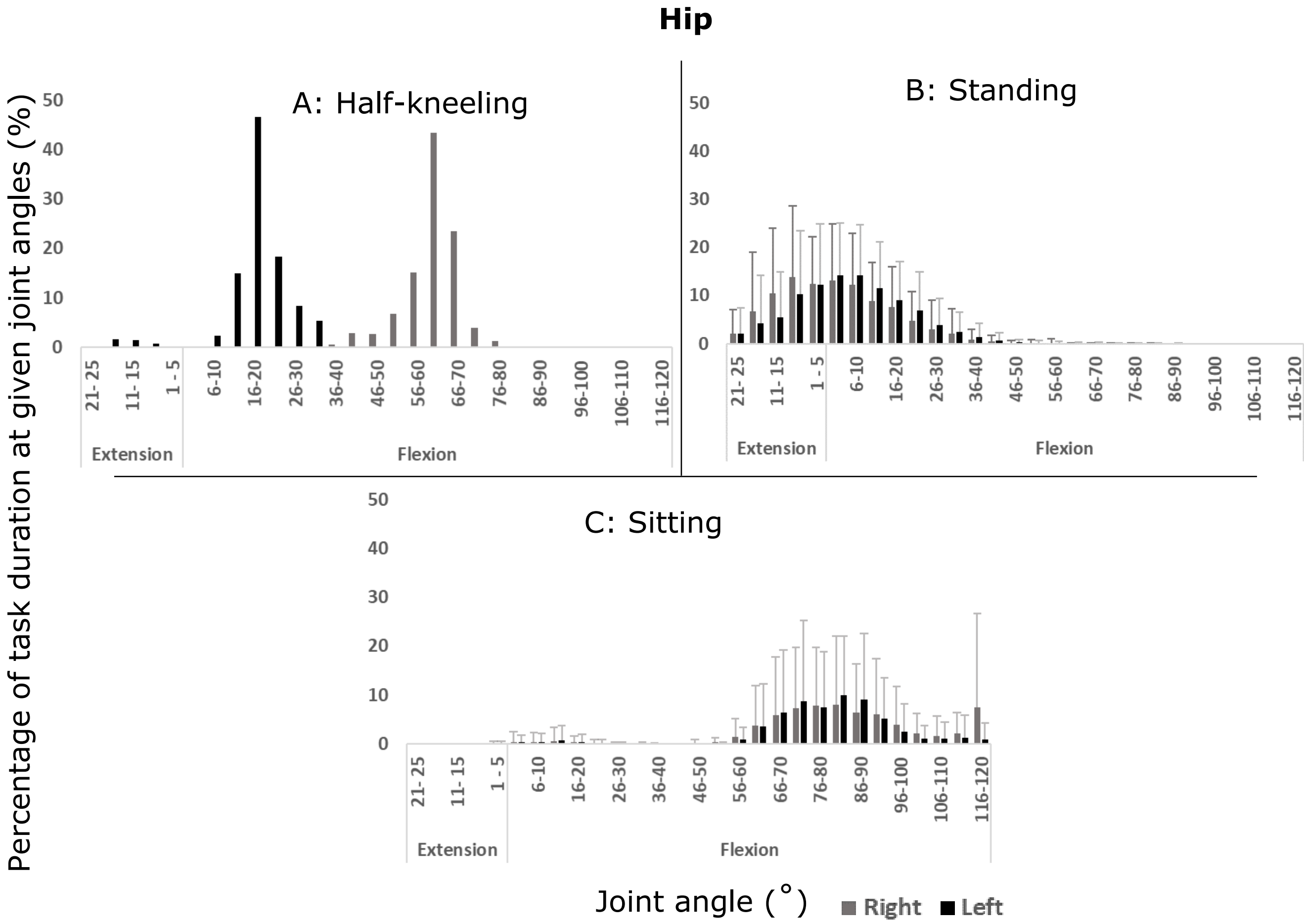


Figure 5.76: Walking: Hip joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

Knee movement

Half-kneeling showed both of the physiotherapists' knees were flexed between 121-135° for the task (Figure 5.77A). Despite the differences measured at the physiotherapists left and right hips in half-kneeling, increased knee flexion would be required bilaterally. Standing showed most of the task time was spent between neutral to 40° knee flexion (Figure 5.77B). When the physiotherapists were standing and walking with the patients, the knees would be expected to move into slight flexion. Sitting showed the physiotherapists knees were mostly flexed between 71-100° (Figure 5.77C). The range in knee flexion angles measured are likely related to the physiotherapist sitting on a stool and moving with the patient. Individual variations in physiotherapist height would also vary the knee flexion position measured.

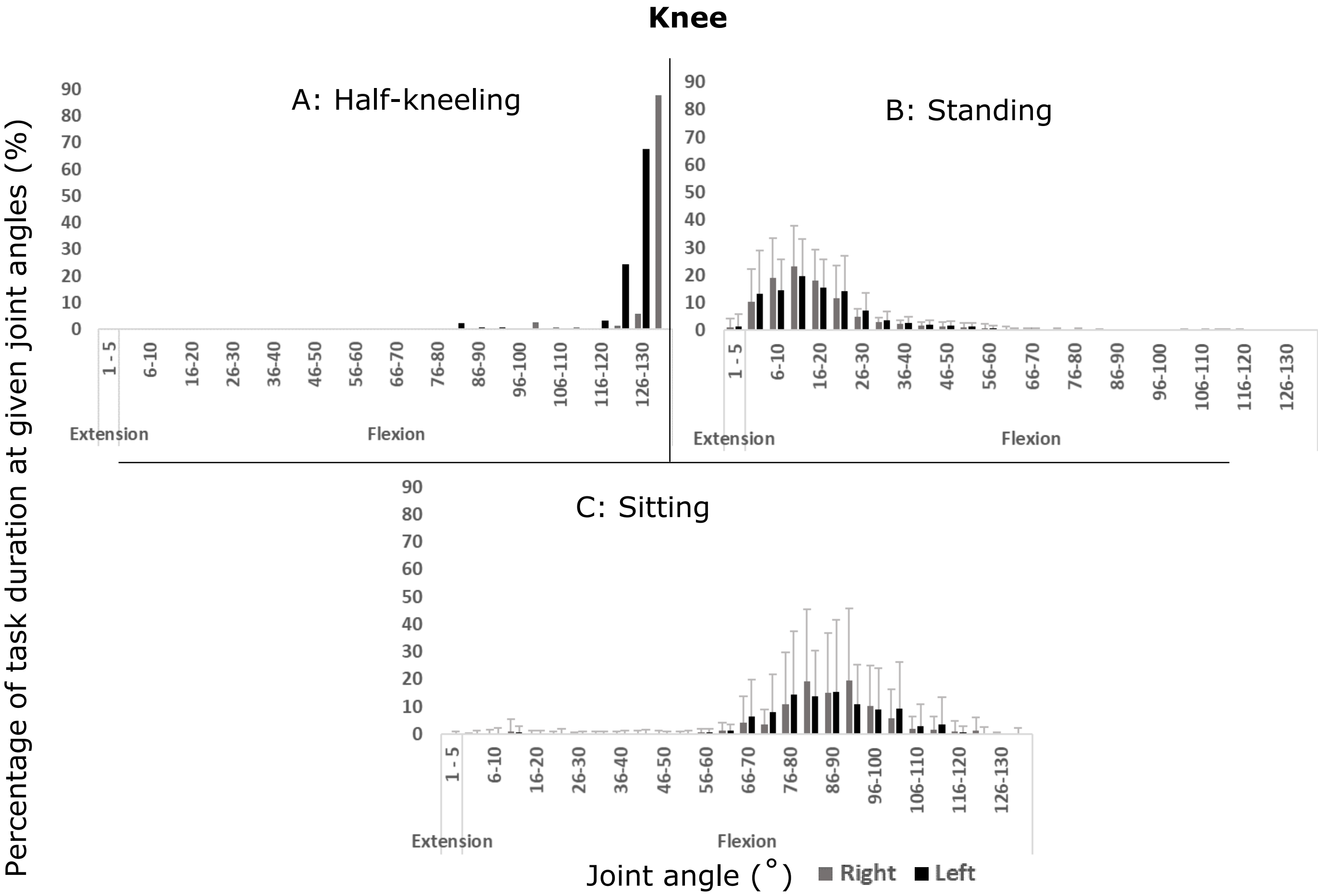


Figure 5.77: Walking: Knee joint angle organised into physiotherapist position for flexion and extension with data collected in contiguous 5-degree bins (+1SD)

5.12.2 Walking Facilitation Summary

Standing (n=44) and sitting (n=30) were the two most frequently used positions by the physiotherapists when facilitating patients' walking. When in standing, the physiotherapists were often supporting and facilitating the patients' hips and trunk. When in standing, the physiotherapists were observed to assist at the patient's trunk. When in sitting, the physiotherapists were sitting on a stool and helping at the patients' lower limbs and hips during walking. When sitting, the physiotherapists were on a small, wheeled stool which allowed them to move with the patient during the walking task. This position was generally used when patients’ required assistance with moving and placing their lower limbs due to reduced strength or control of the lower limb. By sitting on a stool, the physiotherapist was able to facilitate the patient’s lower limb more easily.

Different regions and muscle groups of the patient were facilitated in each physiotherapist position. The physiotherapist’s neck was more extended when sitting as the physiotherapist was looking up to the patient or a staff member. Standing showed neutral to slight neck flexion, as the physiotherapist would potentially be looking down to the patient or to where they were walking towards. Both standing and sitting positions demonstrated flexion at the cervicothoracic junction. Standing demonstrated slightly increased cervicothoracic flexion than sitting, potentially due to the physiotherapists reaching down to the patient’s trunk or pelvis. More differences between physiotherapist positions were seen at the thoracolumbar and lumbosacral junctions. Sitting demonstrated a spread in thoracolumbar and lumbosacral extension to flexion, suggesting the physiotherapist’s trunk was moving more during the walking facilitation tasks. Standing showed a smaller spread in joint angles measured at the thoracolumbar and lumbosacral junctions, which could suggest the trunk was more stationary during trunk facilitation tasks.

The main difference in physiotherapist position is found between at the physiotherapists’ shoulders. Shoulder flexion showed an increase in task time spent at higher shoulder flexion angles when in sitting compared to standing. Increased shoulder flexion would be required to reach forward and assist the patient’s foot or hip. The position maintained by the physiotherapists when sitting could be uncomfortable for physiotherapists due to the hip, lumbosacral, thoracolumbar and shoulder flexion in combination with neck extension. From observation, the physiotherapists often ‘walked’ the stool forwards to move with the patient whilst also assisting with movement of the lower limb. This ‘walking’ was achieved by planting their feet and flexing at the knees, pulling the stool forwards. This task could be quite demanding on the physiotherapists’ hamstrings.

5.13 Physiotherapist Movements and Postures Summary

This section has described physiotherapist movement during eight patient handling tasks by quantifying the duration of the task spent in joint angles. Lie-to-sit, sit-to-lie and sit-to-stand also included time normalised joint angles. In addition to the joint angles, a general description of each task and physiotherapist position was provided for all tasks. The physiotherapists facilitated patient movement from four positions: kneeling, half-kneeling, sitting and standing. Minimal movement away from neutral for rotation and side bend was found at the neck and trunk for all patient tasks when in kneeling, standing and sitting positions. Half-kneeling did, however, demonstrate slight preferences in slide bend and rotation during lie-to-sit, sit-to-stand, upper limb, trunk, standing, and walking facilitation tasks. The side bend and rotation could be due to turning to the patient and also from the asymmetrical BoS when half-kneeling or handedness impacting the physiotherapist’s choice for positioning.

For lie-to-sit and sit-to-stand, kneeling was found to show the most neutral trunk position. This is in contrast to upper limb, trunk and standing treatments where the trunk was found to demonstrate a flexed posture. The trunk was found to be mostly flexed for all positions with standing frequently showing the most cervicothoracic junction flexion, often with a neutral position at the mid and lumbosacral junction. Sitting and kneeling showed increased lumbosacral junction flexion for lower limb, trunk, standing and walking treatments. These two positions also often showed more shoulder, hip and knee flexion. Kneeling frequently showed a large portion of the task duration towards end range knee flexion. Tasks where the trunk and hips were flexed with neck extension have potential to become uncomfortable for physiotherapists if maintained for a long period.

5.14 Relation to Ergonomics Literature

There is an abundance of literature investigating ergonomics and working postures, as discussed previously in section 1.3. Ergonomics and ergonomic assessment tools are used for analysing and assessing working postures for potential risk of WRMSD. As discussed in the Materials and Methods chapter (Section 4.13.2), the Rapid Upper Limb Assessment (RULA) ergonomic tool was chosen to compare the physiotherapist movement against. The assessment could identify patient handling tasks of physiotherapist positions that score highly.

For this study, the scores for the upper arm, neck and trunk were used for assessment of physiotherapist postures. The joint positions and relative RULA scores were used in this study as an indication for potential positions of discomfort for the physiotherapists during patient handling tasks and indicate areas for future research. The scores were also used to identify patient treatment tasks or physiotherapist positions that could benefit from further investigation based on the potential increased risk of injury to the physiotherapist. Joint angles and times maintained were compared against physiotherapist positions and illustrated graphically. Left and right sided upper limb average task times were summarised with each graph as the movement varied between left and right sides.

Two main movements were explored when assessing the shoulder for risk of injury in this thesis; flexion and abduction. Shoulder flexion over 90° has been stated as a joint position of risk in both literature and the RULA tool (score of 4) (Punnett et al. 2000). It has been demonstrated previously that increased risk of shoulder discomfort when more than 10% of the working day was spent over 90° shoulder flexion (Punnett et al. 2000) (Table 5.3). When assessing working postures with the RULA, the score is increased by one point when the shoulder flexion was combined with abduction. The method of data processing within this study did not allow for analysis of static physiotherapist positions. However, the data presented previously, illustrated most of the task was spent with the shoulder in an abducted position, suggesting shoulder abduction and flexion were likely combined.

5.14.1 Shoulder Posture

The graphs of joint angles during the patient handling tasks, presented previously in sections 5.5 to 5.12, were adapted to include the RULA scores (Table 5.3). In addition to the RULA score, the time of the patient handling tasks spent over 90° shoulder flexion was calculated following Punnett et al's (2000) threshold of 10% of time over 90° shoulder flexion. The percentage time over 90° is calculated as an average of left and right shoulder movement unless a substantial difference between sides was found.

Table 5.3: Shoulder flexion ergonomic values

Source	**Joint position**	**Time of day/task**
Ergonomics literature	Neutral (0) to 90 flexion	Increase in intramuscular pressure (Palmerud et al. 2000)
(Palmerud et al. 2000; Punnett et al. 2000)	>90 flexion	10% working day (Punnett et al. 2000)
RULA		**Score**
(Middlesworth, 2021)	20 flexion 20 extension	1
	20-45 flexion >20 extension	2
	45-90 flexion	3
	>90 flexion	4

Shoulder Flexion and Extension

Lie-to-sit Facilitation

When assisting lie-to-sit, the physiotherapists' shoulders spent little time of the task in extension for all physiotherapist positions. Standing showed the most task time spent over 90° shoulder flexion (5% task time average in region 4) (Figure 5.78C). However, half-kneeling showed most of the task time was spent between 45-90° flexion (72% task time average in region 3) (Figure 5.78B). Kneeling spent an average of 39% of the task time in region 3, standing showed an average of 40% of the task time in region 3 (Figure 5.78A, C). Half-kneeling demonstrated potential to score highly due to the large percentage of the task time spent in region 3, however, standing also showed potential to score highly due to the increased time in region 4. Facilitating lie-to-sit from either half-kneeling or standing positions could score highly with the RULA due to the greater proportion of the task spent in higher scoring postures.

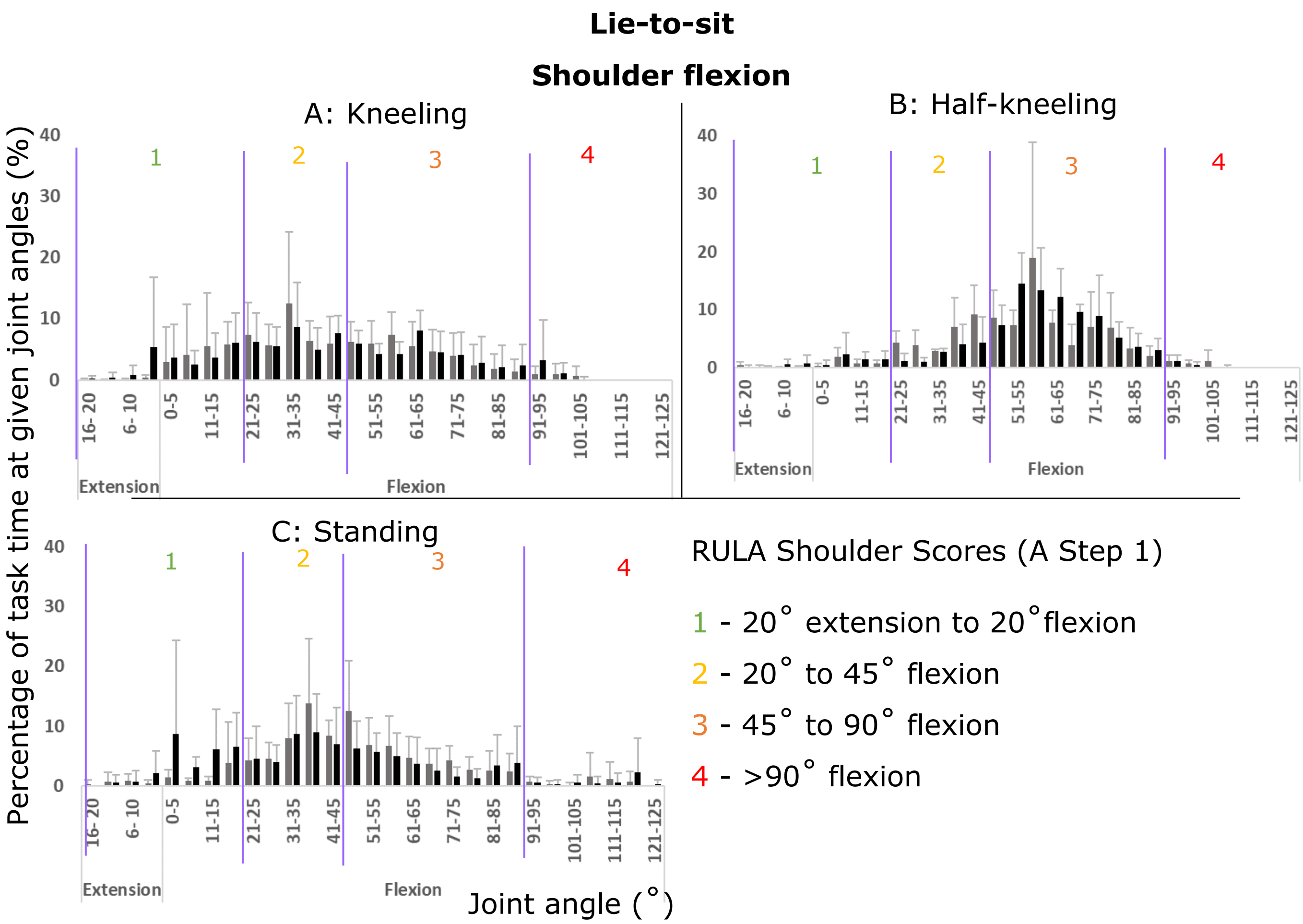


Figure 5.78: Vertical lines identifying RULA shoulder scores for A: kneeling, B: half-kneeling and C: standing

Sit-to-lie Facilitation

During facilitation of patients from sit-to-lie, 90° shoulder flexion was not reached when the physiotherapists were in standing; and only 1% of the task time in kneeling was spent over 90° shoulder flexion (region 4) (Figure 5.79A). Standing showed more task time was spent between 45-90° shoulder flexion (average of 57% task time in region 3) than kneeling (47% task time in region 3) (Figure 5.79B). Standing also showed more of the task time was spent over 20° shoulder extension (average of 9% task time) compared to kneeling which showed almost no time task time extended more than 20°. This suggested physiotherapists facilitating sit-to-lie from both kneeling and standing positions could score highly with the RULA due to the greater proportion of task time spent in higher scoring postures.

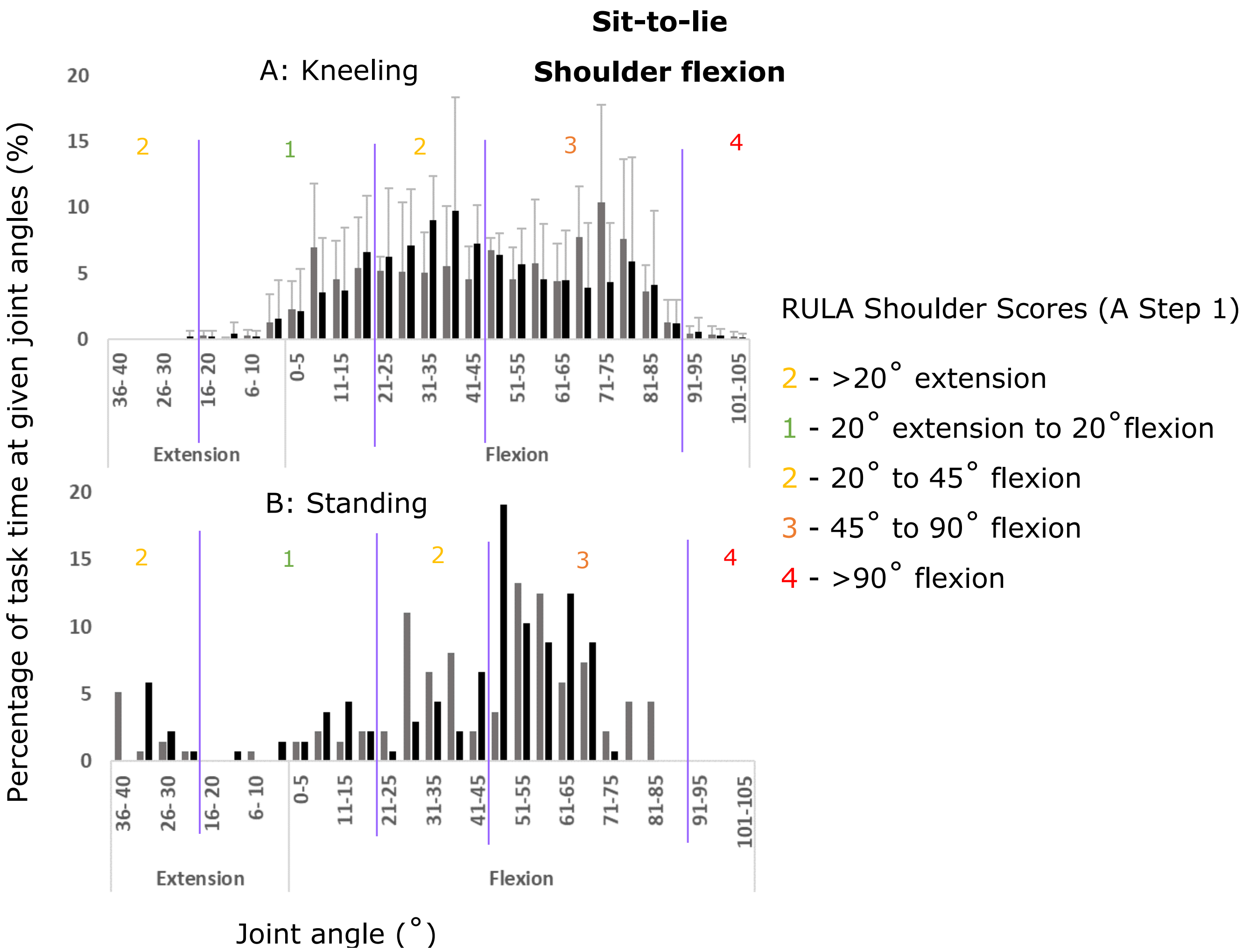


Figure 5.79: Vertical lines identifying RULA shoulder scores for A: kneeling and B: standing

Sit-to-stand facilitation

When assisting sit-to-stand, sitting showed more of the task time in higher scoring regions than the other positions (Figure 5.80D). In addition, both of the physiotherapists' shoulders were flexed over 90°; 13% of task time for the right and 15% task time for the left shoulder (Figure 5.80D). Assisting a patient from sit-to-stand with the phyisotherapist in a seated position would require increased shoulder flexion as the physiotherapist would be reaching towards the patient when they are seated a the start of the task. More sit-to-stand tasks were facilitated from sitting in front of the patient (n=22). The physiotherapists remained sitting while the patient stood up, meaning the physiotherpaist often had to reach up to the height of the patient from a sitting position. Sitting demonstrated more task time was spent between 45-90° shoulder flexion than other phyisotherapist positions (average of 57% task time when sitting) (Figure 5.80D).

Half-kneeling showed more task time was spent in shoulder extension than the other physiotherapist positions (right shoulder 8% task time in extension region 2) (Figure 5.80B). Standing demonstrated 75% task time was spent in regions scoring 1 or 2 (shoulder extension to 45° flexion) (Figure 5.80C) compared with kneeling, half-kneeling and sitting positions (62%, 60% and 30% task time respectively). Sitting showed the greatest proportion of sit-to-stand tasks were spent in higher scoring RULA postures and therefore could demonstrate more risk of WRMSD.

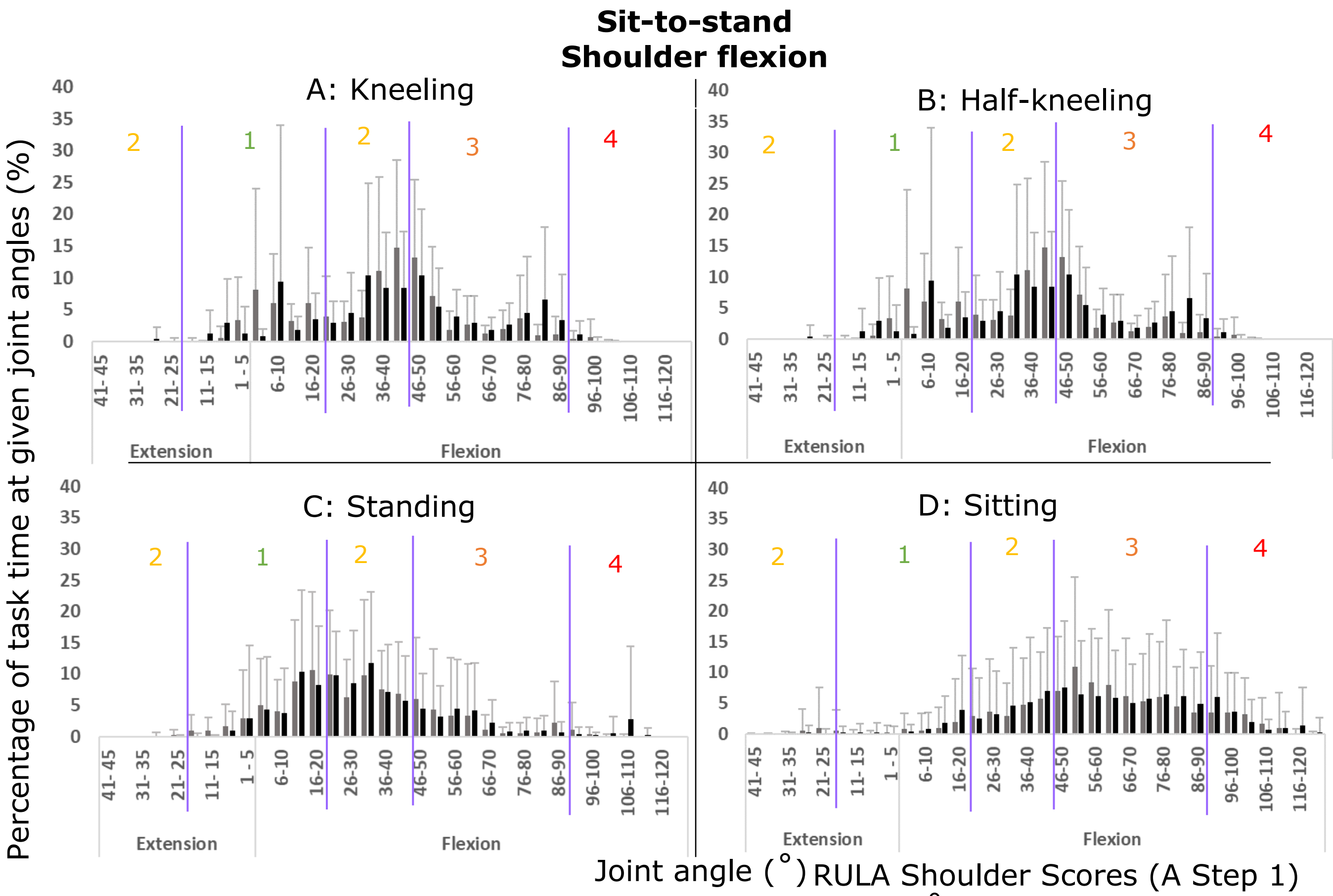


Figure 5.80: Vertical lines identifying RULA shoulder scores for A: kneeling, B: half-kneeling, C: standing and D: sitting

Upper Limb Facilitation

During facilitation of upper limb tasks, little time was spent in shoulder extension over 20° or flexion over 90° for all physiotherapist positions. Sitting demonstrated the least task time spent between 20° shoulder extension to 20° shoulder flexion (average of 16% task time spent in region 1) (Figure 5.81D). Kneeling and sitting positions showed a similar distribution of task time with a larger portion of time between 20-45° flexion (average of 36% and 37% task time respectively in region 2) (Figure 5.81A, D). In standing, 29% of the task time was spent between 20° shoulder extension to 20° shoulder flexion (region 1), with the largest portion spent between 20-45° flexion (average 45% task time in region 2) (Figure 5.81C). All physiotherapist positions demonstrated potential to score similarly with the RULA tool, with the largest portion of task time spent with the shoulders flexed in region 2. Compared with other patient handling tasks this scores generally lower and could indicate less associated risk of injury.

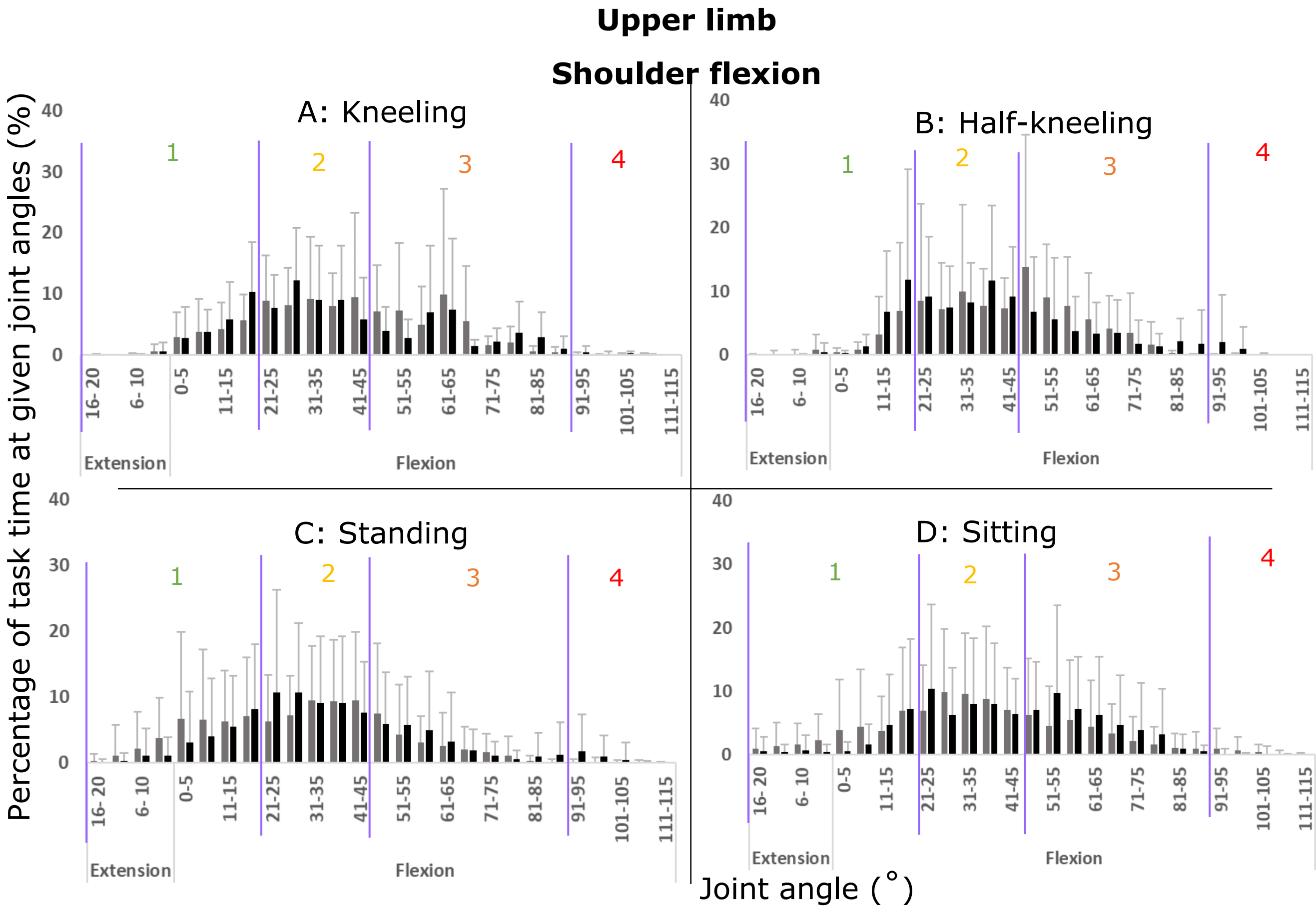


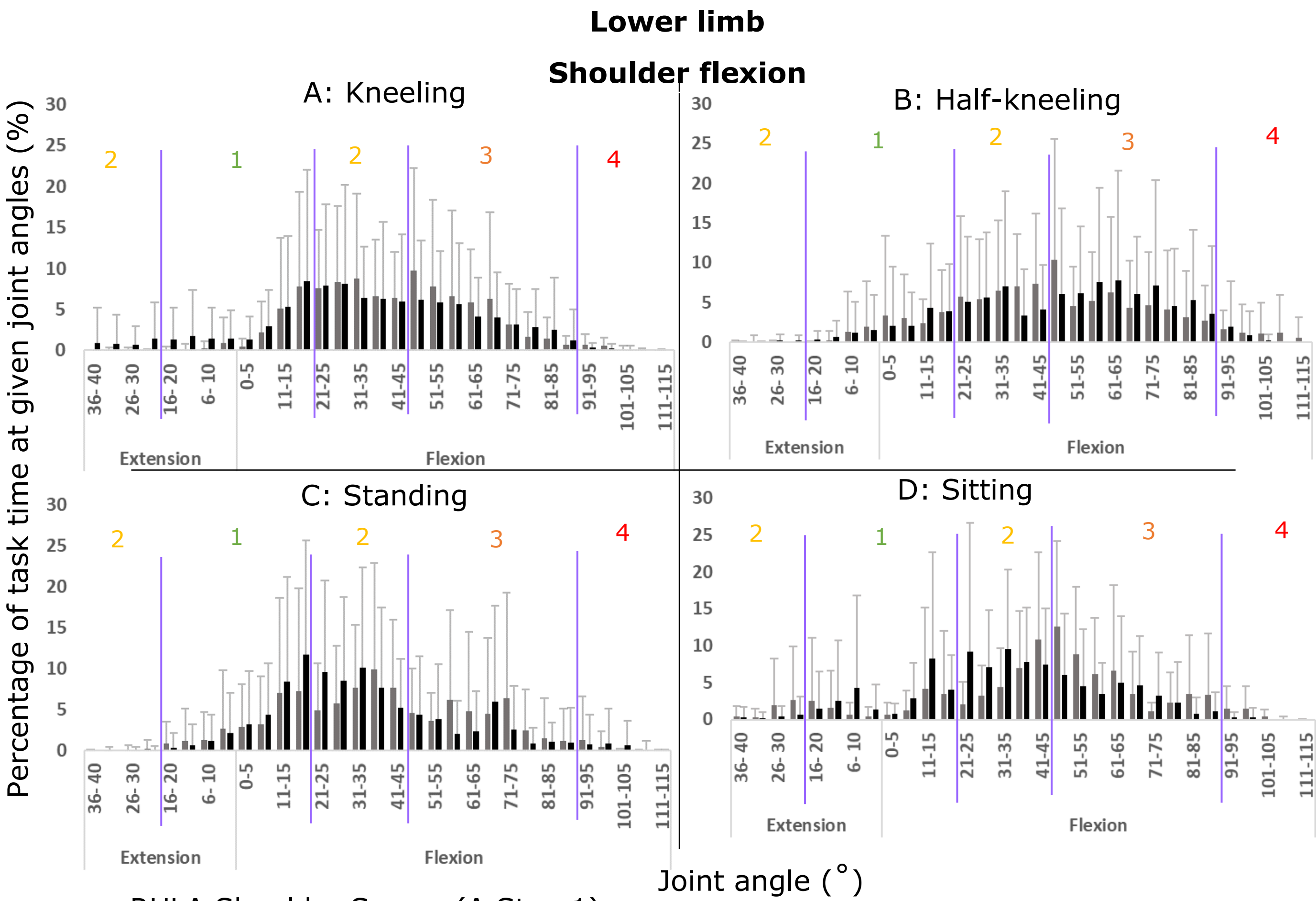
Figure 5.81: Vertical lines identifying RULA shoulder scores for A: kneeling, B: half-kneeling, C: standing and D: sitting

RULA Shoulder Scores (A Step 1)
1 - 20° extension to 20° flexion
2 - 20° to 45° flexion
3 - 45° to 90° flexion
4 - >90° flexion

Lower Limb Facilitation

During facilitation of lower limb tasks, little task time was measured over 20° shoulder extension for all physiotherapist positions. Half-kneeling demonstrated the most task time spent over 45° shoulder flexion of all physiotherapist positions (50% task time in region 3; 5% task time in region 4) (Figure 5.82B). Kneeling and sitting showed similar proportions of task time spent over 45° shoulder flexion; kneeling spent 37% task time in region 2 and 40% in region 3, sitting spent 35%task time in region 3 and 40% in region 4 (Figure 5.82A, D).

Standing demonstrated more task time spent between 20° extension to 20° flexion (average 29% task time in region 1) than other physiotherapist positions. Half-kneeling spent the greatest proportion of lower limb facilitation tasks in higher scoring RULA regions compared to other physiotherapist positions.



RULA Shoulder Scores (A Step 1)

2 - >20° extension

1 - 20° extension to 20°flexion

2 - 20° to 45° flexion

3 - 45° to 90° flexion

4 - >90° flexion

Figure 5.82: Vertical lines identifying RULA shoulder scores for A: kneeling, B: half-kneeling, C: standing and D: sitting

Trunk Facilitation

During facilitation of trunk tasks, half-kneeling showed the largest proportion task time spent between 20-45° shoulder flexion of all physiotherapist positions (average of 59% task time spent in region 2) (Figure 5.83B). Sitting demonstrated the most task time spent over 90°; the right shoulder showed 13% and the left shoulder showed 8% of the task time was spent in region 4 (Figure 5.83D). Sitting exceeded the 10% task time threshold proposed by Punnet et al (2000). Kneeling and half-kneeling positions showed an average of 6% and 7% of the task time was spent in region 4 (Figure 5.83A, B); with standing only spending 1% of the task time in region 4.

Standing next to the patient would still require shoulder flexion, 42% of the task time was spent between 45-90° shoulder flexion (region 3) (Figure 5.83C). However, less flexion over 90° may be a result of the physiotherapist standing next to the patient who was sitting or lying down. The physiotherapists, when in standing would be more likely to reach forward and down to the patient. Kneeling, half-kneeling and sitting positions would require the physiotherapist to reach forward and up to the patient as they would be more similar in height with the patient. Half-kneeling and sitting positions demonstrate differences between left and right sided shoulder flexion over 90°. One shoulder may demonstrate increased task time spent at higher shoulder flexion angles related to the physiotherapists position in relation to the patient, handedness or preferences in areas of facilitation. The increased task time spent flexed over 90° could score higher when assessing physiotherapist posture with the RULA during trunk facilitation tasks. The increased shoulder flexion and associated RULA score suggests increased risk of WRMSD.

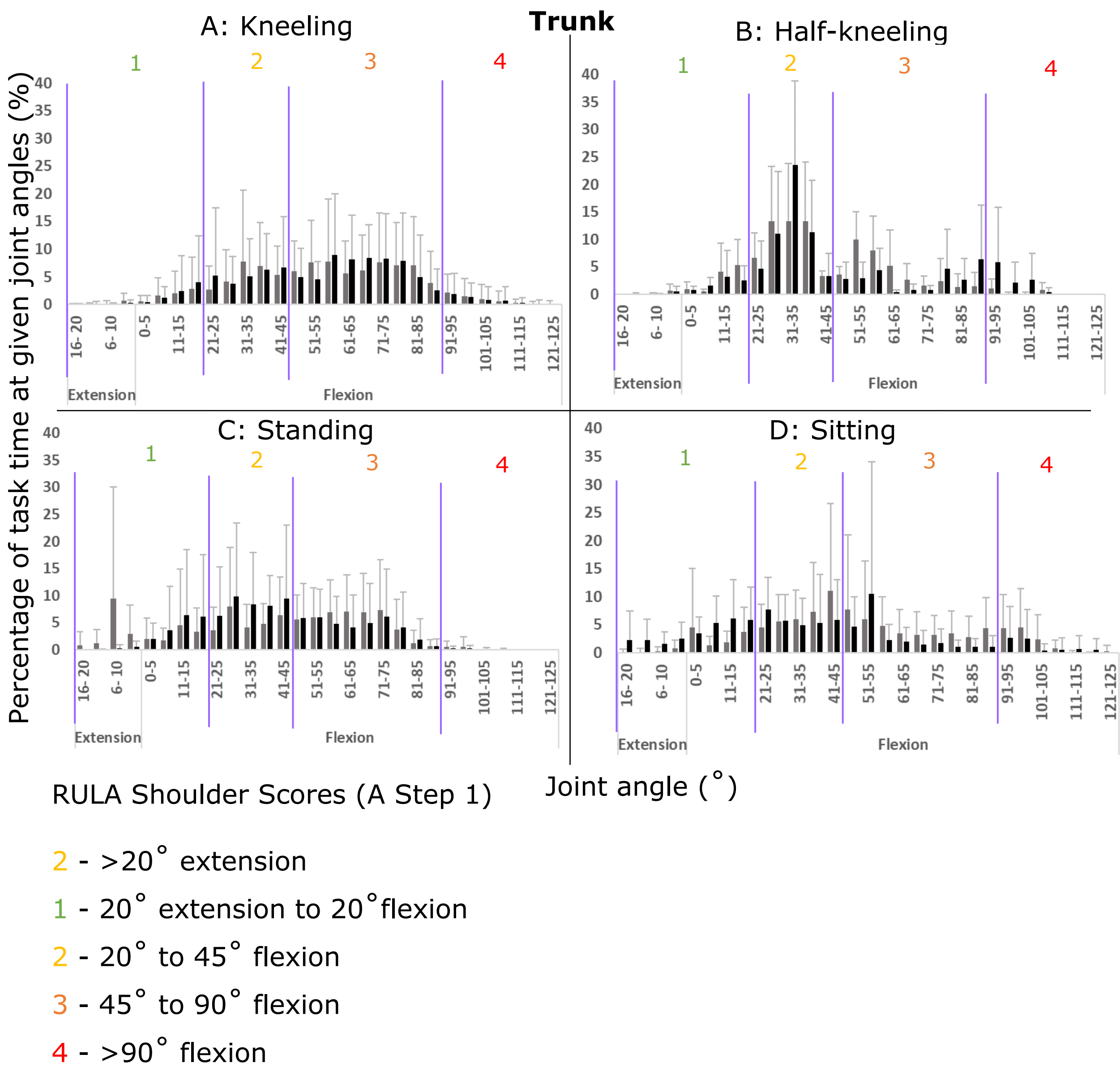
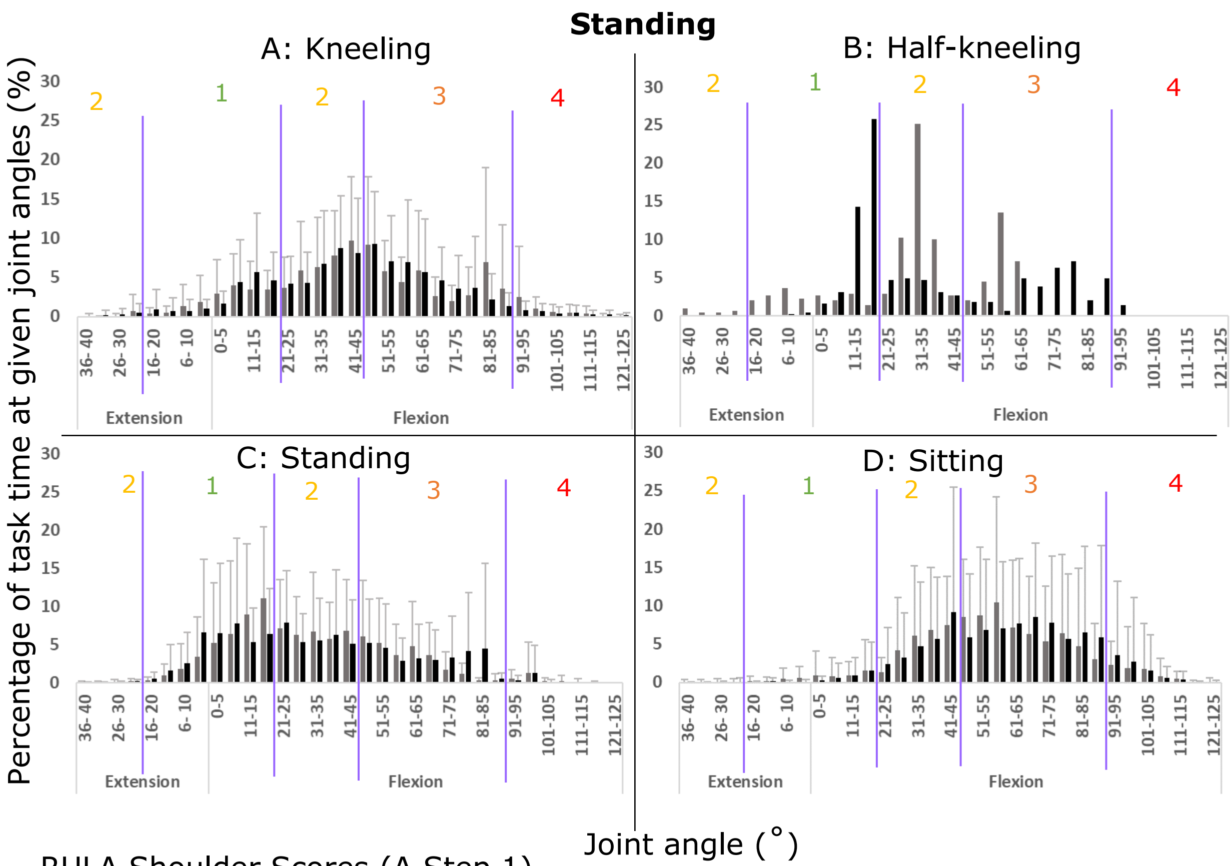


Figure 5.83: Shoulder flexion during trunk treatments with RULA scores for A: kneeling, B: half-kneeling, C: standing and D: sitting

Standing Facilitation

During facilitation of standing tasks, minimal task time was measured over 20° shoulder extension in all physiotherapist positions. Additionally, half-kneeling and standing showed minimal task time over 90° shoulder flexion (average 1% and 2% task time respectively) (Figure 5.84B, C). Sitting and kneeling positions showed more task time spent over 90° shoulder flexion, with sitting spending 4% and kneeling spending 8% of the task time in region 4 (Figure 5.84A, D). Sitting also demonstrated 62% of the task time was spent between 45-90° shoulder flexion (region 3) (Figure 5.84D). This proportion of time during facilitation of standing tasks in region 3 was greater in sitting than the other three physiotherapist positions. The greater proportion of the task time spent in higher scoring regions (3 and 4) could indicate a higher risk of WRMSD when the physiotherapists were sitting while facilitating standing tasks. The physiotherapist would have to reach up to the height of the patient during standing tasks. The physiotherapists would also have to flex at their shoulders if leaning forward to reach to the patients' lower leg and feet.



RULA Shoulder Scores (A Step 1)

2 - >20° extension

1 - 20° extension to 20° flexion

2 - 20° to 45° flexion

3 - 45° to 90° flexion

4 - >90° flexion

Figure 5.84: Shoulder flexion during standing treatments with RULA scores for A: kneeling, B: half-kneeling, C: standing and D: sitting

Walking Facilitation

Facilitation of walking tasks showed minimal task time was spent over 20° shoulder extension in all physiotherapist positions. Kneeling and sitting positions demonstrated most of the task time was spent between 45-90° shoulder flexion; kneeling demonstrated 95% and sitting 73% of task time in region 3 (Figure 5.85A, C). Sitting demonstrated the greatest proportion of the task time spent over 90° shoulder flexion; with an average of 7% of the task time spent in region 4. Standing demonstrated more task time spent between 20° shoulder extension to 45° shoulder flexion (total average of 79% in range 2 and 3). Standing and kneeling showed minimal task time was spent over 90° shoulder flexion (average of 1% task time for each position). Sitting and kneeling positions demonstrate the largest proportion of walking task time spent in higher scoring RULA regions and therefore increased potential risk of WRMSD.

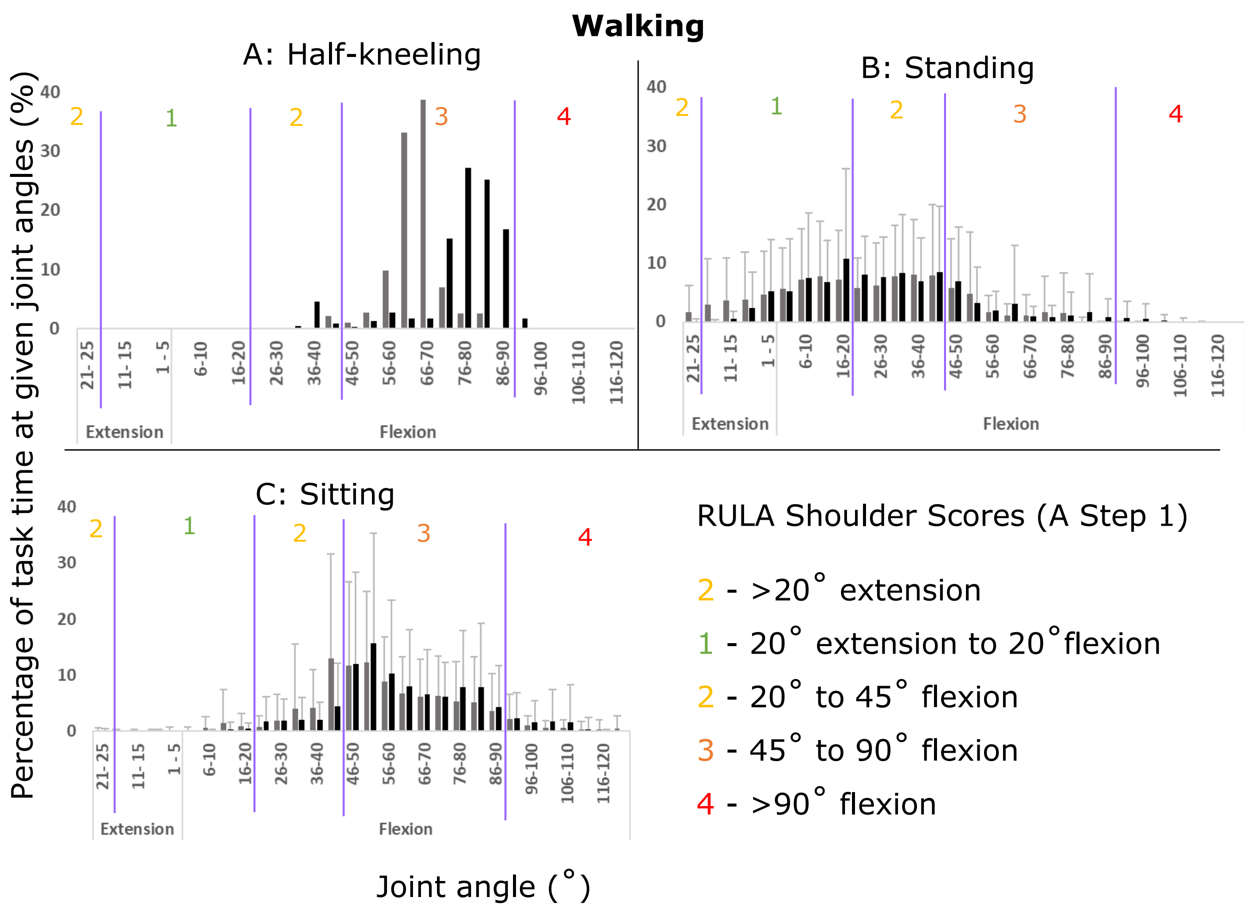


Figure 5.85: Shoulder flexion during walking tasks with RULA scores for A: half-kneeling, B: standing and C: sitting

Shoulder Flexion and Extension Summary

The RULA tool was used as a guide for crude estimation of WRMSD risk of physiotherapist shoulder postures during patient handling tasks. The method of processing and analysing physiotherapist movement initially in this study fitted with the joint ranges stated in the RULA. The RULA joint ranges and associated scores were placed over the previously used shoulder joint movement graphs. Sitting was highlighted as a position that had potential to score higher when assessing shoulder posture with the RULA in four patient handling tasks: sit-to-stand, trunk, standing and walking. Half-kneeling showed potential to score higher for shoulder postures with the RULA during lie-to-sit, lower limb, and walking tasks.

Shoulder Abduction

The other main shoulder movement that is discussed in the ergonomics literature is shoulder abduction (Finsen et al. 1998). However, this movement is not considered alone in the RULA. When assessing working postures with the RULA the posture score is increased by one point when shoulder flexion is combined with shoulder abduction. To allow for analysis of shoulder abduction position the joint angle data was compared against Finsen et al's (1998) findings, which suggest increased risk of injury over 30° shoulder abduction for >33% of the task time. The RULA does not state an abduction angle at which the score increases by one point. For this study, if the physiotherapists were found to exceed Finsen's shoulder abduction threshold, there is increased potential for them to score higher if their posture was assessed with the RULA. The time of the patient handling tasks for the left and right shoulders was calculated separately against Finsen's threshold. Only the patient handling tasks and positions that exceeded 33% of the task over 30° abduction and these are described here.

When assisting patients from lie-to-sit, physiotherapists in kneeling, half-kneeling and standing positions exceeded 30° shoulder abduction for more than 33% of the task time with at least one shoulder. When in kneeling, the left arm spent 42% task time over 30° shoulder abduction (Figure 5.86A). When in half-kneeling, the right upper limb spent 37% and the left upper limb 35% of the task time over 30° shoulder abduction (Figure 5.86B). When in standing, only the right arm exceeded the threshold with 44% of the task time (Figure 5.86C). The shoulder asymmetry found when in kneeling and standing positions could be due to physiotherapist preference, handedness or position in relation to the patient. The physiotherapist varied in position in relation to the patient during lie-to-sit tasks meaning identification of a pattern was more challenging.

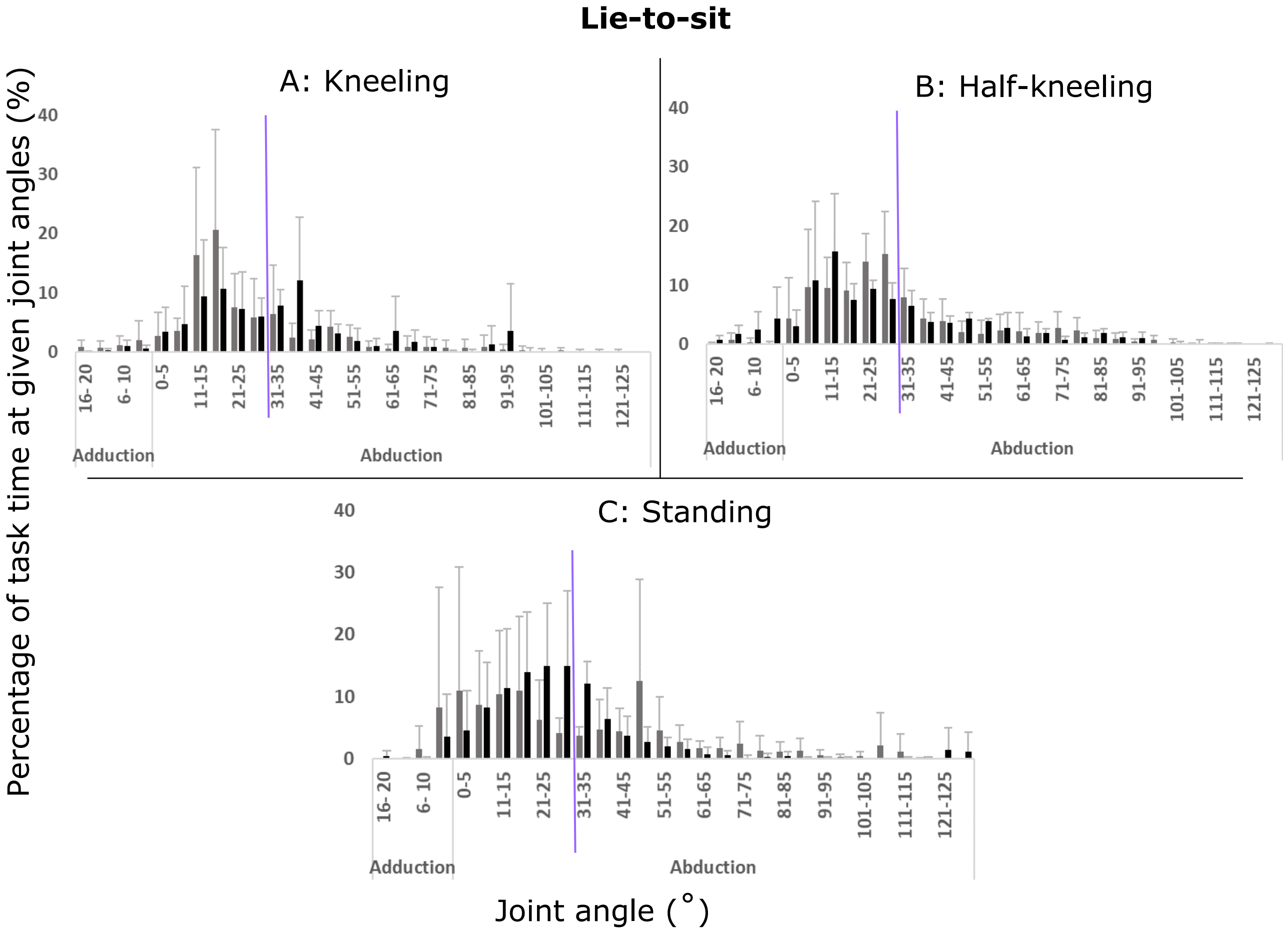


Figure 5.86: Shoulder 30° abduction threshold (purple line) during lie-to-sit tasks in A: kneel, B: half-kneeling and C: standing positions

When assisting patients from sit-to-lie, only physiotherapists in a standing position were found to exceed the set threshold. The physiotherapist's right shoulder showed 33% of the task time was spent over 30° shoulder abduction. In contrast, the left upper limb only spent 7% of the task time over 30° (Figure 5.87). The increased time spent in shoulder abduction at the right shoulder could be due to the physiotherapist reaching across and over the patient with their right arm. The physiotherapist was positioned to the right of the patient and reached over with their right arm to the patient's left shoulder, which would require shoulder abduction.

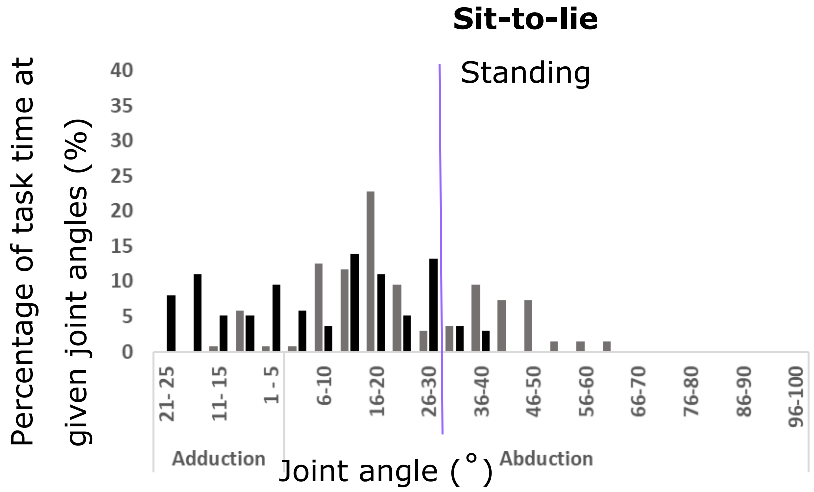


Figure 5.87: Shoulder 30° abduction threshold (purple line) during a sit-to-lie task in a standing position

When treating patients' lower limbs, only physiotherapists in the half-kneeling position exceeded the set threshold. The right shoulder spent 38% of the task time over 30° shoulder abduction (Figure 5.88). Although it did not meet the threshold, the left upper limb spent 31% of the task over 30° abduction. Most of the physiotherapists facilitating lower limb tasks in half-kneeling were positioned to the left of the patient (n=9). This position would require the physiotherapist to reach over with their right arm to facilitate the patient's movement, therefore requiring greater time spent in shoulder abduction.

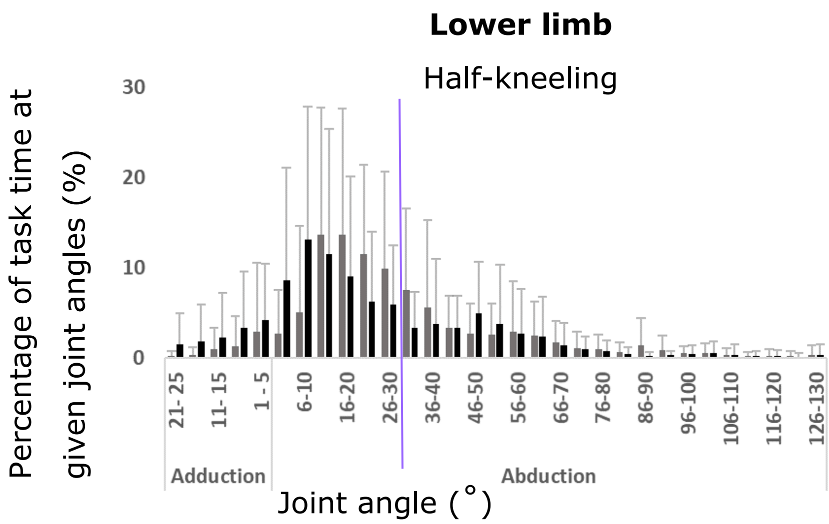


Figure 5.88: Shoulder 30° abduction threshold (purple line) during lower limb treatments task in half-kneeling

When facilitating trunk tasks; kneeling and sitting positions exceeded the 30° shoulder abduction threshold for 37% of the task time in kneeling for the right shoulder (Figure 5.89A) and 34% of the task time in sitting for the left shoulder (Figure 5.89B). The physiotherapists' other shoulders did not meet the threshold but did spend 30% of the task over 30° for both positions.

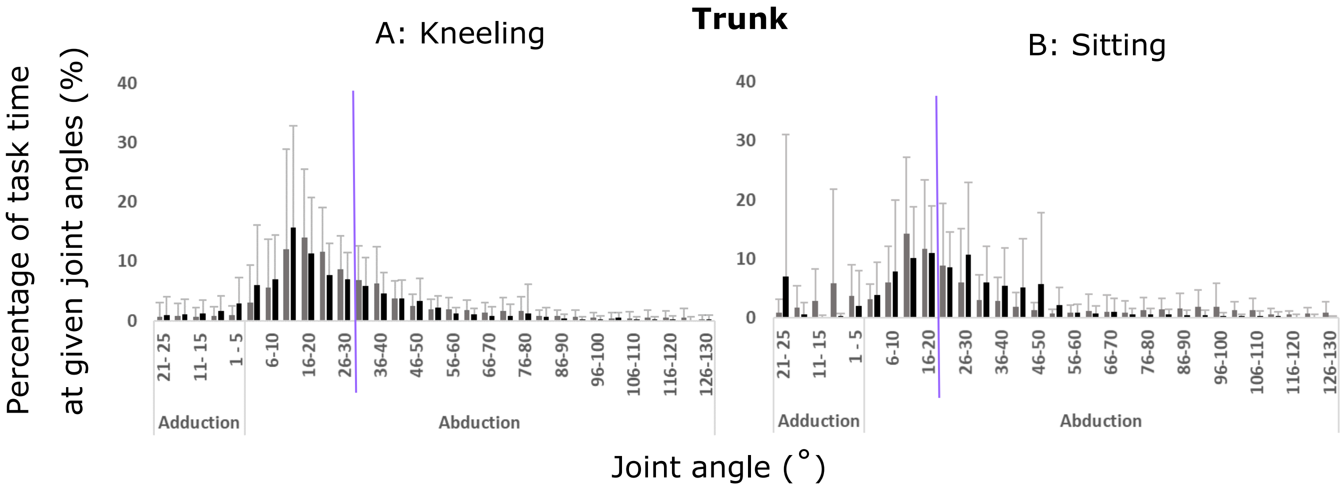


Figure 5.89: Shoulder 30° abduction threshold (purple line) during trunk treatments task in A: kneeling and B: sitting positions

During facilitation of standing tasks, all four physiotherapist positions and both shoulders were found to exceed the shoulder abduction threshold. Kneeling showed 51% of the task time on the right and 41% of the task time on the left was spent over 30° shoulder abduction (Figure 5.90A). Half-kneeling showed 100% of the task on the right and 99% of the task time on the left was spent over 30° shoulder abduction (Figure 5.90B).

Standing showed 41% of the task time during trunk facilitation tasks was spent over 30° shoulder abduction on the right and 48% of the task time on the left (Figure 5.90C) Sitting demonstrated 57% of the task time was spent over 30° shoulder abduction on the right and 43% of the task time on the left (Figure 5.90D). The physiotherapists were often observed to reach to the patients with both arms to the patient. The position required internal rotation and abduction of the physiotherapists' shoulders to reach and support at the patients' hips, trunk or lower limbs.

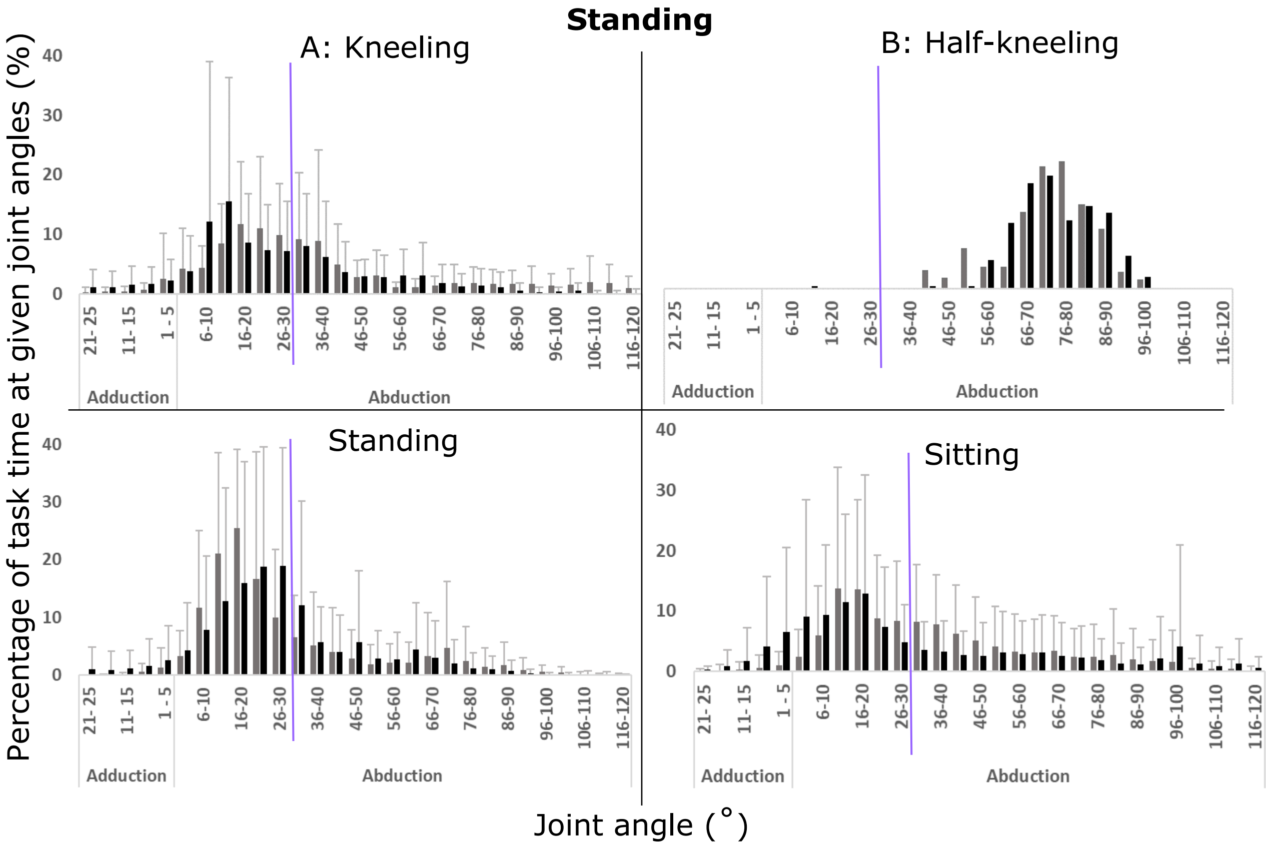


Figure 5.90: Shoulder 30° abduction threshold (purple line) during standing treatments in A: kneeling, B: half-kneeling, C: standing and D: sitting positions

Facilitation of walking tasks in half-kneeling, standing and sitting positions exceeded the set shoulder abduction threshold. When in half-kneeling, the right shoulder spent 98% of the task and the left spent 80% of the task time over 30° abduction (Figure 5.91A). When in standing, only the right shoulder exceeded 33%, with 41% of the task time abducted over 30° (Figure 5.91B). When sitting both the left and right shoulders exceeded 33% of the task time with 39% of the task abducted over 30° (Figure 5.91C).

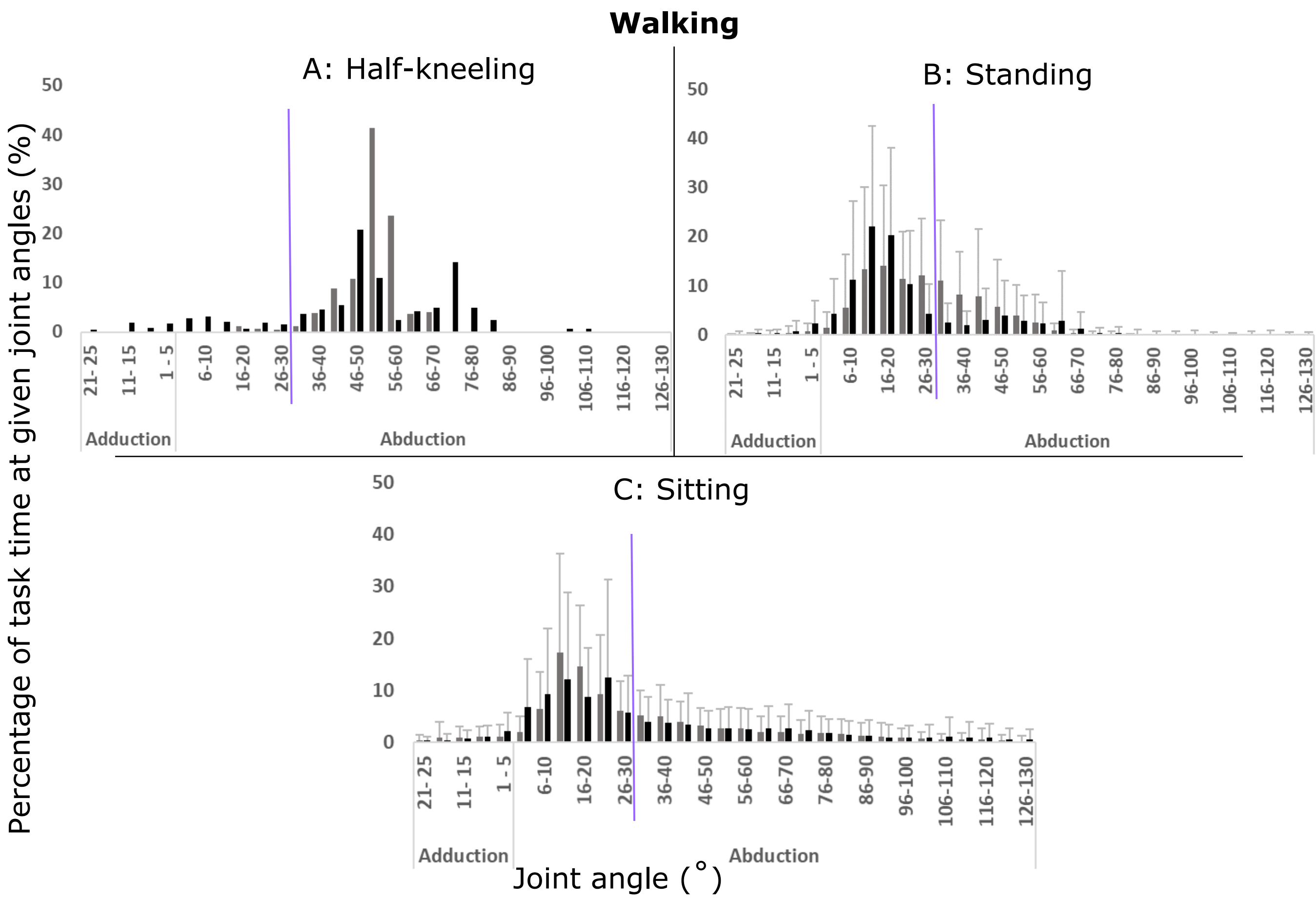


Figure 5.91: Shoulder 30° abduction threshold (purple line) during walking treatments in A: half-kneeling, B: standing and C: sitting positions

In summary, when the physiotherapists were sitting, the shoulders were often in region 3 as assessed by the RULA ergonomic tool. In addition, the shoulders exceeded 90° flexion for >10% of the task time when seated during sit-to-stand and trunk treatments. The shoulder was also found to exceed 33% of the task time over 30° abduction during trunk tasks when the physiotherapists were sitting. If grading the sitting position against the RULA tool, the physiotherapist could score higher due to the amount and combination of shoulder flexion and abduction.

The other tasks and positions to exceed the 10% task time spent over 90° flexion threshold, was during trunk treatments when in half-kneeling and sitting positions. Half-kneeling also showed higher scoring for shoulder flexion during facilitation of lie-to-sit and walking. Half-kneeling was also found to exceed the set abduction threshold during lie-to-sit tasks. Standing tasks exceeded the shoulder abduction threshold for all positions. However, when comparing shoulder flexion to RULA scoring, kneeling and sitting showed a higher pattern of scoring. Many patient tasks scored higher against RULA and also exceeded the abduction threshold; this combination of movements would add a point to the RULA tool score suggesting increased risk of injury. These tasks are summarised in Table 5.4.

Table 5.4: Summary of combined shoulder flexion and abduction tasks that scored highly with the RULA tool

Position	Patient task
Kneeling	Lie-to-sit Trunk
Half-kneeling	Lie-to-sit Lower limb
Standing	Sit-to-lie
Sitting	Trunk Standing Walking

5.14.2 Neck Posture

The main neck movement discussed in the literature is flexion (Andersen et al. 2003; Ariëns et al. 2001; Delleman and Dul 2007; Vieira and Kumar 2004). Table 5.5 summarises the RULA scoring system for neck postures of increased risk of WRMSD at the neck. The RULA scores are then applied to the physiotherapist movement as described previously in this thesis (section 4.13.2). Application of the RULA scores to the physiotherapist neck postures allowed for crude RULA scoring and suggestion of patient tasks and physiotherapist positions that would score higher.

Table 5.5: Neck ergonomic positions of potential risk

Source **RULA**	**Joint position (˚)**	**Time of day/task** **Score**
(Middlesworth, 2021)	0-10 flexion	1
	10-20 flexion	2
	>20 flexion	3
	Extension	4

Lie-to-sit Facilitation

During facilitation of lie-to-sit tasks, kneeling and half-kneeling positions showed potential to score higher than when the physiotherapists were standing due to the larger time in an extended neck posture (Figure 5.92A, B). Kneeling and half-kneeling spent 91% and 98% of the task time respectively with the neck in extension (region 4). Standing spent 63% of lie-to-sit tasks with the neck in extension (region 4). Standing demonstrated more time of the task was spent between neutral to 20˚ neck flexion than the other physiotherapist positions; with 37% of the task time spent in regions 1 and 2 (Figure 5.92C). Kneeling and half-kneeling spent 9% and 2% of the task time in regions 1 and 2 respectively. Kneeling and half-kneeling positions place the physiotherapist lower down than the patient who was positioned on the bed and therefore require increased neck extension than the standing position.

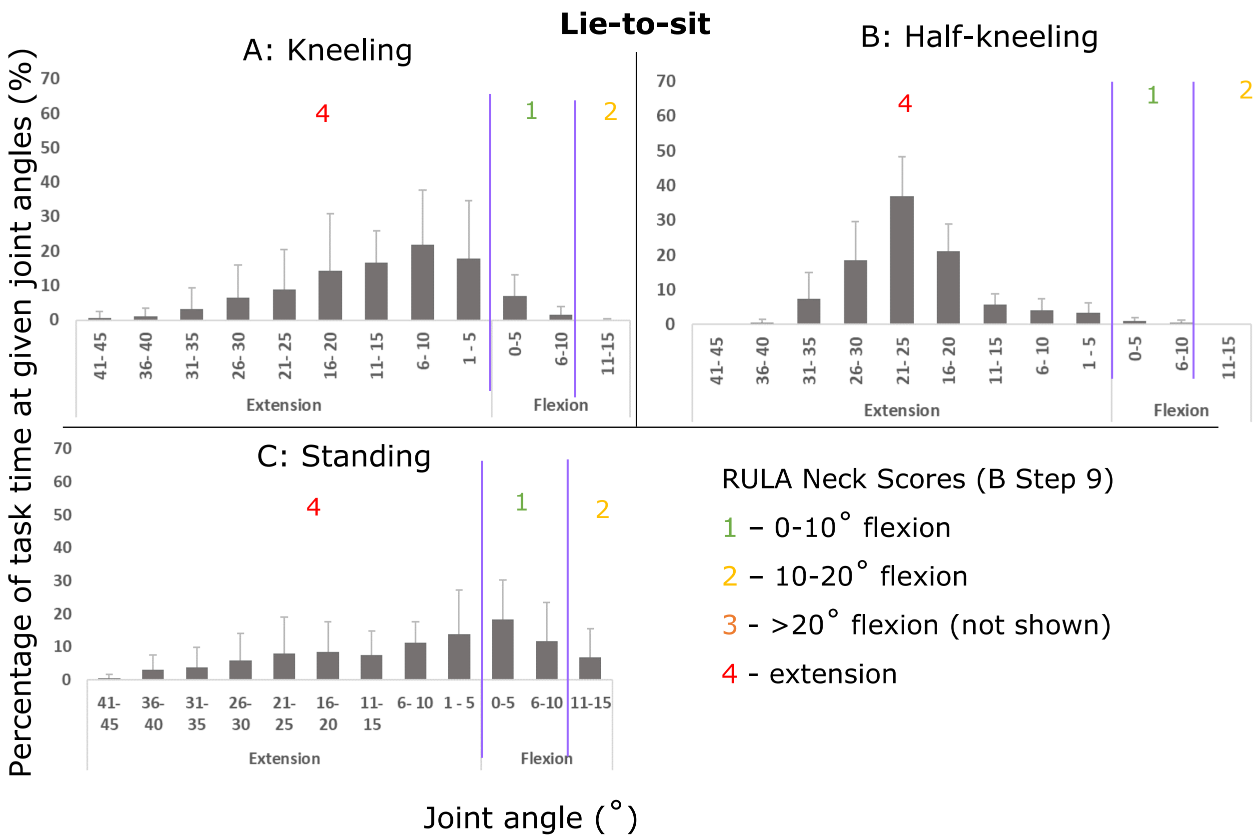


Figure 5.92: Neck position during lie-to-sit with RULA scores for A: kneeling, B: half-kneeling and C: standing positions

Sit-to-lie Facilitation

When facilitating sit-to-lie tasks the physiotherapists' necks were mostly extended. Kneeling showed 89% of the task time and standing showed 99% of the task time was spent in extension (RULA region 4) (Figure 5.93A, B). Kneeling showed more time between neutral and 10° flexion (10 % in RULA region 1) than standing (1% in RULA region 1). The neck extension found when standing is contrasting to other patient tasks performed in standing, where the neck spent more time closer to neutral and slight neck flexion. The physiotherapists' trunk posture could affect the amount of neck extension required for this recording.

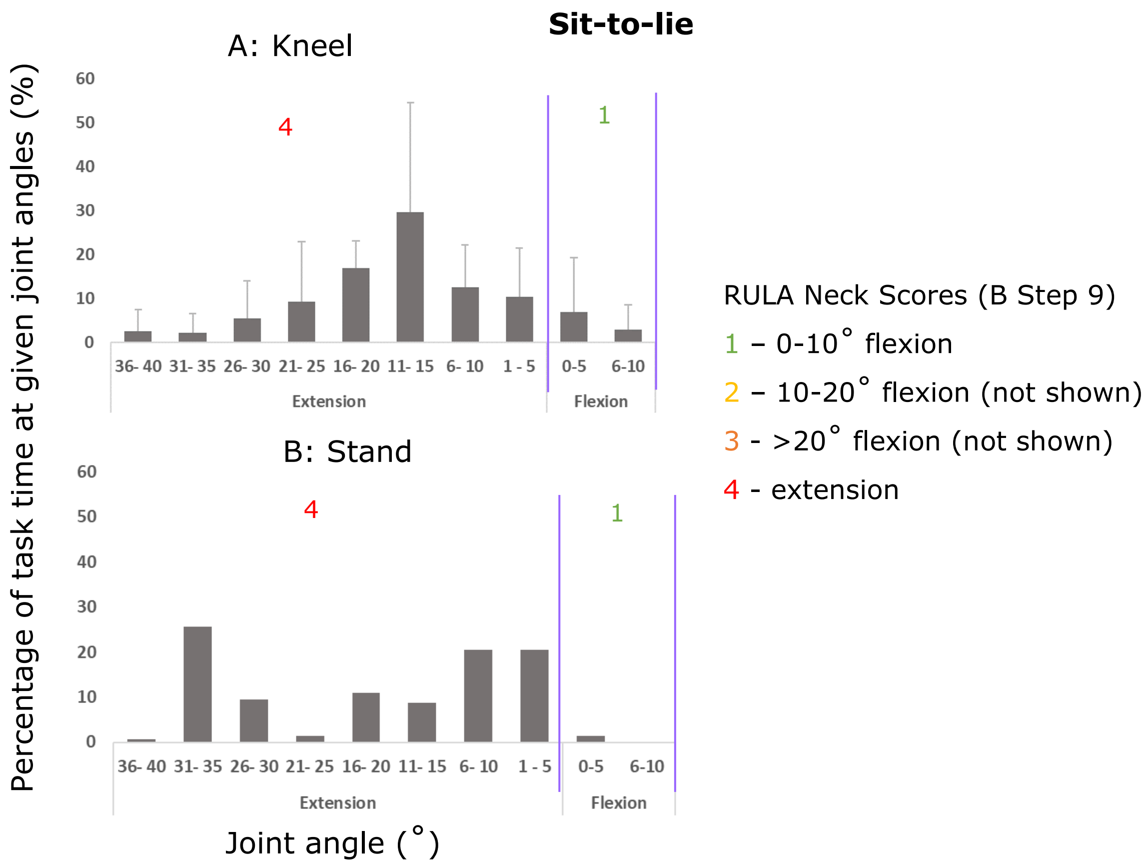


Figure 5.93: Neck position during sit-to-lie with RULA scores for A: kneeling and B: standing positions

Sit-to-stand Facilitation

When facilitating sit-to-stand in a standing position, more task time was spent between neutral to 20° neck flexion (43 % in regions 1 and 2) (Figure 5.94C) compared to the other physiotherapist positions. Sitting showed the least time in regions 1 and 2 (6% of task time) (Figure 5.94D) and therefore had potential to score higher when using the RULA scale. Kneeling, half-kneeling and sitting positions showed most of the task time was spent with an extended neck; 83%, 89% and 94% of the task time in RULA region 4 respectively (Figure 5.94A, B, D). Standing would be expected to have the least extension as the patient would be closer in height to the physiotherapist, requiring neutral to slight neck flexion. Kneeling, half-kneeling and sitting positions would position the patient above the physiotherapist and neck extension would be maintained if looking up to the patient or other staff member during facilitation of sit-to-stand.

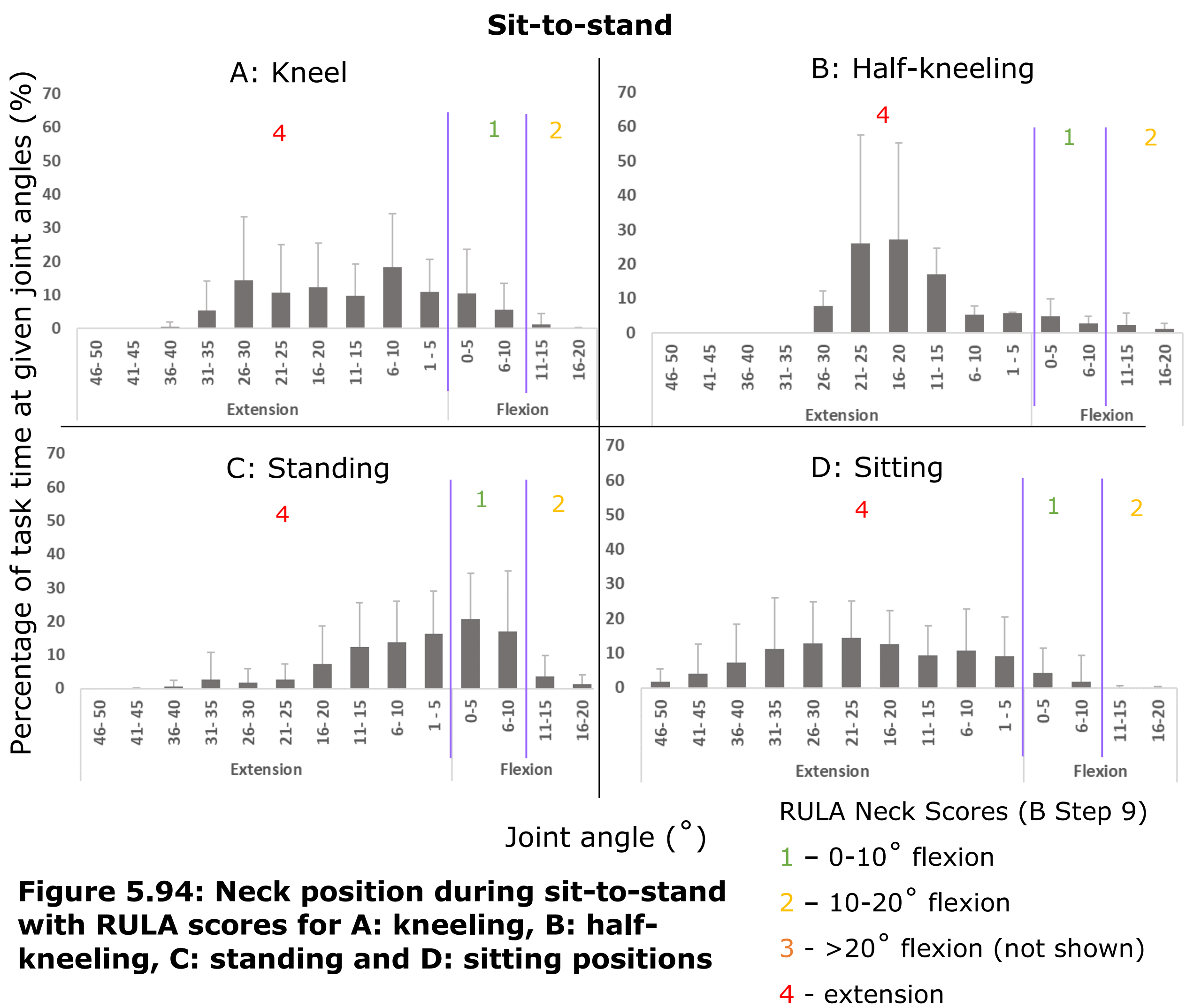
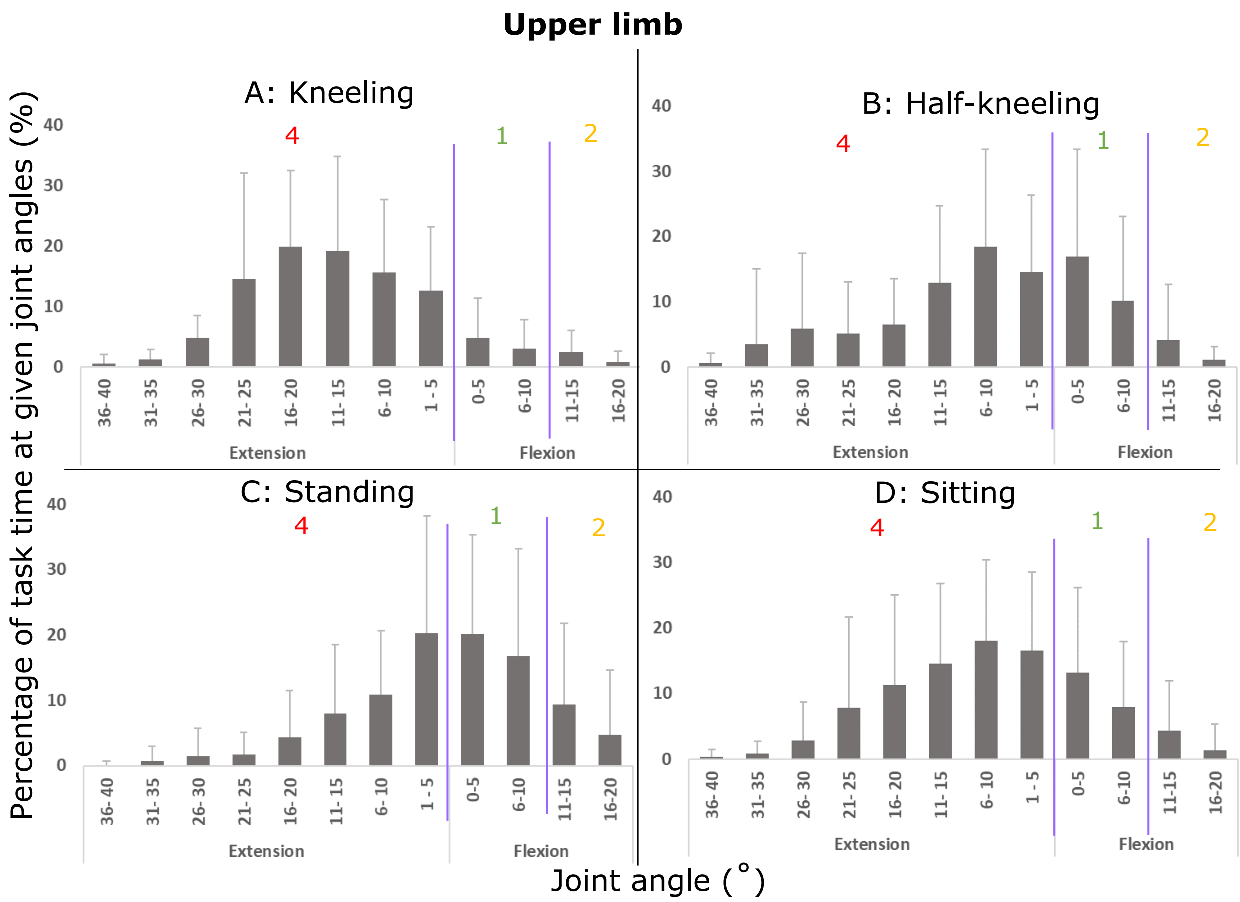


Figure 5.94: Neck position during sit-to-stand with RULA scores for A: kneeling, B: half-kneeling, C: standing and D: sitting positions

Upper Limb Facilitation

Facilitation of upper limb tasks showed kneeling, half-kneeling and sitting positions spent most of the task time in neck extension (RULA region 4) (Figure 5.95A, B, D). Kneeling demonstrated 11% of the task time was spent between neutral to 20° neck flexion; this time was the least of all physiotherapist positions spent in RULA regions 1 and 2. Standing showed the least task time in an extended position (48% of the task time in RULA region 4) compared to the other physiotherapist positions during facilitation of upper limb tasks. The physiotherapists were standing beside the patients when facilitating upper limb tasks which would reduce the amount of neck extension required. Some neck extension may remain when standing as compensation from the physiotherapists' trunk posture.



RULA Neck Scores (B Step 9)

1 – 0-10° flexion

2 – 10-20° flexion

3 - >20° flexion (not shown)

4 - extension

Figure 5.95: Neck position during upper limb treatments with RULA scores for A: kneeling, B: half-kneeling, C: standing and D: sitting positions

Lower Limb Facilitation

When facilitating lower limb tasks, kneeling, half-kneeling and sitting positions showed similar patterns of task time spent in each RULA scoring region (Figure 5.96A, B, D). Most of lower limb tasks were spent with the neck extended for all physiotherapist positions (RULA region 4). Standing showed 27% of the task time was spent between neutral to 20° neck flexion (RULA regions 1 and 2)

(Figure 5.96C); this is a larger proportion of the task time than the three other physiotherapist positions in the RULA regions. All physiotherapist positions showed potential to have higher scores with the RULA scoring system for neck postures during facilitation of lower limb tasks.

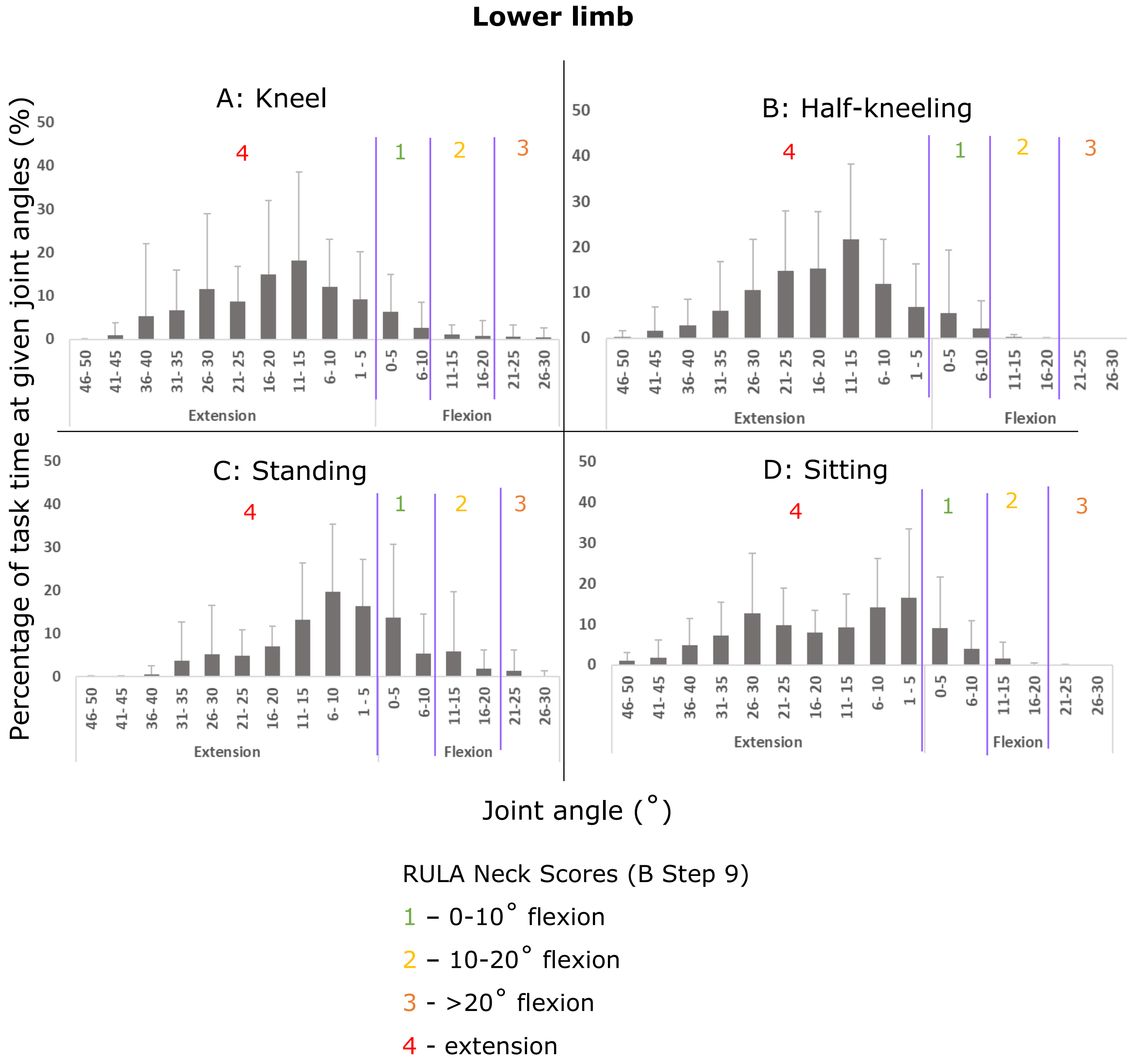


Figure 5.96: Neck position during lower limb treatments with RULA scores for A: kneeling, B: half-kneeling, C: standing and D: sitting positions

Trunk Facilitation

During facilitation of trunk tasks, kneeling, half-kneeling and sitting positions showed a similar pattern of task time in RULA scoring regions for neck posture. Kneeling spent 87% of the task, half-kneeling 86%, and sitting 86% of the task time in neck extension (RULA region 4) (Figure 5.97A, B, D). Standing demonstrated most of the task time was spent in neck extension (61% task time in RULA region 4). However, standing also demonstrated the most time spent between neutral to 10˚ neck flexion of all physiotherapist positions (30% task time in RULA region 1) (Figure 5.97C). If assessing physiotherapist posture with the RULA during facilitation of trunk tasks, all physiotherapist positions demonstrate potential to have higher scores due to most of the task time spent in region 4.

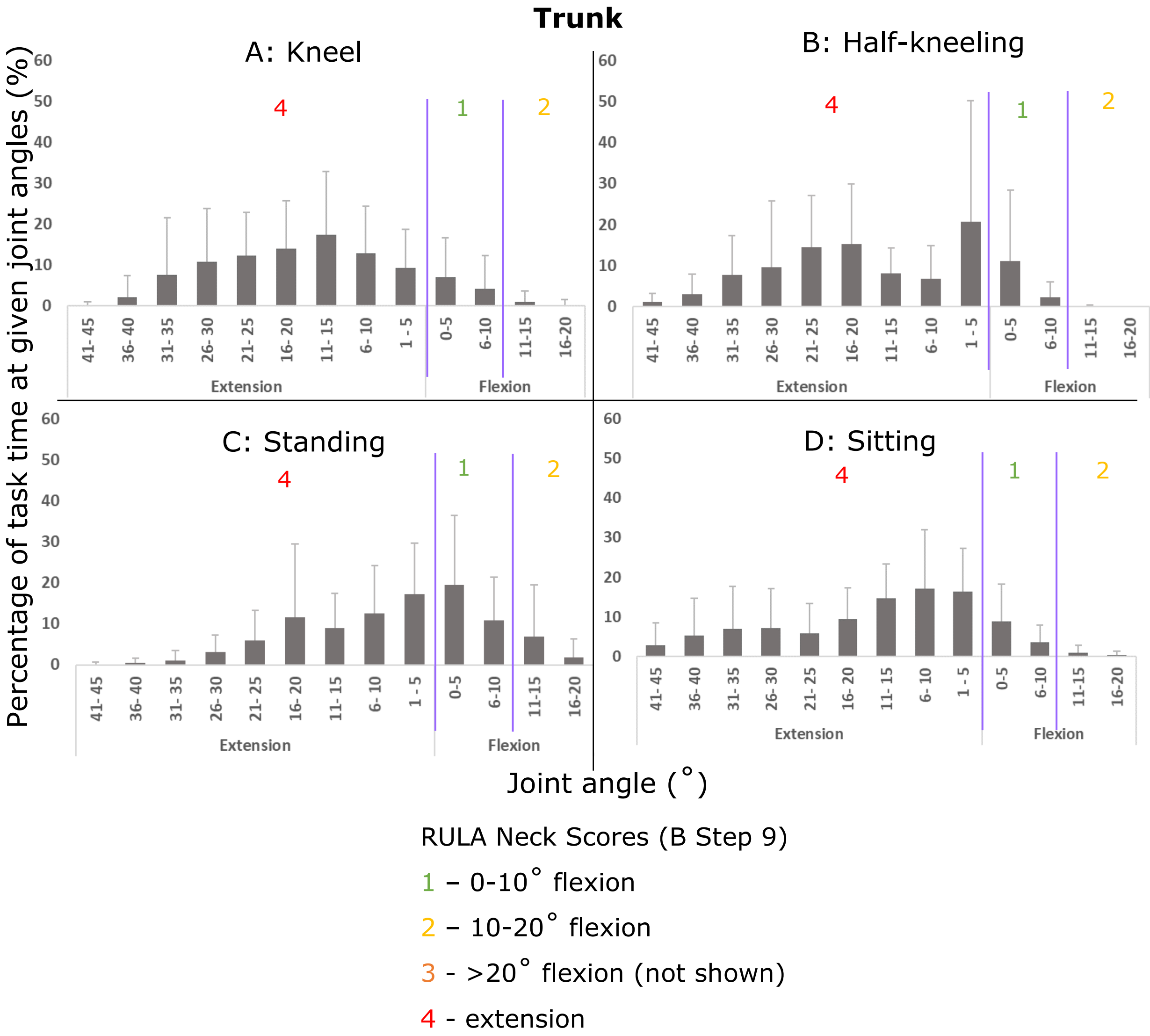


Figure 5.97: Neck position during trunk treatments with RULA scores for A: kneeling, B: half-kneeling, C: standing and D: sitting positions

Standing Facilitation

During facilitation of standing tasks, kneeling and sitting showed a similar pattern of time of the task within the RULA scoring regions. Both kneeling and sitting positions showed most of the task time was spent in neck extension (RULA region 4); 85% of the task time when kneeling and 91% of the task time in sitting (Figure 5.98A, D). Standing demonstrated 68% of standing tasks was spent in neck extension (RULA region 4) (Figure 5.98C). In contrast to other patient facilitation tasks, half-kneeling showed more task time was spent between neutral to 10° neck flexion with 47% of the task time spent in RULA region 1 (Figure 5.98B). The time spent near neutral neck posture when in half-kneeling could be due to the physiotherapist half-kneeling to the left of the patient with one leg on the plinth. If the plinth were raised, the physiotherapist could be closer to the standing height of the patient and would not require as much neck extension. However, standing demonstrated more task time was spent in neck extension than half-kneeling, the physiotherapists were potentially extending more at the neck to compensate for trunk posture. If assessing physiotherapist postures with the RULA tool, kneeling, standing and sitting show potential to have higher scores when facilitating standing due to the proportion of time spent with the neck extended.

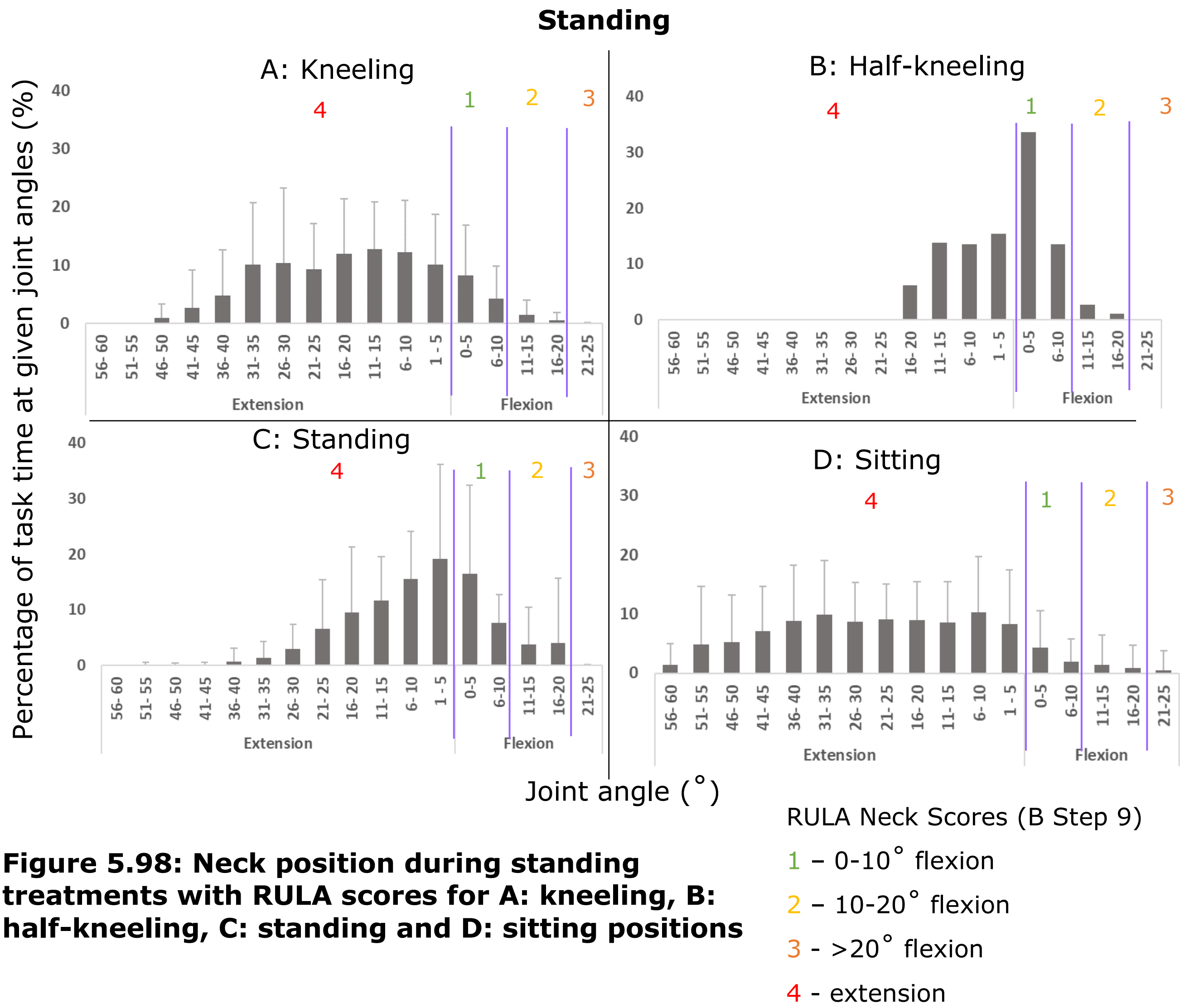


Figure 5.98: Neck position during standing treatments with RULA scores for A: kneeling, B: half-kneeling, C: standing and D: sitting positions

Walking Facilitation

Facilitation of walking from half-kneeling and sitting positions demonstrated most of the task time was spent in neck extension (RULA region 4); 98% of the task in half-kneeling and 97% of the task in sitting (Figure 5.99A, C). Standing showed more of the walking task time was spent between neutral to 10° neck flexion (46% of task time in RULA region 1), with 41% of the task spent extended (RULA region 4) (Figure 5.99B). Half-kneeling and sitting positions had potential to have higher scores if assessing physiotherapist posture with the RULA tool due to the large proportion of walking facilitation tasks spent with the neck extended.

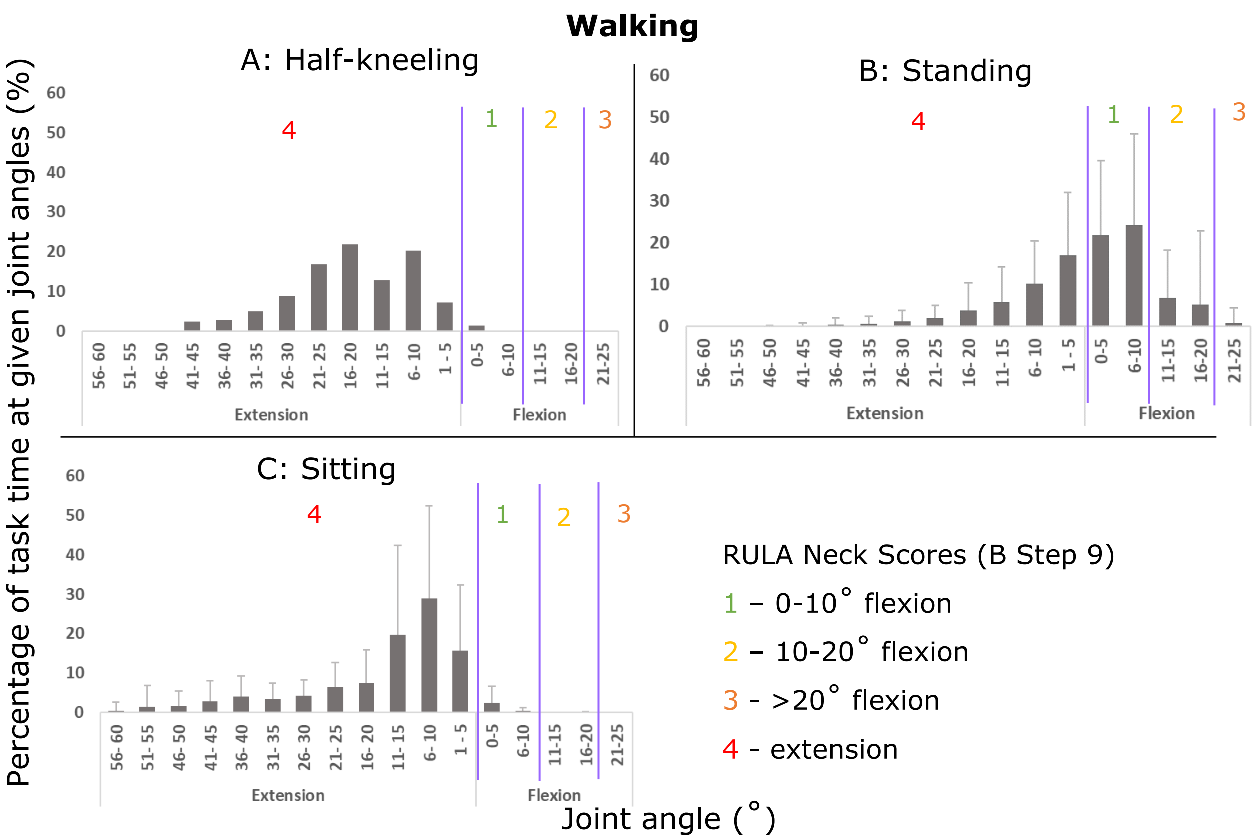


Figure 5.99: Neck position during walking treatments with RULA scores for A: half-kneeling, B: standing C: sitting positions

Summary

Most of the facilitation tasks had potential to score highly using the RULA tool due to the number of tasks and positions in which the neck was extended (RULA region 4). Facilitation of upper limb tasks showed more time in lower scoring RULA regions than other facilitation tasks. Standing often showed more task time spent between neutral posture to neck flexion (RULA regions 1 and 2). Kneeling, half-kneeling and sitting positions frequently spent most of the task time in neck extension, which could score highly for these positions during patient handling tasks. The physiotherapists were often looking up toward the patient for communication and monitor for pain or discomfort. Therefore, depending on the physiotherapist position in relation to the patient, this could require them to extend their necks to look up. Most of workplace ergonomics literature focuses on neck flexion, especially towards computers or workstations, with little mention of extension. This contrast with ergonomic tools which give more attention to neck extension, scoring it as high risk, especially when compared to standing (Kee and Karwowski 2001).

5.14.3 Trunk Posture

Assessing physiotherapist trunk position in relation to ergonomics literature and assessment tools is more complicated than for the shoulder and neck. Often in the literature and assessment tools, the trunk is referred to as a single segment rather than separate regions of the spine. The most frequently stated trunk postures of risk are >20° and >60° flexion, and are shown in Table 5.6 (RULA, Hoogendoorn et al. 2000; Kee and Karwowski 2001). Figure 5.100 shows an illustration of trunk flexion as referred to in literature and ergonomic assessment tools (Korshøj et al. 2014). This study measured trunk motion with the Xsens system and three of the possible five Xsens MVN Analyze trunk segments were chosen for analysis (C7/T1, T12/L1 and L5/S1).

The joint motion for each segment has been displayed with the RULA trunk scoring to show the time of the task in each assessment region as displayed in Table 5.6. The highest scoring RULA region of more than 90° trunk flexion is not illustrated in the following figures as this threshold was not reached during any of the patient handling tasks in this study. The trunk joint angles stated in the RULA are not as directly applicable to the trunk data collected in this study, however, the scoring regions provide a general assessment of physiotherapist trunk positions for each task and position.

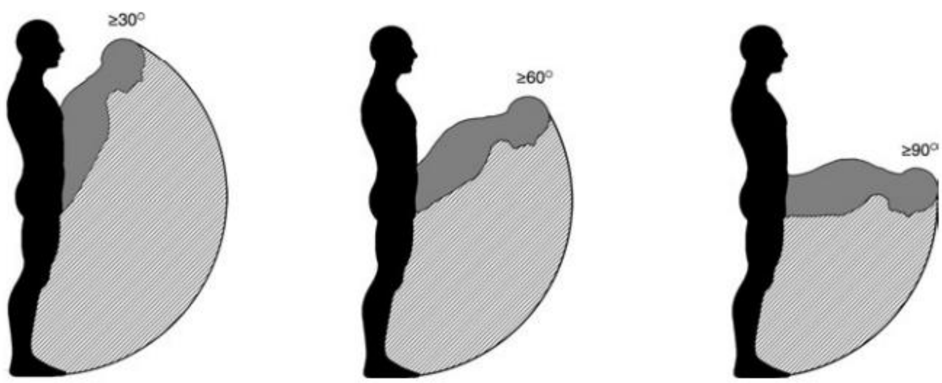


Figure 5.100: Illustration of forward bending at the trunk (Korshøj et al. 2014)

Table 5.6: Trunk ergonomic positions of potential risk

Source	**Joint position (˚)**	**Time of day/task**
Ergonomics literature	≥30 flexion	>10% working day (Hoogendoorn et al. 2000)
(Hoogendoorn et al. 2000)	≥60 flexion	>5% working day (Hoogendoorn et al. 2000)
	≥30 rotation	>10% working time/day (Hoogendoorn et al. 2000)
RULA		**Score**
(Middlesworth, 2021)	Upright	1
	0-20 flexion	2
	20-60 flexion	3
	>60 flexion	4

Lie-to-sit Facilitation

During facilitation of lie-to-sit, the physiotherapist's cervicothoracic junction was mostly between neutral and 20° flexion (RULA region 2) when in kneeling and half-kneeling positions (92% and 99% of task time respectively) (Figure 5.101A, B). Standing showed 34% of the task time was spent over 20° cervicothoracic flexion (RULA region 3) (Figure 5.101C).

The thoracolumbar junction showed most of the task time was spent near neutral posture and therefore would score one or two if assessing physiotherapist posture with the RULA for all physiotherapist positions during facilitation of lie-to-sit (Figure 5.102A, B, C).

Similar to the cervicothoracic junction, the lumbosacral region showed more task time was spent between neutral to 20° flexion (region 1 and 2) when in kneeling and half-kneeling positions (Figure 5.102D, E). Standing showed 19% of the task time was spent time over 20° lumbosacral flexion. However, most of the task time was spent within region 2 (71% task time) (Figure 5.102F). When the physiotherapists facilitated lie-to-sit from standing, there was potential to score highly with the RULA due to the increased task time spent in cervicothoracic and lumbosacral flexion.

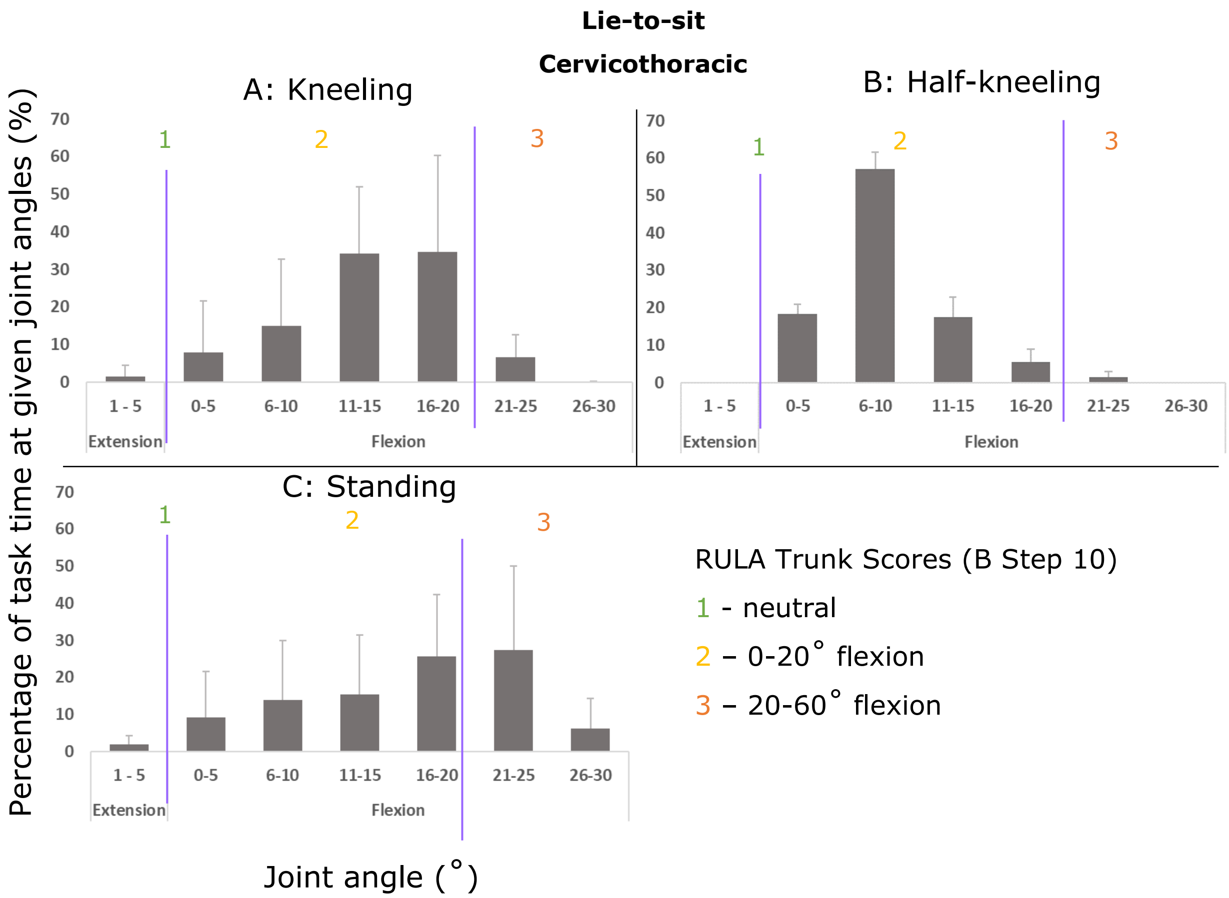
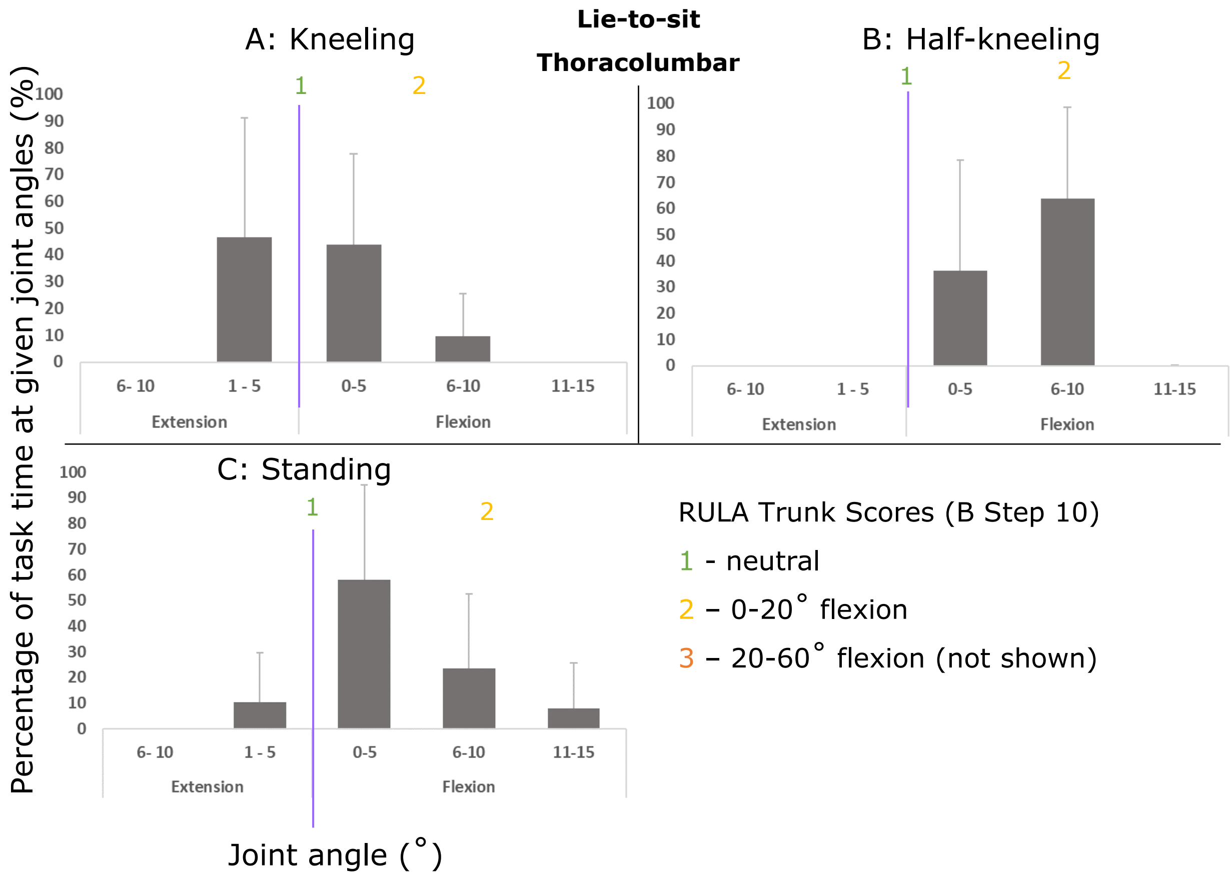


Figure 5.101: Cervicothoracic position during lie-to-sit with RULA scores for A: kneeling, B: half-kneeling and C: standing positions



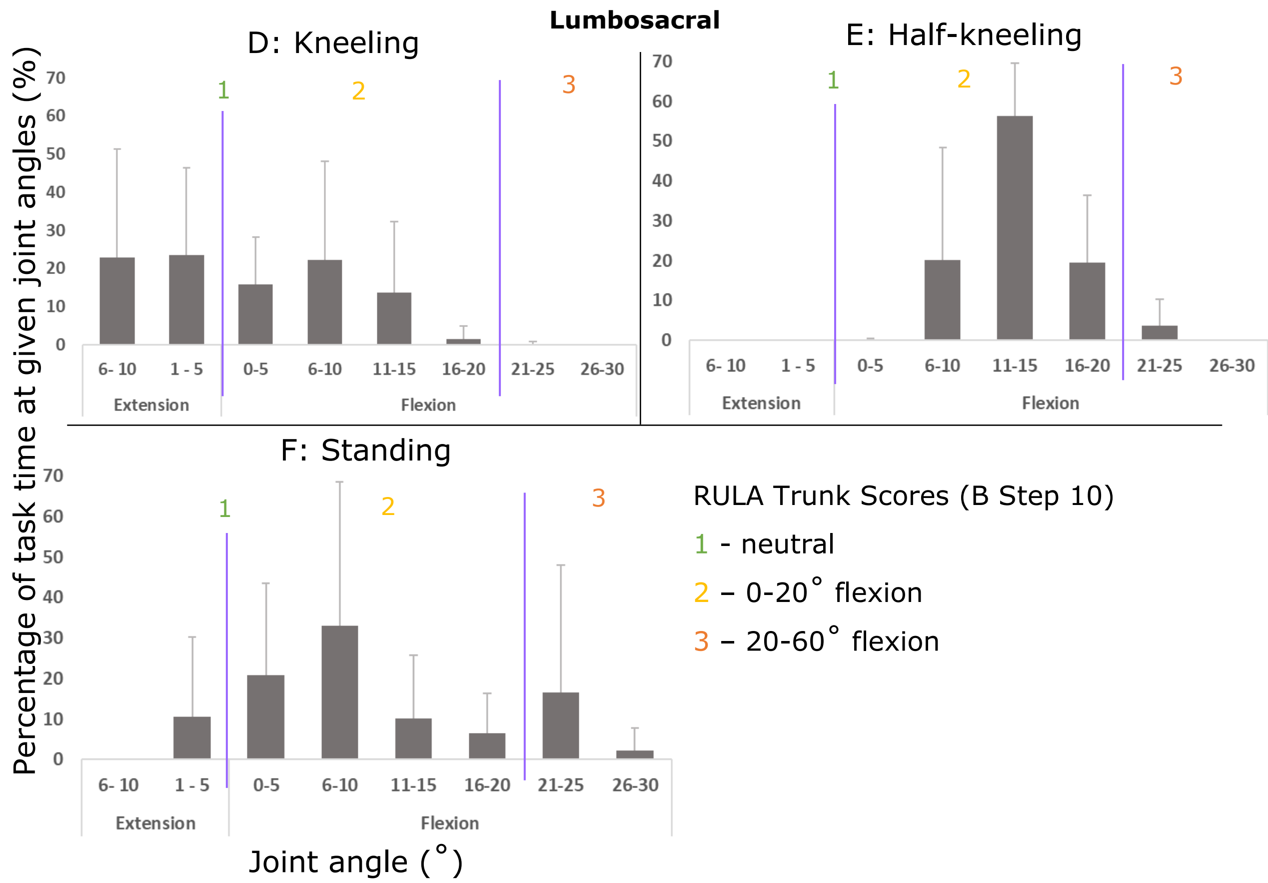


Figure 5.102: Thoracolumbar and lumbosacral positions during lie-to-sit with RULA scores for kneeling, half-kneeling and standing positions

Sit-to-lie Facilitation

When facilitating sit-to-lie, the cervicothoracic and thoracolumbar junctions spent most of the task time within neutral to 20° flexion (RULA region 2) for both kneeling and standing positions (Figure 5.103A-D). When in standing, the entirety of the task time at the lumbosacral junction was spent within neutral to 20° flexion (RULA region 2) (Figure 5.104A). Kneeling showed task time spent in lumbosacral extension; most of the task time (63% task time) was spent flexed within RULA region two (Figure 5.104B). Trunk extension is not considered in the RULA tool, therefore there is no score associated with this posture. Following the RULA tool scoring, kneeling and standing positions had potential to score similarly, with most of the task time spent scoring two with the RULA.

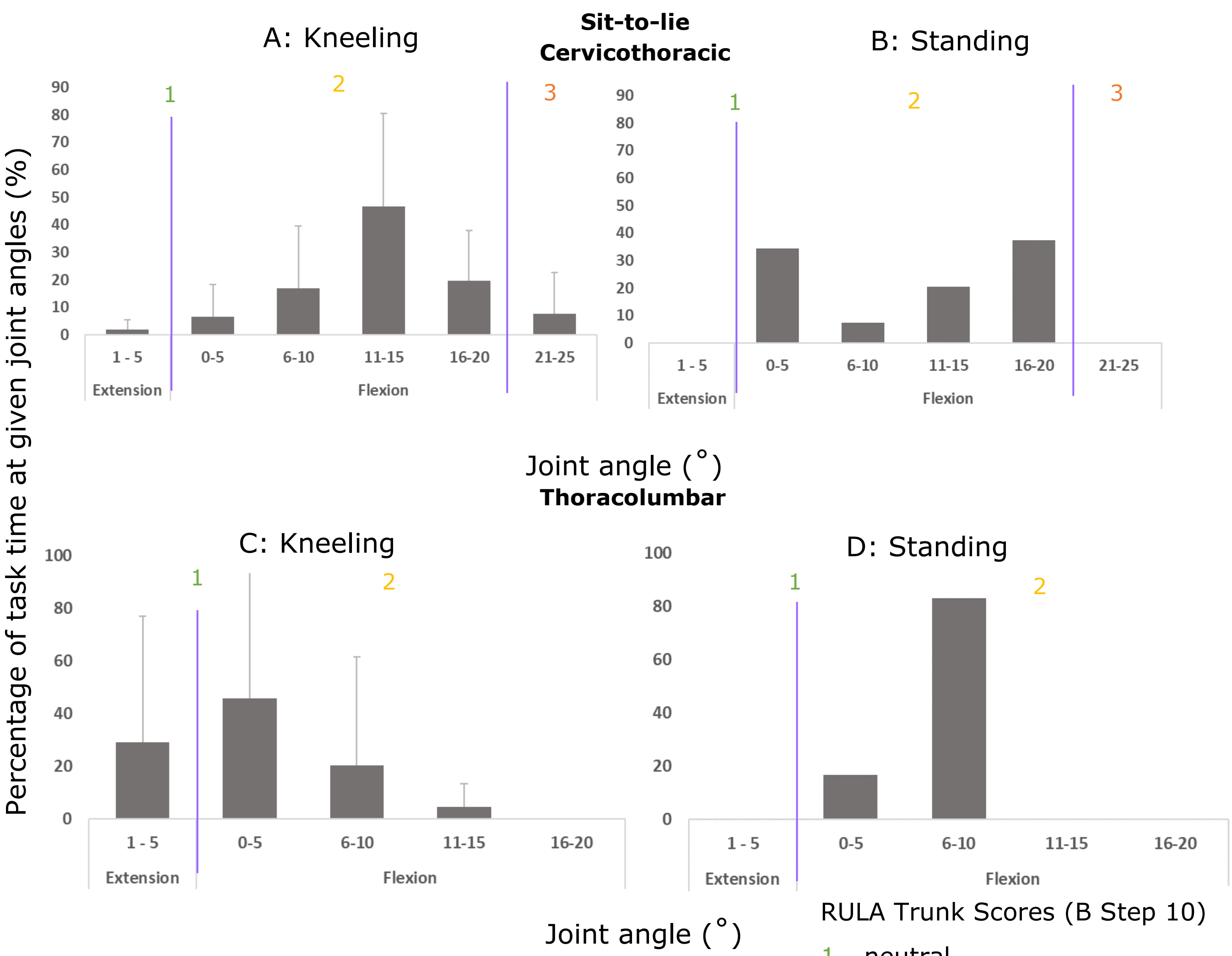


Figure 5.103: Cervicothoracic and thoracolumbar position during sit-to-lie with RULA scores for kneeling and standing positions

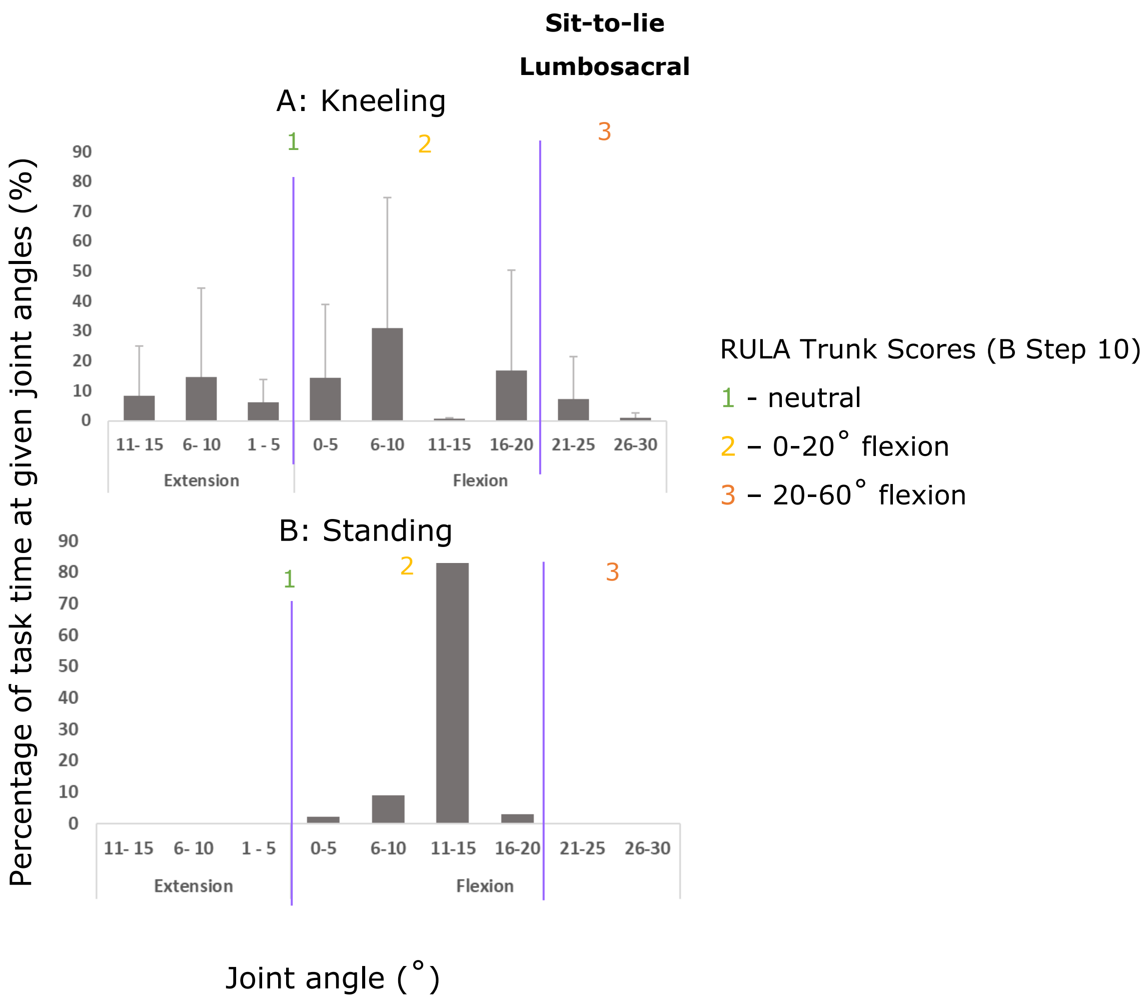


Figure 5.104: Lumbosacral position during sit-to-lie with RULA scores for A: kneeling and C: standing positions

Sit-to-stand Facilitation

When facilitating sit-to-stand from kneeling, half-kneeling and sitting positions, most of the task time was spent between neutral to 20° cervicothoracic flexion (RULA region 2) (Figure 5.105A, B, D). Kneeling showed the most time over 20° cervicothoracic flexion of kneeling, half-kneeling and sitting positions, with 15% of the task time spent in RULA region 3. Standing demonstrated the most task time spent over 20° cervicothoracic flexion of all physiotherapist positions, with 39% task time spent in RULA region 3 (Figure 5.105C).

The thoracolumbar junction showed most of sit-to-stand tasks was spent within RULA region 2 (Figure 5.106E-H). Kneeling and standing positions showed time measured in slight thoracolumbar extension (Figure 5.106E, G). However, the most extension reached was 5°, and could be considered close to a neutral posture.

The lumbosacral junction showed most of the task time was spent within RULA region 2 for all physiotherapist positions during sit-to-stand tasks. Kneeling showed slightly more lumbosacral extension than other physiotherapist positions (Figure 5.106A). Half-kneeling and sitting showed more time flexed over 20° (17% and 12% task time respectively) than kneeling and standing positions (region 3) (Figure 5.106B, D). Assessing the physiotherapists' posture with the RULA tool, facilitating sit-to-stand from a standing position showed potential to score higher at the cervicothoracic junction. Half-kneeling and sitting positions could score highly with the RULA due to the lumbosacral flexion measured.

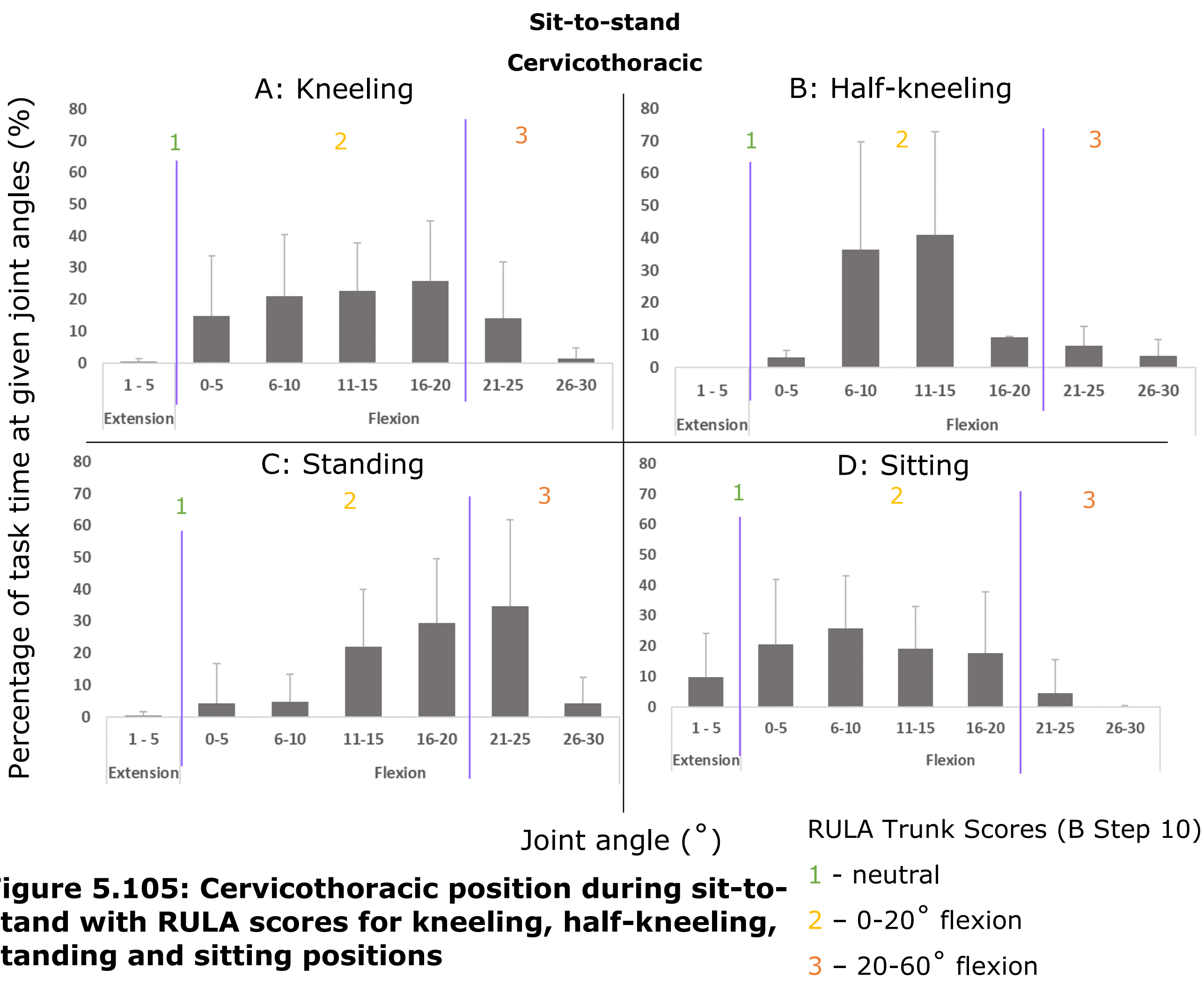


Figure 5.105: Cervicothoracic position during sit-to-stand with RULA scores for kneeling, half-kneeling, standing and sitting positions

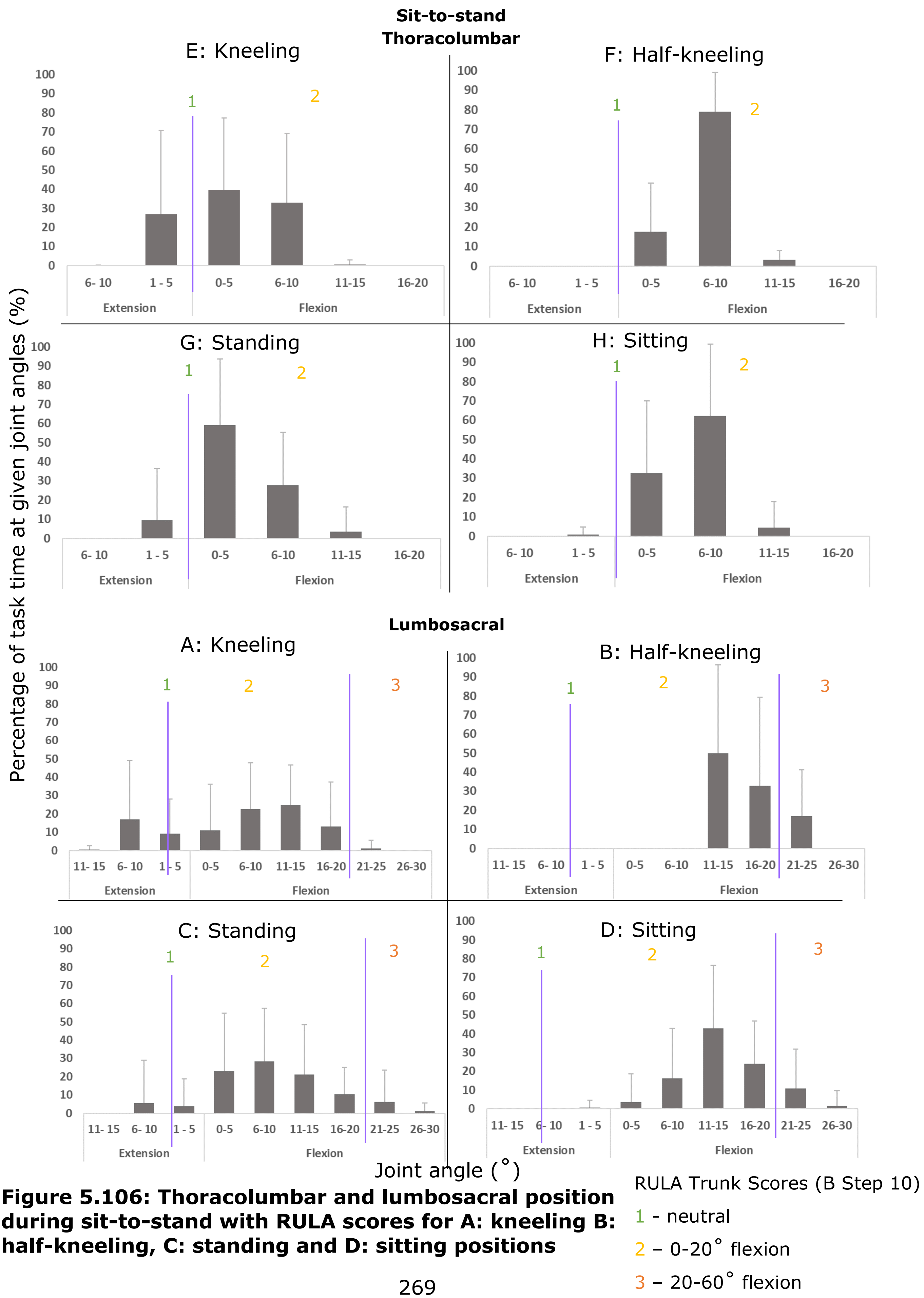


Figure 5.106: Thoracolumbar and lumbosacral position during sit-to-stand with RULA scores for A: kneeling B: half-kneeling, C: standing and D: sitting positions

Upper limb Facilitation

When facilitating upper limb tasks from kneeling, the physiotherapists demonstrated the least time spent over 20° cervicothoracic flexion (10% in RULA region 3) of all positions (Figure 5.107A). Standing demonstrated the largest percentage of the task time spent over 20° cervicothoracic flexion of all physiotherapist positions (48% task time in RULA region 3) (Figure 5.107C). The thoracolumbar region spent most of the task time between neutral to 20° flexion (RULA region 2). A small percentage of the task time was spent between neutral to 5° thoracolumbar extension. This small range of movement is close to the neutral position so would likely score low with the RULA tool.

The lumbosacral region showed more time over 20° flexion (21% task time in RULA region 3) when the physiotherapists were kneeling (Figure 5.107E). Half-kneeling, standing and sitting all showed most of the task time between neutral to 20° flexion (region 2) (Figure 5.107F, G, H). Following the RULA scoring system, standing has potential to score highly due to the increased time spent in cervicothoracic flexion and kneeling due to the increased time spent in lumbosacral flexion.

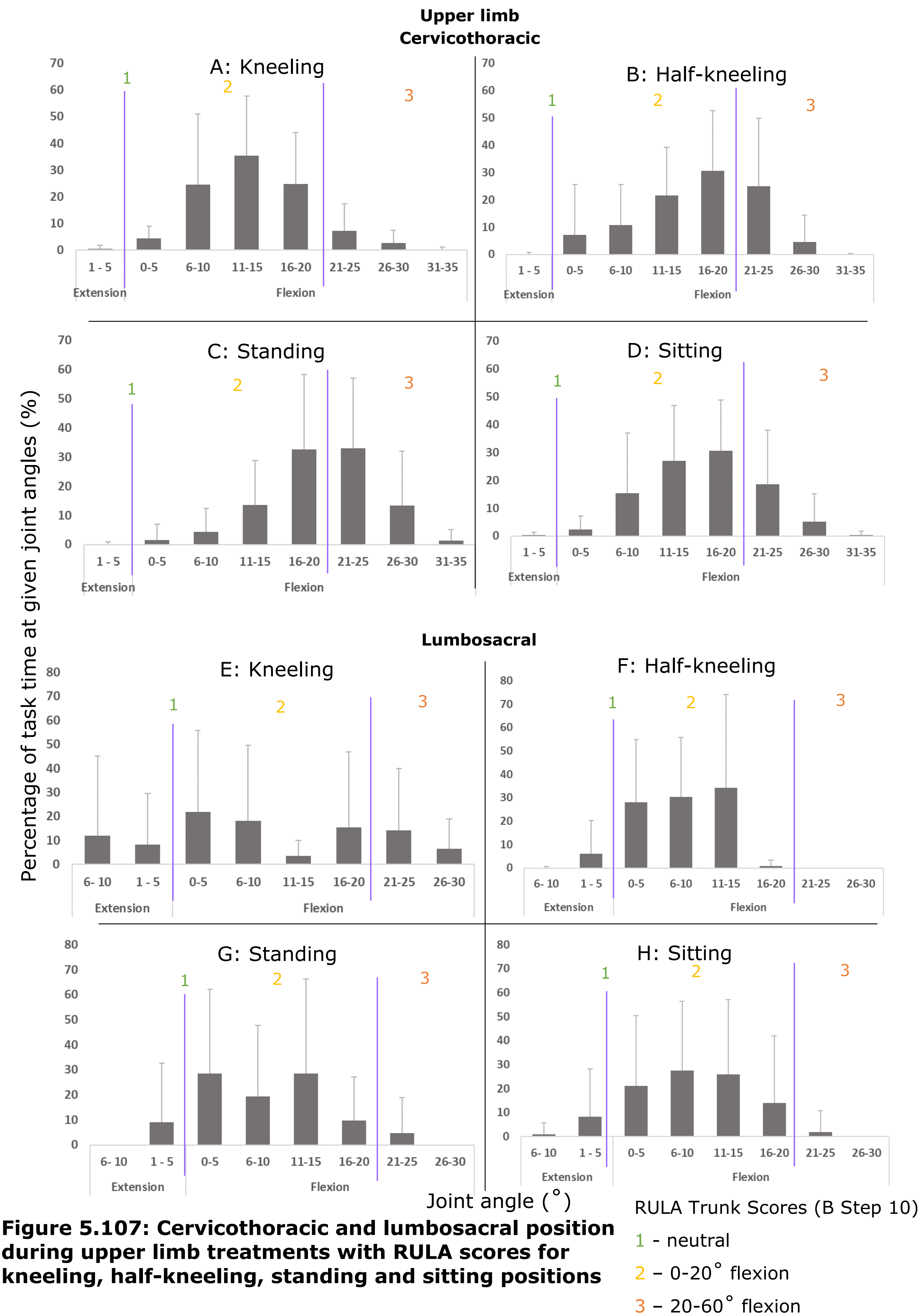


Figure 5.107: Cervicothoracic and lumbosacral position during upper limb treatments with RULA scores for kneeling, half-kneeling, standing and sitting positions

Lower Limb Facilitation

When facilitating lower limb tasks from a standing position, the cervicothoracic region spent more task time over 20° cervicothoracic flexion than the other physiotherapist positions (25% task time in RULA region 3) (Figure 5.108C). The thoracolumbar region is within RULA region two for all physiotherapist positions, and no task time was measured over 20° thoracolumbar flexion. All physiotherapist positions showed a small portion of the task time was spent over 20° lumbosacral flexion (region 3), with half-kneeling showing a larger portion of the task time (23% task time) (Figure 5.109B). Following RULA scoring, all physiotherapist positions would likely score two or three with the RULA due to the similar percentages of time spent in cervicothoracic, thoracolumbar and lumbosacral flexion postures.

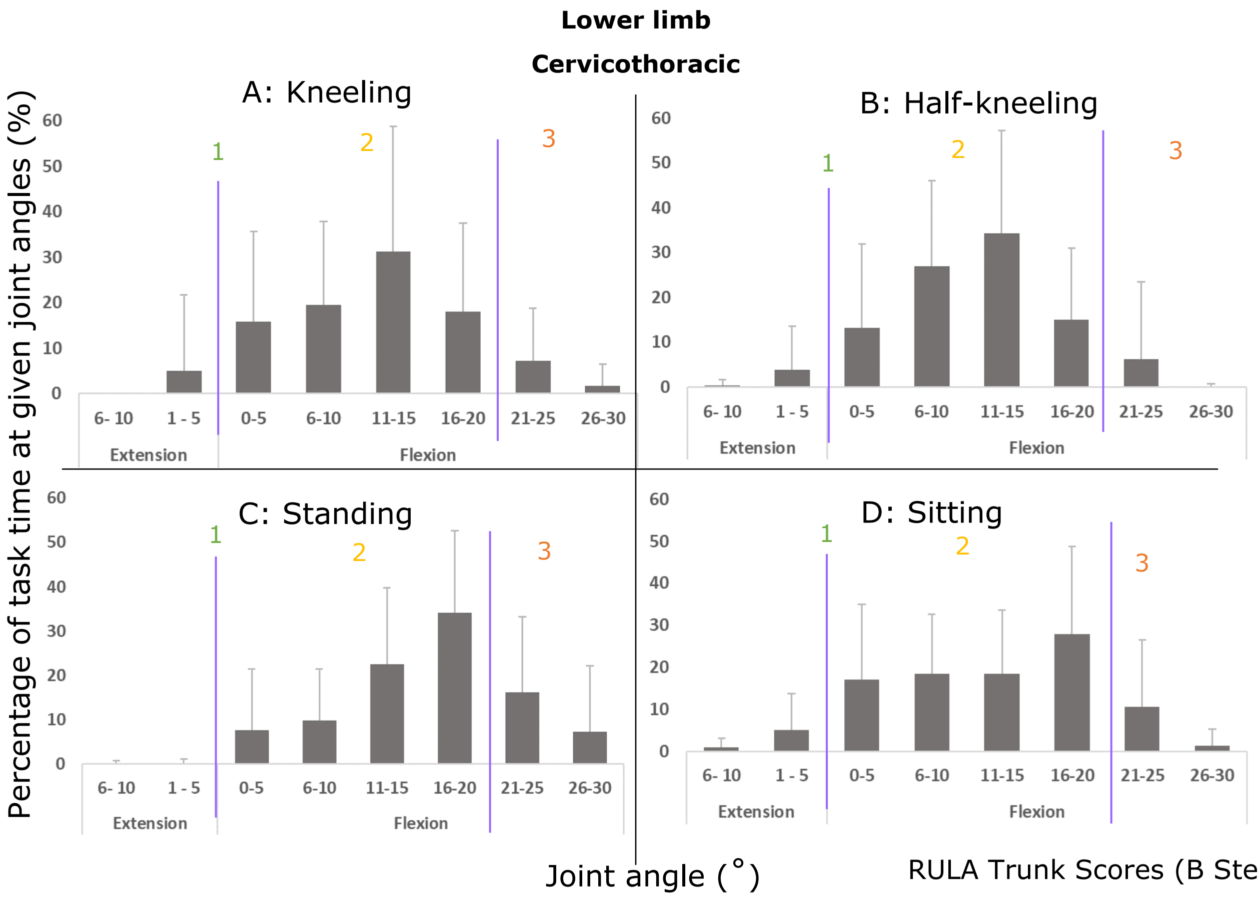


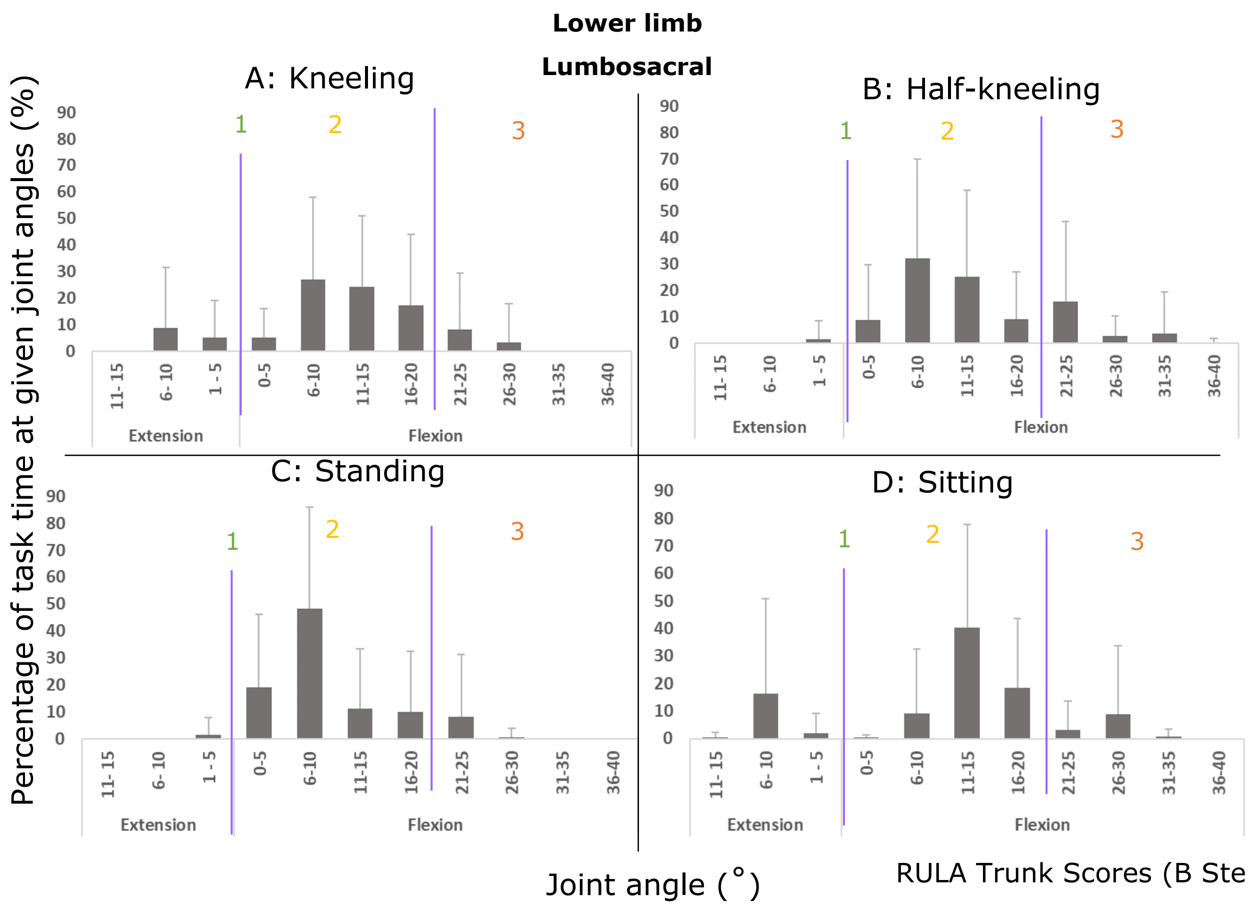
Figure 5.108: Cervicothoracic position during lower limb treatments with RULA scores for A: kneeling, B: half-kneeling, C: standing and D: sitting positions

RULA Trunk Scores (B Step 10)

1 - neutral

2 – 0-20° flexion

3 – 20-60° flexion



RULA Trunk Scores (B Step 10)
1 - neutral
2 – 0-20° flexion
3 – 20-60° flexion

Figure 5.109: Lumbosacral position during lower limb treatments with RULA scores for A: kneeling, B: half-kneeling, C: standing and D: sitting positions

Trunk Facilitation

When facilitating trunk tasks in standing, the cervicothoracic junction showed the largest percentage of time over 20° flexion (32% task time in RULA region 3) (Figure 5.110C). The thoracolumbar junction showed most of the task time was spent between neutral to 20° thoracolumbar flexion (RULA region 2), with no time found over 20° flexion. The lumbosacral junction showed most of the task time was between neutral to 20° flexion for all positions (RULA region 2) (Figure 5.110E-H). Kneeling showed the most task time spent over 20° lumbosacral flexion (18% task time in RULA region 3) than the other physiotherapist positions (Figure 5.110E). Standing showed potential to score highly with the RULA due to the larger percentage of task time spent over 20° cervicothoracic flexion. Kneeling, however, showed potential to score highly due to more task time spent over 20° lumbosacral flexion.

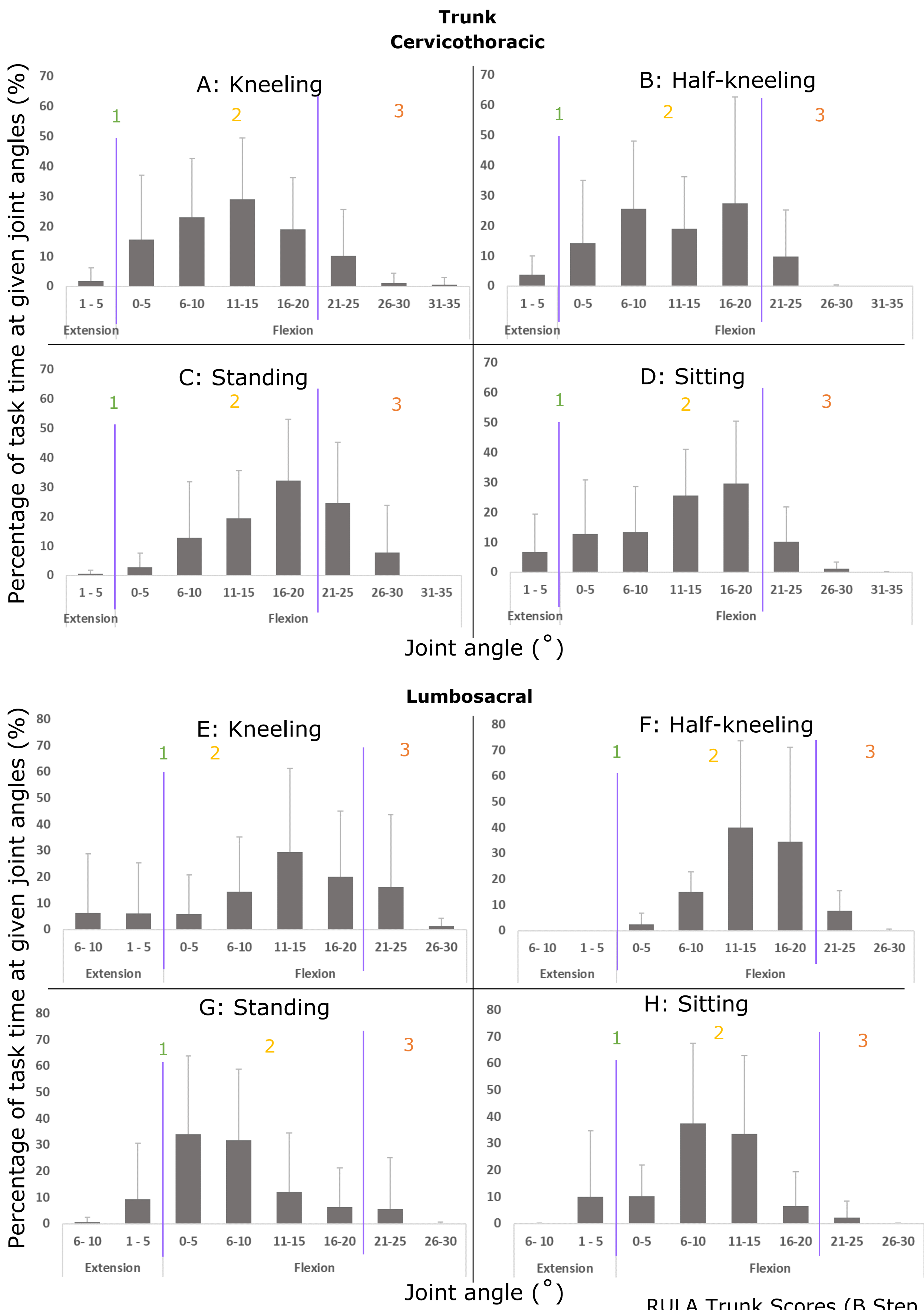


Figure 5.110: Cervicothoracic and lumbosacral position during trunk treatments with RULA scores for kneeling, half-kneeling, standing and sitting positions

RULA Trunk Scores (B Step 10)

1 - neutral

2 – 0-20° flexion

3 – 20-60° flexion

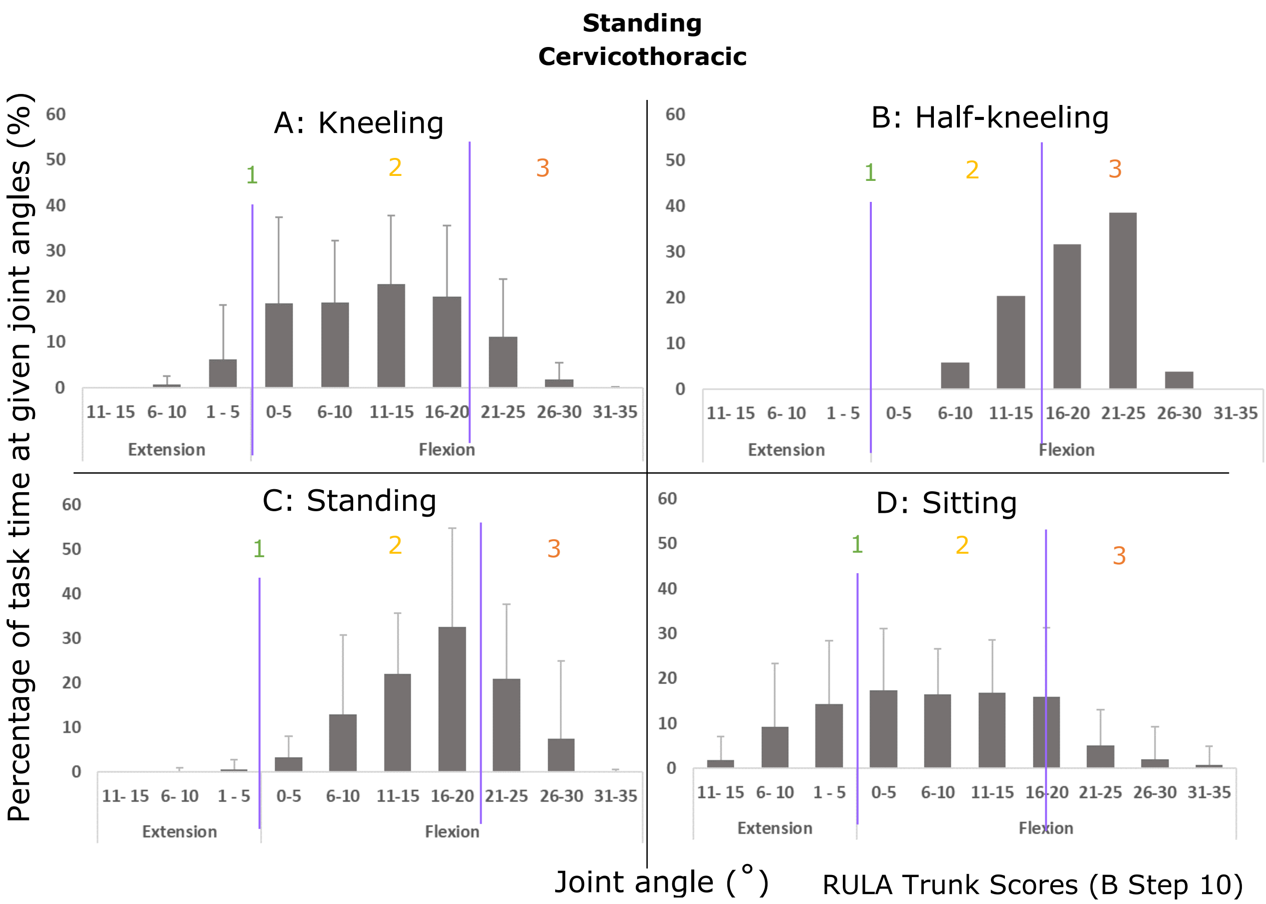


Figure 5.111: Cervicothoracic position during standing treatments with RULA scores for A: kneeling, B: half-kneeling, C: standing and D: sitting positions

RULA Trunk Scores (B Step 10)

1 - neutral

2 – 0-20° flexion

3 – 20-60° flexion

Standing Facilitation

When facilitating standing tasks, half-kneeling demonstrated the largest percentage of task time spent over 20° cervicothoracic flexion (42% task time spent in RULA region 3) (Figure 5.111B). The thoracolumbar junction spent most of task time between neutral to 20° flexion for all physiotherapist positions, with no time over 20° flexion. The lumbosacral junction showed most of task time within region 2 for all positions (Figure 5.112A-D). Kneeling showed the most task time spent in RULA region three (12% task time) (Figure 5.112A). Half-kneeling demonstrated potential to score highly with the RULA due to the larger portion of task time over 20° cervicothoracic flexion. This contrasts with other facilitation tasks, where standing often scores highly for cervicothoracic flexion. Kneeling demonstrated the largest percentage of task time spent over 20° lumbosacral flexion and therefore could score highly with the RULA tool during facilitation of standing.

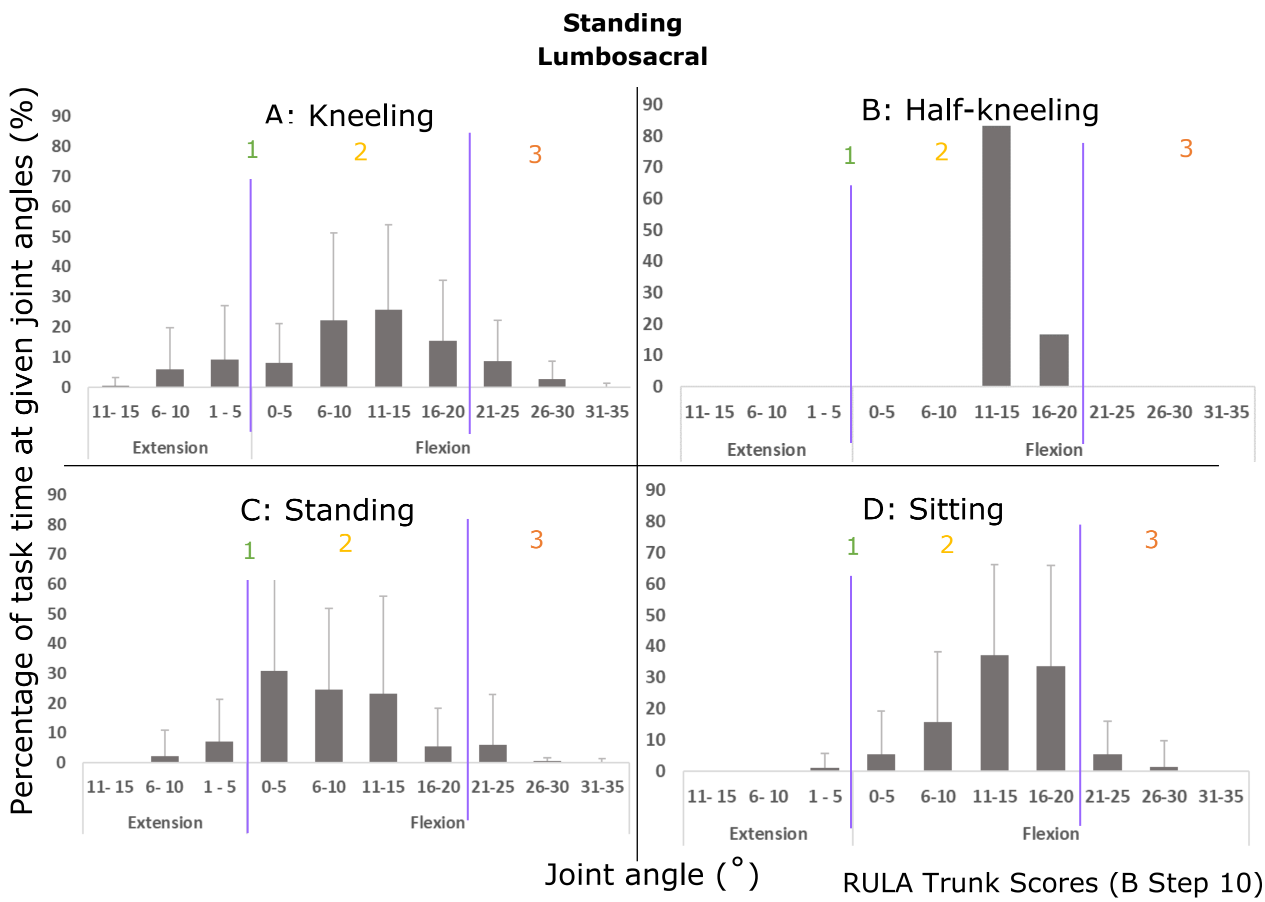


Figure 5.112: Lumbosacral position during standing treatments with RULA scores for A: kneeling, B: half-kneeling, C: standing and D: sitting positions

RULA Trunk Scores (B Step 10)
1 - neutral
2 – 0-20° flexion
3 – 20-60° flexion

Walking treatments

When facilitating walking from a standing position, most of the task time was spent over 20° cervicothoracic flexion (55% task time in RULA region 3) (Figure 5.113B). For all physiotherapist positions, the thoracolumbar junction was found to spend most of the task time within RULA region two, with no joint movement into region three measured. The lumbosacral junction showed the largest percentage of task time flexed over 20° flexion (17% task time in RULA region 3) (Figure 5.113D). If assessing physiotherapist posture with the RULA tool for the cervicothoracic junction, standing showed potential to score highly due to the larger portion to task time in RULA region three. If assessing lumbosacral posture, half-kneeling showed potential to score highly due to the percentage time of walking tasks spent in RULA region 3.

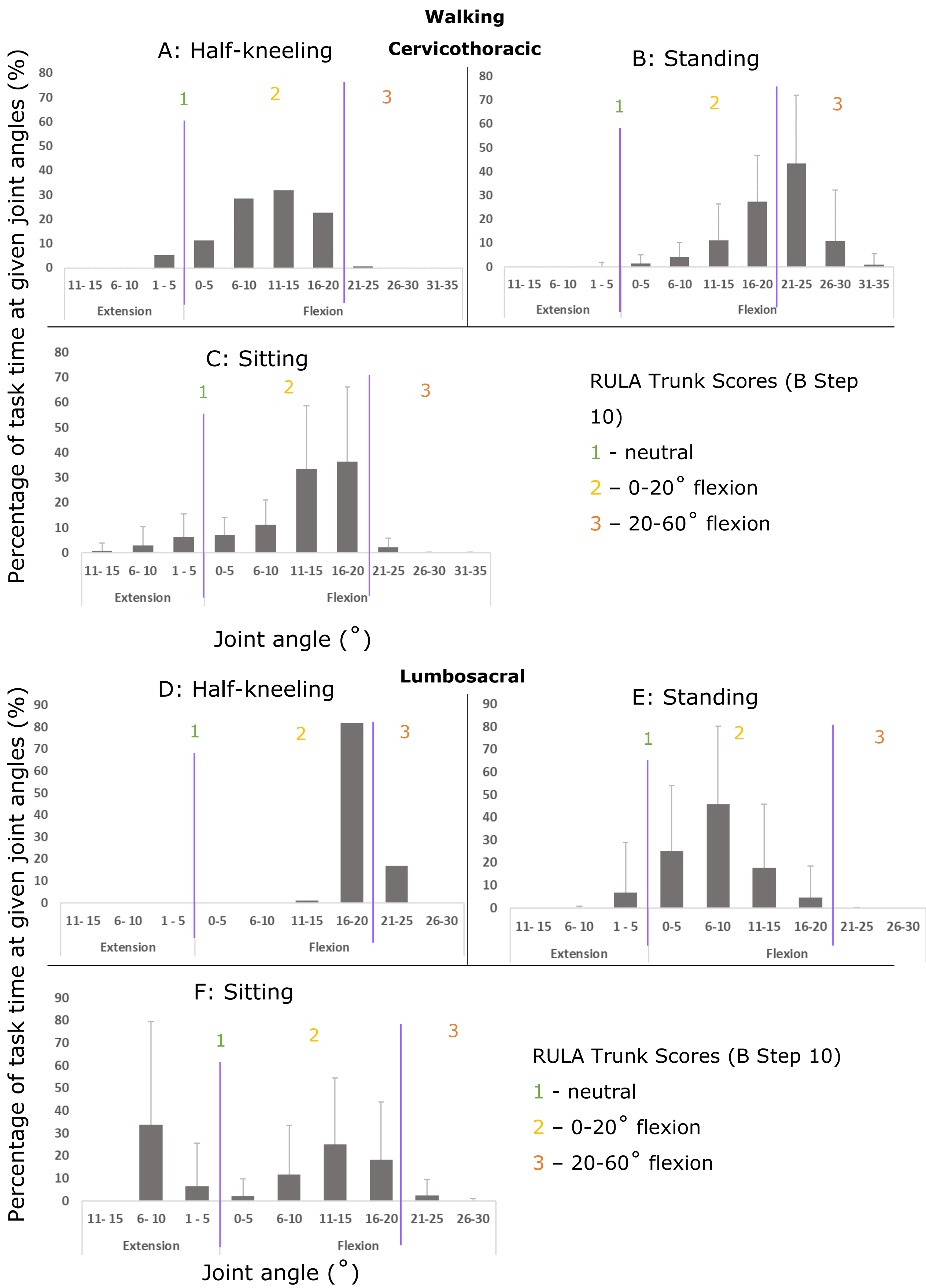


Figure 5.113: Cervicothoracic and lumbosacral position during walking treatments with RULA scores for half-kneeling, standing and sitting positions

The trunk posture of physiotherapists during patient facilitation tasks has been compared with a frequently used ergonomic assessment tool, the RULA. The RULA allowed for crude assessment and scoring of each patient facilitation task and physiotherapist position. The method of calculating trunk movement was modified in this study as the trunk was measured at three trunk regions rather than one segment as considered in the RULA tool. The RULA assumes the subject is standing; however, for this study the values were applied to all positions (kneeling, half-kneeling and sitting) to allow for comparison of joint postures. The physiotherapists' trunk movements were assessed with the RULA values to investigate if any positions or tasks could score higher with the tool. Standing showed an increased flexion angle at the upper back for most of the patient handling tasks and frequently showed joint data in the higher scoring region (3 points). Kneeling often showed the potential to score higher when assessing the low back movement, again often with more of the task time in the higher scoring 3-point region. The thoracolumbar region showed a smaller ROM overall, with no tasks or positions showing data in region 3. Further investigation of ergonomic tools for different subject positions as not all physiotherapy tasks can be performed in sitting or standing and could allow for further investigation of positions and tasks of risk when involved with patient handling.

5.14.4 Ergonomics Summary

When assessing the movements at the shoulder during patient handling tasks against the RULA and the threshold set by Punnett et al (2000), there were only three instances when 90° shoulder flexion was maintained for more than 10% of the task time: sit-to-stand from a sitting position; facilitation of trunk tasks from a sitting position; and facilitation of trunk tasks from a half-kneeling position. Of these three facilitation tasks, the shoulder only exceeded 30° abduction for more than 33% of the task during trunk treatments from a sitting position. Using the literature (Punnett et al. 2000) and RULA ergonomic tool as a guide, trunk tasks would be indicated as increasing risk of discomfort to the worker; with recommendations to amend the position to lower the score. The physiotherapists would be either sitting on a stool in front of the patient or on the plinth next to the patient. Either sitting position would require the physiotherapist to reach forward to the patient and also around the patients to reach the trunk.

When assessing neck postures against the RULA, kneeling, half-kneeling and sitting positions were frequently identified as spending a larger percentage of the task times in extension. Neck extension scores four with the RULA tool, therefore kneeling, half-kneeling and sitting would score highly. These three positions often positioned the physiotherapist lower than the height of the patient and neck extension would be required to look up and communicate with the patient or other staff member. Standing often showed more time closer to a neutral position and therefore could score lower with the RULA tool. Tasks where the neck spent a greater task time in extension when the physiotherapists were in standing were sit-to-lie and lower limb tasks. These two tasks could have demonstrated greater percentage time of task in neck extension due to trunk flexion.

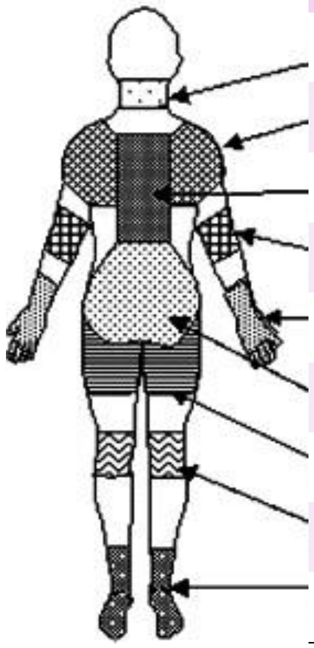
When assessing trunk posture with the RULA tool during patient facilitation, standing often showed more task time was spent in a posture of potential increased risk of WRMSD for the upper back. Standing often showed increased task time in increased cervicothoracic flexion angles than the other physiotherapist positions. This could be due to the physiotherapist rounding and stooping to the height of the patient during facilitation tasks. Kneeling often showed more task time spent in postures of potential increased risk of WRMSD at the lumbosacral junction. Kneeling often demonstrated larger proportions of task time spent in increased lumbosacral flexion angles than other physiotherapist positions.

When assessing physiotherapist postures against literature and an ergonomic assessment tool, certain facilitation tasks and physiotherapist positions have been identified as potentially increasing risk of WRMSD at the shoulders, neck and trunk. Further investigation into how long these positions are maintained for or repeated during the physiotherapists working day could provide further insight into any potential risks involved.

5.15 NMQ-E Findings

This section summarises the findings from the NMQ-E, which investigated incidence and impact of WRMSD within the physiotherapy cohort. All ten participants completed the NMQ-E questionnaire on the day of data collection. Table 5.7 summarises the incidence of WRMSD in each anatomical region and the average age of onset within the physiotherapists involved in this study. The NMQ-E initially investigated if the physiotherapists 'had ever had trouble (ache, pain, discomfort)', before further investigating how recently they had experienced 'trouble' and the personal and work impact of the WRMSD. Four of the participants stated they had never experienced a WRMSD in their working career. The remaining six participants had experienced WRMSD in at least one region, with all six having experienced low back discomfort. The youngest age of onset at the low back was 25, with the oldest 51 years.

Table 5.7: NMQ-E lifetime WRMSD incidence (n=10)



	Number affected	**Average age of onset (SD)**
Neck	0	-
Shoulders	1	47
Upper back	1	25
Elbows	1	55
Wrists/hands	0	-
Low back	6	36 (10.14)
Hips/thighs	2	35 (12.73)
Knees	1	35
Ankles/feet	1	42

The NMQ-E then further investigated incidence of WRMSD, by asking if the physiotherapists had experienced any 'trouble' at any time during the last 12 months, last month, and today. Table 5.8 summarises the incidence at each anatomical region over the last 12 months, one month and that day within the physiotherapy cohort. At the low back, three of the six participants had experienced ‘trouble’ in the last 12 months, with one incidence in the last month. Participants were experiencing ‘trouble’ in their elbows, low back and hips/thighs on the day of data collection. These participants who were experiencing ‘trouble’ on the day of data collection still adhered with the inclusion criteria as they had not altered their normal daily clinical duties.

Table 5.8: WRMSD incidence over various timescales

Anatomical region	Ever had trouble (%)	Trouble in last 12 months (%)	Trouble in last month (%)	Trouble today (%)
Neck	0	0	0	0
Shoulders	10	10	10	0
Upper back	10	10	10	0
Elbows	10	10	10	10
Wrists/hands	0	0	0	0
Low back	60	30	10	10
Hips/thighs	20	20	20	10
Knees	10	10	0	0
Ankles/feet	10	10	0	0

The NMQ-E investigated work and personal impact in addition to incidence; these impacts are summarised in Table 5.9. One participant stated they had to change jobs (even temporarily) as a result of their back pain within their physiotherapy career, with treatment sought from a clinician and medication taken. One participant also had to change jobs due to shoulder pain and had taken medication in the last 12 months related to their shoulder WRMSD. One participant stated they had experienced elbow pain which prevented them from their normal work, they sought medical advice from a doctor, physiotherapist or chiropractor and had also taken medication because of their elbow pain. However, this participant had not changed jobs due to their elbow WRMSD. None of the participants who had experienced WRMSD in the last 12 months had taken sick leave as a result of their discomfort.

Table 5.9: Work and personal impact of WRMSD

Anatomical region	Had to change jobs (even temporarily)	In the last 12 months:			
		Prevented from normal work	Seen doctor, physiotherapist or chiropractor	Taken medication	Taken sick leave
Neck	0	0	0	0	0
Shoulders	1	0	0	1	0
Upper back	0	0	0	0	0
Elbows	0	1	1	1	0
Wrists/hands	0	0	0	0	0
Low back	1	0	1	0	0
Hips/thighs	0	0	1	0	0
Knees	0	0	0	0	0
Ankles/feet	0	0	0	0	0

Further investigation of physiotherapist injuries or suspected patient handling tasks was not conducted in this study. Despite the small sample size within this study, low back discomfort was notably more prevalent than other anatomical regions in this cohort (n=6). Kneeling and sitting positions were highlighted previously in section 5.14.2 of this thesis as scoring highly with the RULA due to increased angles and percentage time spent in lumbosacral flexion. Kneeling was the most common position used during lie-to-sit and trunk facilitation tasks. Sitting was the most common position used during sit-to-stand, upper limb, and standing facilitation tasks. Kneeling and sitting positions were found to score highly with the RULA due to neck extension and trunk flexion, suggesting increased risk of WRMSD. These two positions were used most often for five of the eight patient handling tasks. Patient facilitation tasks require further detailed investigation to allow for greater understanding of the potential risks associated with each physiotherapist position. Further discussion into physiotherapist positions and potential risks involved with patient handling tasks will be discussed further in Chapter 6.

5.16 Results Summary

This chapter summarised the results from this study, addressing the three study objectives set previously. The physiotherapist movement was quantified by processing the data into five-degree bins to allow for illustration of percentage time of each facilitation task in joint angles. A narrative description of physiotherapist position was provided with the quantification of physiotherapist movement. The results then compared and assessed physiotherapist postures against ergonomics literature and the RULA ergonomic tool to investigate tasks and positions of potential risk. Finally, the results summarised the findings from the NMQ-E which investigated the incidence of WRMSD within the physiotherapist cohort and associated personal and work impact. The results are discussed further with comparison and synthesis from the wider literature in Chapter 6.

6 DISCUSSION

Work related musculoskeletal disorders are a significant issue within healthcare populations, with patient handling is often cited as a significant risk factor. Physiotherapists often therapeutically handle patients to aid patient rehabilitation and function. Therapeutic patient handling can be manually intensive for the physiotherapist, as identified from the scoping review, with little research has been conducted on the specific tasks, movements, and postures performed.

To address the identified gap in the evidence base, this study aimed to investigate physiotherapist movement and positioning during therapeutic handling in a neurological setting. A portable motion analysis system (Xsens MTw Awinda) was used to measure physiotherapists in the clinical setting with minimal impact to patient treatment sessions. The physiotherapist's movement was described in relation to each patient task observed during the data collection sessions. Physiotherapist movement and positioning was then assessed against the RULA ergonomic tool and incidence of WRMSD was investigated within the cohort. Physiotherapist movement during each of the eight patient handling tasks and four physiotherapist positions was described, quantified, and compared against the RULA ergonomic tool. This chapter discusses key findings of the research and compares these findings to literature within the field. Finally, this chapter discusses the strengths and limitations of the research and suggests areas for future study.

The first key finding from this study was that therapeutic handling was performed from four main physiotherapist positions; kneeling, half-kneeling, standing, and sitting. Kneeling and sitting were utilised for therapeutic handling more frequently than standing. Principles of safe patient handling consider the handler from a standing position (Wanless 2016); therefore, it is likely that the physiotherapists position themselves and perform manual handling in a manner that they have not had formal training for.

The second key finding was differences in physiotherapist neck, cervicothoracic and lumbosacral movements and postures were found between standing, kneeling, and sitting. Standing often scored highly with the RULA for cervicothoracic flexion, whereas kneeling and sitting often scored highly for neck extension and lumbosacral flexion. The risk of WRMSD may vary dependent on the physiotherapist position during patient handling tasks.

The third key finding was that the lumbosacral region was the most commonly reported area of WRMSD within the cohort of physiotherapists. It was found that some of the cohort had temporarily changed their jobs, sought professional help or taken medication related to their WRMSD. However, none of the physiotherapist cohort had taken sick leave related to their WRMSD in the last year.

This chapter now discusses the physiotherapists’ movement, ergonomics, and incidence of WRMSD during therapeutic handling to interpret the findings in relation to the wider body of literature.

6.1 Physiotherapist Movement and Patient Handling Tasks

6.1.1 Patient Treatments and Physiotherapist Positioning

Variation of Physiotherapist Positioning and Movement

The physiotherapists were advised to complete each patient treatment task as normal, meaning a large amount of variation of patient handling tasks and physiotherapist positions was observed. Investigation of the eight patient tasks individually allowed for more specific description of physiotherapist movement during each task. The patient tasks were not investigated in further detail, e.g., reaching or strengthening tasks within upper limb treatments, due to the large heterogeneity of individual treatments performed. For future research, it could be beneficial to focus on a specific patient handling task to allow more specific investigation. For example, sit-to-stand and trunk facilitation were frequently performed by the physiotherapists in this study; these may therefore be appropriate tasks to focus on.

The physiotherapist position varied when in kneeling, half-kneeling and sitting positions, with the physiotherapists in either high or low kneeling, half-kneeling with one leg on the plinth and sitting on a stool or the plinth. There were insufficient trials of each variation of physiotherapist position to consider individual analysis of movement. Investigating a specific patient handling task with a larger cohort could allow for more detailed investigation of the variations in physiotherapist position. A larger sample size could allow for separate analysis of physiotherapist movement during half-kneeling on the plinth compared to half-kneeling on the floor. These two half-kneeling positions place the physiotherapists' lower limbs in different positions and could increase risk of knee injury due to the degree of flexion and the time that the position is maintained for during patient treatment. The two half-kneeling positions could be used by the physiotherapists to position themselves in relation to the patient. Half-kneeling on the plinth compared to the floor could impact trunk and neck postures. This study found that a large variation of positions was used during patient handling tasks by all the physiotherapists involved. Further research is required to investigate if physiotherapists in other locations and specialties also vary their positioning. If differences between specialities was found, specific training to consider the variation of positions and patient tasks found in physiotherapist specialties could be developed.

Position of healthcare staff in relation to their environment and the patient while performing patient handling tasks is rarely described in the literature, therefore the findings of this study are novel. Patient handling tasks are often investigated with the handler in a standing position, or without the handler position being stated (Callison and Nussbaum 2012; Daynard et al. 2001; Doss et al. 2018). Additionally, moving and handling training principles typically consider the handler in a standing position (Wanless 2016). The findings of this study therefore suggest that such training principles are inadequate for therapists conducting therapeutic handling in kneeling and sitting positions.

Safe patient handling principles state that a ‘natural’ spine shape should be maintained to allow stability of the spinal structures and aid shock absorption (Wanless 2016). The trunk should not bend forwards or be straight upright due to the effect on loading and muscle activity (Wanless 2016). However, physiotherapists and manual handling advisors have been found to perceive straight back lifting during manual material as the safest technique (Nolan et al. 2018). Nolan et al. (2018) investigated perceptions of 400 physiotherapists and manual handling advisors via an electronic survey. They perceived that straight lifting postures maintained a neutral spine or good posture and avoided rounding of the spine (Nolan et al. 2018). However, the portion of the respondents that perceived rounded postures as safer stated so due to comfort and efficiency (Nolan et al. 2018). The differences in perception surrounding safe lifting postures identified that lifting style may be influenced by personal preference.

Variation in spinal curvature has been found to show natural preferences towards stoop or squat lifting; with straighter spine shapes preferring a squatting technique and curvier spines preferring a stoop technique (Pavlova et al. 2018). Individuals with low back pain have also been found to demonstrate different patterns of muscle activity during lifting tasks (Sanderson et al. 2019). In addition, individuals with back pain have also been found to move and lift differently to pain-free individuals; with movement described as stiff and slow (Nolan et al. 2020). These differences and adaptions related to natural variations in spinal shape or discomfort suggest that one size does not fit all when developing training and guidelines for manual patient handling. If individuals are found to lift more naturally with one style, instructing them to lift with a different technique may increase their discomfort. Training, therefore, should consider the variation of physiotherapist positions, patient tasks, and also the natural movement of the individuals involved. Development of training will likely be complex due to the wide variability and individuality of patient handling tasks and physiotherapist movement. Future qualitative and quantitative research should help with developing well-rounded and comprehensive training programmes.

The scoping review conducted as part of this thesis (Chapter 2), identified therapeutic handling by physiotherapists as a gap in the literature. This lack of literature demonstrates there has been less investigation into physiotherapist movements, postures, and methods of patient handling. Different positioning and handling was found during therapeutic handling in this research. The physiotherapists performed many patient treatments from a sitting, kneeling or half-kneeling position. Standing was the most used position for lower limb and walking treatments, with sitting or kneeling the most common positions for all other facilitation tasks. A strength of this observational study was that the researcher did not manipulate the treatments, patient handling or physiotherapist positions used. Having no impact on the tasks performed allowed for a naturalistic investigation into patient handling in the clinical setting; however, it did result in heterogeneous data. To reduce the variation when investigating patient handling, specific patient handling tasks or physiotherapist positions could be chosen.

Kneeling and Sitting Physiotherapist Positions

Sitting positions involved the physiotherapists either sitting on a stool or the plinth during patient treatments. Sitting is considered as a position of risk when maintained for a prolonged period, such as during desk-work (Dubey et al. 2019). Therefore, advice surrounding sitting ergonomics may not be applicable to therapeutic handling settings. The physiotherapists were found to reach forwards to move patients' limbs, hold flexed trunk postures for the duration of patient tasks, and maintain neck extension when sitting. Specific advice on positions of comfort, methods to reduce trunk flexion, or guidance on how frequently they should move or stretch could benefit physiotherapist physical health related to patient handling tasks. Moreover, ergonomic assessment tools largely assess the worker in a standing position, with three tools (REBA, RULA, and Loading on the Upper Body Assessment) stated as considering a sitting position (Joshi and Deshpande 2019). The RULA, REBA, OWAS, and NIOSH lifting equations have been used on healthcare populations previously (Kee 2022; Robielos et al. 2018). Physiotherapists were found to use varied and dynamic postures during therapeutic handling of patients. Ergonomic tools need to be reviewed and adapted to consider the range of tasks and postures to allow for effective assessment of physiotherapists' postures during therapeutic handling.

Kneeling and sitting positions overall showed similar patterns of movement of lumbosacral flexion, shoulder flexion and neck extension compared to standing for all patient facilitation tasks. Some similarities could be expected as kneeling and sitting positions can place the physiotherapist in a similar position in relation to the height of the patient, especially if the patient is standing and therefore above the physiotherapist. The main difference in joint angles was found in the physiotherapists' lower limbs. Kneeling requires more knee flexion than sitting. It is stated that kneeling increases risk of knee pain in occupational settings, with prolonged kneeling (>15 minutes) discouraged due to the increased risk of knee pain associated with this (Herquelot et al. 2014; Nahit et al. 2001). Kneeling has also been found to increase spinal loading forces during lifting (Splittstoesser et al. 2007). Splittstoesser et al. (2007) used an EMG-driven biomechanical model to calculate the loading experienced at the spine during a manual material lifting task. The spinal loading was calculated as the participants moved luggage of varying weight to a destination of increasing height. Compression, anterior-posterior shear and lateral shear forces increased with increasing weight and for increasing destination height.

Therapeutically handling patients could involve moving or lifting patients' limbs from a kneeling position. The tasks performed in kneeling during physiotherapy are different from those performed in manual material handling sectors. However, the potential for increased spinal loading remains. Kneeling was the most frequently used position for sit-to-lie and trunk treatments, and second most frequent for lie-to-sit and lower limb treatments. There is also the possibility that the physiotherapists will repeatedly kneel during the day. Possible cumulative effects of kneeling during patient treatments are currently not known. Future research could follow a similar method to that of Splittstoesser et al's (2007), measuring spinal loading experienced by physiotherapists during patient treatments. This could identify how loading changes depending on the patient limb or task being performed.

Half-kneeling Physiotherapist Positions

Neck rotation, trunk rotation, and side bend were consistent traits among treatments performed from a half-kneeling position; potentially as a result of the asymmetric position of the physiotherapists' legs. The asymmetric lower limbs and BoS when half-kneeling could impact the alignment of the trunk and neck. Kneeling and half-kneeling are postures often used in mining sectors, with research having investigated the associated loading and risks of WRMSD of these positions during manual handling (Gallagher et al. 2011). Gallagher et al. (2011) investigated muscle activity of the thighs during a lateral load transfer in kneeling, half-kneeling, and squatting postures. Half-kneeling was associated with greater muscle activity compared to kneeling postures (Gallagher et al. 2011). In this study, the physiotherapists were found to adopt a half-kneeling position more frequently during upper limb and lower limb facilitations, and rotation and side bending was also observed during these tasks. Minimal research has described patient handling from a kneeling or half-kneeling position, despite the stated increased risks of knee and low back discomfort (Herquelot et al. 2014; Nahit et al. 2001; Warren 2016). Future research should investigate movement and loading during patient handling from kneeling and half-kneeling postures.

Facilitation of Sit-to-stand Tasks

Assisting sit-to-stand has been identified as potentially increasing the risk of WRMSD in physiotherapists (Campo et al. 2008). Although there is guidance on safe patient handling for this task it assumes the physiotherapist is standing (Thomas 2005) (Figure 6.1). Therapeutic handling can involve coaching and guiding the patient to gain better quality movement and requires assessing and taking risks related to patient handling (Kneafsey et al. 2015). Most sit-to-stand tasks in this study were performed with the physiotherapist sitting. The physiotherapists therefore did not use the method of assisting sit-to-stand as illustrated in Figure 6.1. Therapeutic handling involves specific facilitation or guidance of movement (Kneafsey et al. 2015) meaning the method in Figure 6.1

may not have been appropriate for this setting. This is likely due to the physical disabilities found in neurological settings, and that sit-to-stand was used as a treatment rather than solely a movement involved in transferring a patient. Physical deficits could reduce the independence of the patient when moving to standing. When the physiotherapist was sitting there was often another staff member involved in the patient treatment to provide additional support at the patient's trunk and hips. The physiotherapists' sitting in front of the patient were observed to position their knees in front of the patient's affected knee for further support (Figure 6.2). Positioning themselves in this manner could subject the physiotherapists to increased loading related to maintaining the patient's upright standing posture.

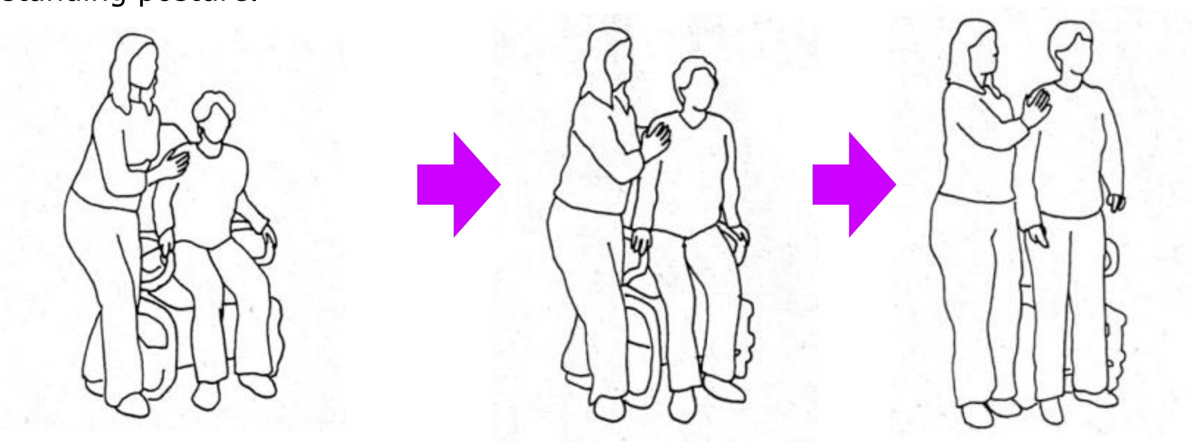


Figure 6.1: Assisting sit-to-stand (Adapted from Thomas 2005)

Figure 6.2: Facilitation of standing with the physiotherapist sitting in front of the patient

When patients do not have sufficient strength and/or balance to achieve a stand, equipment should be used to reduce the loading placed on the handler (Backcare 2005). As discussed previously in Section 5.7 equipment was used to assist patients with sit-to-stand if the patient required additional help to stand. However, physiotherapists were also often therapeutically handling at the same time. As described in Section 5.7, the physiotherapists were often assisting the patients' hips and lower limbs when sitting in front of the patient. The physiotherapists reached forward to the patients' hips and supported the knee if required. There are no widely published guidelines for facilitation of patient tasks from a sitting position. The lack of guidance on safe ways to facilitate patient movement from a sitting position may result in the physiotherapists using individual techniques which may not be ergonomically sound and therefore may increase their risk of WRMSD. As many sit-to-stand tasks were performed from the sitting position, more needs to be known about the potential risks of these approaches and methods to ensure safety for both patient and physiotherapist.

Facilitation of Upper Limb Tasks

The third patient treatment assisted mostly from a sitting position was upper limb facilitation. The physiotherapists often positioned themselves close to the patient's upper limb, and performed sensation work, joint mobilisations or facilitated active movements. Physiotherapists had a similar distribution of shoulder flexion during facilitation of upper limb tasks regardless of position; with less flexion than other tasks performed in sitting or kneeling positions. The similarity in shoulder flexion distribution suggests sensation work and joint mobilisations did not require much movement at the physiotherapists' shoulders. Furthermore, less time was spent in higher risk scoring regions of the RULA tool for shoulder and low back movement for all physiotherapist positions during upper limb facilitation. The neck and upper back demonstrated the potential to score highly due to combination of neck extension and cervicothoracic flexion. Compared with other patient treatments there was less shoulder flexion for all positioning especially when in kneeling and sitting positions. Potentially as the physiotherapists are reaching forwards rather than upwards, this could decrease the flexion angle at the shoulder. To perform functional tasks, such as reaching, patients do not require their full active upper limb range of movement (Namdari et al. 2012), therefore the physiotherapists may not have to facilitate large movements. Upper limb facilitation did not require the physiotherapist to reach as far forwards as other facilitation tasks and scored lower with the RULA, indicating less risk of WRMSD independent of the physiotherapist's position. Facilitation of upper limb tasks appears to be of less concern for future research compared with other facilitation tasks.

Physiotherapist Neck Postures

An observation that was often made when assisting patient treatments from kneeling, half-kneeling and sitting positions was the presence of greater neck extension compared to facilitating from a standing position. Using the RULA to estimate risk of WRMSD, neck extension scored higher than neck flexion suggesting that extension may increase the risk of discomfort.

Maintaining maximal neck extension during overhead work has been found to increase risk of discomfort in manual material handling settings (Shin and Yoo 2015). Upper back and shoulder muscle activity was measured during overhead working tasks at varying heights and distances from the participants (Shin and Yoo 2015). Neck extension was found to be greatest when the overhead task was 20cm above and 15cm away from head height, with significantly more sternocleidomastoid muscle activity than 20cm above and 30cm away from head height ($p<0.05$). However, overhead tasks 20cm above and 30cm away showed significantly more muscle activity of the upper back and shoulder than all other tasks ($p<0.05$) (10cm above and 15cm away, 10cm above and 30cm away, 20cm above and 15 cm away) (Shin and Yoo 2015). Shin and Yoo (2015) stated that height was a larger risk factor for WRMSD than distance from the participants. When facilitating sit-to-stand or standing tasks from a sitting or kneeling position, there is potential that the physiotherapist will be working above head height, which could increase the risk of WRMSD. A potential for future research could be to investigate how often physiotherapists perform overhead work and the heights and distances involved. Specific investigation of patient handling tasks could be used to guide development of training for physiotherapists. Guidelines or advice could be developed around which positions should be limited or adapted to manage handler musculoskeletal safety.

In healthcare populations, less primary research has been conducted to investigate the risk of discomfort due to neck extension. Sonographers have been found to experience a high rate of injury at the neck (65.8%), thought to be due to long periods in flexed, extended or rotated postures (Deb and Venkateshvaran 2018; Evans et al. 2009). Ergonomic recommendations stated that sonographers should position the top of the monitor at eye level to achieve a comfortable neck posture (Baker and Coffin 2013). The monitor should not be positioned too high as this would require neck extension (Baker and Coffin 2013). A large amount of ergonomics literature focuses on neck flexion in relation to computer screens or workstations. Ergonomics traditionally has focussed on industrial and office-based settings (Coenen et al. 2016; Delleman and Dul 2007). The nature of work tasks during manual material handling or static desk-based working is different to the tasks performed during therapeutic handling with patients. Manual material handling and office-based ergonomics research provides a sound basis for identifying potential postures and tasks of increased WRMSD risk (Coenen et al. 2016). However, the physiotherapists did not maintain static postures for extended periods of time and the physiotherapists were not handling inanimate standard size objects, such as boxes. There remains the need for specific ergonomic investigation and analysis of therapeutic handling.

Physiotherapist Trunk Postures

Trunk flexion is another widely discussed position of risk in working environments, especially in combination with side bending or twisting (Hoogendoorn et al. 2000; Nourollahi et al. 2018; Vieira and Kumar 2004). Hoogendoorn et al. (2000) investigated a mix of workers in blue-collar, white-collar and caring professions during a three-year period. Physical workload, risk factors, and incidence of low back pain was investigated as a baseline. Physical workload was assessed with video recordings and force measurements in each workplace. These recordings were then grouped into similar tasks for postural, movement, and force analysis. Trunk flexion was considered as one segment in a range of thresholds, from neutral (<30°), mild (30-60°), extreme (60-90°), and very extreme (>90°) flexion. Trunk rotation was also considered as neutral (<30°) and twisting (>30°). The number of times a day a load over 10kg was lifted was observed during the recordings and extrapolated to the 8-hour working day. The incidence of low back pain was investigated using an adapted NMQ and was followed up annually for three years. Hoogendoorn et al. (2000) found that there was increased risk of low back pain with increasing angles of trunk flexion and also if the trunk was rotated for 10% of the working time. Lifting a weight of 25kg more than 15 times in the working day was also associated as a risk of low back pain. Future research could use a similar extrapolation of lifting involved with therapeutic handling from one treatment to the wider working day or week. Physiotherapists do not lift an object of known weight; anthropometric calculations could be used to estimate patient limb weight and allow for assessment of risk of injury related to lifting of patients' limbs.

Research on the risk of WRMSD associated with nursing working postures investigated the prevalence of low back pain using an adapted NMQ and observing trunk postures during a full shift with an inclinometer (Nourollahi et al. 2018). The 12-month prevalence of WRMSD was high among the nursing population, with 72% of the participants having experienced low back pain (Nourollahi et al. 2018). The nurses were found to have greater median and peak trunk flexion angles in general, orthopaedic, and critical care units; with peak angles ranging from 80° to 88° flexion. Nourollahi et al (2018) stated that nurses in orthopaedic settings would be involved in patient transferring and handling tasks that required awkward postures more than settings where patients were mobile e.g., gynaecology. Nourollahi et al. (2018) stated there was a relationship between percentage work time over 45° trunk flexion and prevalence of low back pain. General, orthopaedic, and critical care unit nurses were found to perform high-risk tasks more frequently than the other settings investigated (Nourollahi et al. 2018).

Nourollahi et al. (2018) and Hoogendoorn et al. (2000) investigated the trunk as one segment, therefore, the trunk flexion angles stated are larger than those measured in this research. However, they identified tasks such as transferring patients or holding patients' extremities as high-risk. These tasks were performed by the physiotherapists in this study. For future research, if a specific handling task is investigated, movement of the trunk segments measured using the Xsens MTw Awinda could be analysed in combination to provide an overall trunk flexion posture. Physiotherapists in a half-kneeling position demonstrated more asymmetry of trunk side flexion and rotation. Further investigation into physiotherapists in this position could identify if the postures maintained are similar to those described in previous research (Hoogendoorn et al. 2000; Nourollahi et al. 2018; Vieira and Kumar 2004).

Standing often demonstrated decreased flexion at the lumbosacral joint during patient handling tasks. It did, however, show increased cervicothoracic flexion for most patient tasks and also when compared with other physiotherapist positions. The neck was often in neutral to slight flexion, and the cervicothoracic junction could be flexed as a compensatory movement. Time-normalised data demonstrated that the neck and upper back often followed very similar patterns of movement. This similarity is likely due to the limited number of sensors in that area and the way the Xsens MTw Awinda model defines and tracks those segments. However, head movement could impact the movement and position of other parts of the spine. Xsens states that movements at the spinal segments and neck are not directly measured; a biomechanical model is used (Xsens 2021). The increased upper back flexion could also be due to the physiotherapists stooping to the height of the patient or standing with a more protracted posture. If video recording were used in combination with the Xsens MTw Awinda system, the movements of the trunk could be viewed and compared with the calculated trunk joint angles and would allow for a more rounded description of physiotherapist positioning and posture.

Generally, the thoracolumbar joint showed little range of motion for all patient treatments and physiotherapist positions. Anatomically, the thoracic region of the spine allows less ROM in flexion and extension than other regions (Weiner et al. 2012). Thoracic ROM has been measured using Fastrak (Willems et al. 1996) and a Spinal Mouse system (Mannion et al. 2003) in previous research. The small ROM measured in the current physiotherapist cohort could be due to the constraints of the Xsens MTw Awinda model and segment definitions. A range from neutral (0°) to 25 - 34° active thoracic flexion is stated in the literature (Mannion et al. 2003; Willems et al. 1996). Previous research using the Xsens system found thoracic flexion ROM to be 20.5° (Hajibozorgi and Arjmand 2015). The thoracic flexion measured within this study found the physiotherapists' movement was less than all other literature with neutral to 15° thoracic flexion measured. The lower joint ROM measured in this study could be due to the physiotherapists not performing full active thoracic flexion, a limitation, or an error of the system, or biomechanical model. Video recording of the sagittal plane during patient handling could provide an additional visual analysis of the specific and overall trunk positioning.

When the physiotherapist was sitting to facilitating sit-to-stand, the trunk was found to be flexed at all three segments of the spine measured, suggesting a flexed and rounded trunk posture. Other patient tasks and positions that showed most of the task time with all three spine segments in flexion were: sit-to-lie from standing; sit-to-stand in half-kneeling; trunk tasks in half-kneeling; standing tasks in half-kneeling; and walking tasks in half-kneeling. 'Top-heavy' positions have been suggested to increase risk of injury at the lower back (Wicker 2000) and lifting with a rounded back is perceived as dangerous by manual handling advisors and physiotherapists (Nolan et al. 2018; Nolan et al. 2019; Wicker 2000). However, there is little evidence to continue supporting this statement with literature stating that there is minimal difference in spinal loads between straight back and rounded back lifting (Dreischarf et al. 2016). Vertebral body replacements were used to measure the in vivo loading at the lumbar spine during stoop and squat lifting tasks by Dreischarf et al (2016). It was found that only a small difference in force between stoop and squat lifting was calculated (4%), despite larger differences in trunk and knee flexion angles

(Dreischarf et al. 2016). It has been suggested that individuals without low back pain do not need to avoid trunk flexion (Contreras and Schoenfeld 2011), with other research stating the risk of back injury is reduced with decreased trunk flexion angles (Owlia et al. 2020). Trunk flexion during lifting activities is an evolving area of research, however perceptions surrounding 'safer' lifting techniques remain (Nolan et al. 2018). If lifting with a flexed trunk is perceived as unsafe, people may not change their lifting technique despite evidence suggesting there are minimal differences in spinal loading (Dreischarf et al. 2016). In addition, physiotherapists have been found to be more likely to adopt a rounded back posture when lifting than manual handling advisors (Nolan et al. 2018). Individual preferences of movement need to be considered for future research and guidance. Previously an exercise-based treatment programme has been found to reduce incidence rates of WRMSD within nurses (Marshall et al. 2018). Exercise based programmes have also been found to play a role in successful return to work and reduce the amount of sick leave taken (Voss et al. 2019). A potential route for future research is investigating a work conditioning program to train physiotherapists' resilience for the loading involved with therapeutic handling while allowing individuals to move and lift in their natural manner.

Santaguida et al. (2005) used a threshold of 45° trunk flexion above which the handler was believed to be at greater risk of WRMSD. They found that placing and removing slings under patients often placed the handler over this flexion threshold. However, it is not stated why the threshold of 45° was used. Despite devices aiding with patient transfers by reducing loading on healthcare staff, a risk of injury remains due to "unfavourable" positioning and loading during preparatory tasks such as placing of slings. Lifting aids are encouraged and found to be beneficial for both staff and patient health and rehabilitation (Mayeda-Letourneau 2014; Rockefeller 2012; Waters and Rockefeller 2010). If slings are being placed and removed repeatedly, there is a risk of increased cumulative loading (Daynard et al. 2001).

Trunk position in healthcare and ergonomics research is often discussed as one segment (Doss et al. 2018; Hodder et al. 2010; Holmes et al. 2010; Prairie and Corbeil 2014). This research investigated trunk motion of three segments, which provided a more detailed investigation of trunk movement during patient tasks than has been performed previously. However, due to the methods used in previous ergonomics literature, direct comparisons were difficult. The motion data from this research shows the regions of the spine move differently depending on physiotherapist position during patient handling tasks. The different regions of the trunk are known to be structured and move differently to each other (Weiner et al. 2012). The cervical spine demonstrates the largest range of movement, with the lumbar spine able to withstand larger loads (Weiner et al. 2012). If the trunk is continued to be assessed as one segment, any potential differences in postures of each region of the trunk could not be identified. Considering the different regions of the trunk could facilitate specificity in relation to different physiotherapist positioning when developing guidelines, workplace adaptations, and ergonomic assessments. Standing guidance may need to offer different advice to sitting or kneeling. However, as discussed previously, individuality of movement should still be considered.

Motion analysis systems are becoming increasingly portable and accessible allowing for more detailed investigations out of laboratory settings (Lu Bai et al. May 2012; van der Kruk and Reijne 2018; Wang et al. 2021). Research has investigated Microsoft Kinect in a supermarket setting and industrial workspace (Bortolini et al. 2020; Colombo et al. 2013). Both of these studies demonstrated potential for markerless systems such as Microsoft Kinect to be used to measure worker postures and allow for further ergonomic assessment. Motion capture systems in the workplace have the benefit of real workers performing real tasks (Colombo et al. 2013), such as this study which was conducted in the clinical setting.

It has been suggested that there is increased risk of disc compression when the trunk is flexed in sitting (Nachemson 1981). However, Nachemson's (1981) study was conducted 40 years ago, and the findings were based on intradiscal pressure changed in an *in vitro* study. In the present study, flexion at the lumbosacral joint was found when assisting tasks in sitting, especially sit-to-stand and lower limb treatments. Additionally, kneeling often showed increased flexion at the lumbosacral joint. Lumbosacral flexion in kneeling was identified as a position that scored highly when analysing physiotherapist movement with the RULA tool. Increased lumbosacral flexion could partly be compensation from increased hip flexion when sitting or kneeling. It was also observed that the physiotherapists were leaning forward towards the patient, which could increase the flexion angle. Recent improvements in spinal modelling allow spinal loading to be calculated using simulations with greater control over parameters of the material properties of spinal structures (Dreischarf et al. 2014; Dreischarf et al. 2016; Zander et al. 2016). Future research needs to revisit these positions of potential risk to provide up to date evidence to ensure what is taught ergonomically remains accurate. However, disc loading cannot be calculated from kinematics alone. Previously, MRI has been used to investigate disc properties during trunk movements and loading (Alexander et al. 2007; Edmondston et al. 2000). Findings from MRI based research could be used to guide research with a focus on investigating spinal loading in certain physiotherapist positions. In addition, a greater appreciation of disc movement during trunk movement and loading could be used when calculating spinal loads with biomechanical models.

Physiotherapist Shoulder Postures

Assisting sit-to-stand and trunk treatments in a sitting position were found to increase risk of shoulder discomfort using the RULA and literature (Punnett et al. 2000) to interpret physiotherapist positioning. However, the literature largely focuses on manual material handling in industrial sectors. Manual handling in healthcare settings requires moving of people rather than boxes or objects and the postures and positions of risk of WRMSD may differ (Punnett et al. 2000; Vieira and Kumar 2004). The only other task observed in this study to exceed the shoulder flexion threshold was assisting trunk treatments from a half-kneeling position. Shoulder flexion was maintained during three tasks: sit-to-stand from sitting positions, and trunk tasks from sitting and half-kneeling positions. These three tasks scored highly and demonstrated an increased risk of developing a WRMSD related to the maintained shoulder flexion. Increased shoulder flexion during sit-to-stand from sitting or half-kneeling would be expected as the physiotherapist was often assisting at the patient's hips during this task. When the patient is standing, the physiotherapist would have to reach up to the patient's hips due to the difference in height. The increased and sustained shoulder flexion could be difficult to avoid when the physiotherapist positioned lower in relation to the patient. Other positions and methods of facilitation could be explored to investigate if shoulder flexion can be reduced or if certain positional or time thresholds would reduce the risk of WRMSD at the shoulder.

The physiotherapist was often reaching forwards to the patient during treatments when sitting, kneeling and half-kneeling positions. An increase in subjective discomfort for participants has been found with increasing shoulder flexion angles (Lim et al. 2011). Increased subjective discomfort was found at the back, shoulders and upper limb moving from 0° to 130° shoulder flexion with the trunk upright by Lim et al in their study of 20 healthy male volunteers. When the participant's trunk was flexed forwards to 45°, there was increased discomfort reported when the shoulder over 90° flexion (Lim et al. 2011). In the current study, when the physiotherapists were kneeling, half-kneeling and sitting, they often demonstrated greater shoulder flexion and lumbosacral flexion to reach towards and up to the patient; this could increase their subjective discomfort. Additionally, the physiotherapists' shoulders were often found to be flexed for a longer duration of patient handling tasks, which suggests shoulder flexion was sustained. If performing multiple patient handling tasks through the day, the period of time spent in shoulder flexion could be significant and potentially increase risk of discomfort for physiotherapists (Punnet et al 2000). Research investigating cumulative loading stated that calculation methods can be used to adequately assess risk of WRMSD (Johnen et al. 2022). However, these calculation methods are dependent on the accuracy of the data related to exposure risk and cannot be used to assess muscular fatigue (Johnen et al. 2022). Further research is therefore required to explore cumulative loading in occupational settings.

Summary of Physiotherapist Movement

Overall, the physiotherapists were found to vary their movement and positioning during therapeutic handling tasks. There are many possible routes for future research investigating physiotherapists during therapeutic handling tasks. However, little evidence is currently available investigating physiotherapists performing patient handling from kneeling, half-kneeling and sitting positions. Sitting has been identified as a position of risk in relation to disc loading. Kneeling has been found to increase risk of joint degeneration and increased lumbar loading during manual handling tasks. This study found that kneeling, half-kneeling and sitting scored highly when assessed ergonomically due to the greater neck extension and lumbosacral flexion angles measured. Gaining a more detailed understanding into the positioning and loading experienced by physiotherapists in these three positions could provide a sound basis for developing guidelines or training.

6.1.2 Physiotherapist WRMSD

Within the physiotherapy cohort, six of the physiotherapists had experienced at least one WRMSD during their career. Three of these individuals had experienced a WRMSD in the last year. One participant required pain relief and sought advice from a healthcare professional. None of the participants who had experienced WRMSD in the last year had taken sick leave because of their discomfort. Campo et al. (2008) and Darragh et al. (2009) also found that physiotherapists and occupational therapists had not taken time off work as a result of their WRMSD and continued to work whilst experiencing discomfort. One prevention strategy to reduce WRMSD in healthcare is reporting WRMSD to senior staff and occupational health departments (Glover et al. 2005; Sharan and Ajeesh 2012). Improved reporting of WRMSD benefits the physical health of the physiotherapist by providing appropriate time to recover through adequate time off and work adaption (Glover et al. 2005). Furthermore, if WRMSD are reported accurately, the problem task or area can be identified, and solutions investigated (Glover et al. 2005). It is harder to solve an issue if the true scale of it is unknown, therefore accurate reporting of WRMSD is required to identify the nature and scale of the issue.

The physiotherapists involved in this study were not asked if they had reported their WRMSD, however this would be an interesting area to explore. There is a perception that physiotherapists are less likely to injure themselves as they understand the biomechanics of movement and injuries (Cromie et al. 2002; Graham and Grey 2005). This perception is potentially a harmful one as physiotherapists may consider themselves immune to developing WRMSD (Graham and Grey 2005). It is also suggested that physiotherapists believe they can manage their own WRMSD or will seek informal advice from colleagues if experiencing discomfort (Campo et al. 2008; Darragh et al. 2009; Glover et al. 2005). Informal advice may benefit the physiotherapist in the short-term and help reduce their discomfort; however, if WRMSD are improperly reported and hidden, interventions to improve safety may not happen (Glover et al. 2005). Previously, physiotherapists were found to have a lower incidence of WRMSD than other healthcare populations (Hignett 1995). However, the recorded incidence may be confounded by poor reporting of injuries within the profession, meaning that itis potentially higher in realty (Anderson and Oakman 2016; Cromie et al. 2002; Hignett 1995). If WRMSD are not reported, risk factors to injury cannot be investigated and potentially reduced (Glover et al. 2005).

There is a high prevalence of working through health problems, known as presenteeism, in healthcare populations (Campo and Darragh 2012; Lohaus and Habermann 2019; Santos et al. 2018). The perception that healthcare workers do not suffer illness or discomfort is thought to contribute to the high incidence (Santos et al. 2018). Research has found that female nurses experienced presenteeism more than male nurses (Santos et al. 2018; Skela-Savič et al. 2017). Female physiotherapists comprise 78% of registered physiotherapists in the UK (HCPC 2021); in this study all the physiotherapists involved were female. Female physiotherapists may experience presenteeism similar to that of female nurses and could contribute to high presenteeism within physiotherapists due to the high proportion of females within the profession (HCPC 2021). There is recent investigation into presenteeism and the impact that work-life balance, mental health, physical health and working relationships has (Hwang and Jung 2021). A holistic approach to investigating presenteeism in HCP could provide valuable insight into the factors involved with working through discomfort and sickness. The culture within physiotherapists and the perception that they are at less risk of injury could play a role in presenteeism. Future qualitative research using interviews or focus groups to investigate presenteeism in physiotherapists could identify barriers and facilitators to taking appropriate actions to WRMSD.

Graham and Grey (2005) found recently qualified physiotherapists (<5 years) perceived they were at less risk of injury due to their knowledge of human movement and mechanics. However, prevalence of WRMSD remains an issue within newly qualified physiotherapists, suggesting this perception is untrue (Glover et al. 2005; Graham and Grey 2005). In the current study, three of the physiotherapists were recently qualified (<5 years), one of whom had experienced a WRMSD. Further investigation of the contributing factors or rate of reporting their WRMSD to senior staff was not conducted in this study. Campo et al. (2008) and Darragh et al. (2009) found that WRMSD increased with age, especially over 55 years old. Bork et al. (1996) found contrasting results, fewer WRMSD were found with increasing age, suggesting that physiotherapists changed their practices after experiencing WRMSD, termed as 'survivor bias'. Graham and Grey (2005) similarly found through the use of focus groups that there is the perception that experienced physiotherapists learned from previous injuries and positions of discomfort. In the present study, the age of onset of WRMSD within the physiotherapists ranged between 25 and 55 years of age. It was not investigated if the physiotherapists had experienced discomfort in the same region more than once or if incidence decreased with experience. Therefore, further investigation of the incidence of recurrent WRMSD, and if physiotherapists who are more experienced have adapted their practice after they have experienced discomfort would be beneficial. Greater understanding of the physical and psychosocial factors involved in developing WRMSD could allow for improved measures to reduce WRMSD.

The most commonly recorded area of WRMSD in physiotherapists is the low back (Anderson and Oakman 2016; Campo et al. 2008; Darragh et al. 2009; Glover et al. 2005). The findings of this research are congruent with this, with six of the ten participants having experienced low back discomfort within their physiotherapy career. The average age of onset of back discomfort within this cohort was 36 years old, with the youngest 25 years old. The age of retirement is currently 66 years old within the UK and will increase by the time younger staff retire (Department for Work and Pensions 2022). There is therefore the potential for physiotherapists to experience WRMSD early on and for a large portion of their career. To potentially improve physiotherapists' physical and mental wellbeing throughout their career, more needs to be known about the safety of patient handling and reducing the cultural perception of injuries within the profession. Reducing the incidence of WRMSD in healthcare populations could have a positive impact on staffing levels and subsequently on staff workload.

Other anatomical areas that were less affected and showed similar incidence rates with the literature (Campo et al. 2008; Glover et al. 2005) were the upper back (10%), shoulder (10%), elbow (10%), hips/thighs (20%), knees (10%) and ankles (10%). Kneeling has been identified as a position associated with knee pain (Herquelot et al. 2014; Nahit et al. 2001). Increased loading is experienced in the lower limbs due to the greater flexion at the knees and ankles when kneeling (Wang et al. 2017). The cumulative effect of occupational kneeling has been found to alter gait patterns and has been suggested to increase risk of developing knee osteoarthritis (Kajaks and Costigan 2015). A high number of tasks were found to be performed by the physiotherapists in kneeling or half-kneeling positions in this study. Both in industrial sectors and healthcare, further research is required to investigate the cumulative loading effect of kneeling postures during occupational tasks.

No physiotherapists had experienced WRMSD at the neck or wrists in this study. This is in contrast with the literature investigating AHPs, where the neck and wrists are some of the more commonly affected regions (Anderson and Oakman

2016; Campo et al. 2008; Darragh et al. 2009; Glover et al. 2005). This contrast in wrist WRMSD incidence is likely due to the physiotherapist population investigated in the current study. Wrist WRMSD are commonly associated with outpatient musculoskeletal physiotherapists, rather than neurological rehabilitation, as a result of performing manual therapies (Anderson and Oakman 2016; Darragh et al. 2009; Shah et al. 2021). If future research investigates multiple physiotherapy specialties, the different treatments performed and areas of WRMSD should be considered.

Neck WRMSD incidence is reported to affect 15% to 33% of physiotherapists (Darragh et al. 2009; Glover et al. 2005). Despite the prevalence of neck pain found in physiotherapists, the risk factors for developing neck WRMSD are poorly discussed in comparison to hand and wrist WRMSD. From the findings of this research, the amount of time or range of neck extension could be a factor to consider in the future when investigating WRMSD.

6.1.3 Therapeutic Handling and Equipment

The physiotherapists included in this research worked in neurological rehabilitation. It has been noted that neurological rehabilitation physiotherapists often do not use equipment as frequently as is recommended (Ruszala and Musa 2005). The physiotherapists often rely on their own body to manually assist patients instead of using equipment (Sparkes 2000). There is debate within the literature about whether using equipment therapeutically could benefit both the patient and physiotherapy staff (Campo et al. 2013; Darragh et al. 2013; Ruszala and Musa 2005). Some physiotherapists have stated that equipment can, in theory, be used therapeutically (Darragh et al. 2013). However, other physiotherapists feel it may alter the 'normal' standing mechanics of a patient and, because of this, impact their independence in standing (Burnfield et al. 2013; Nelson et al. 2008). There is little evidence to discredit either statement, with many studies focusing on the safety benefits of lifting aids rather than physiotherapists' perceptions or preferences on the potential use of equipment therapeutically (Darragh et al. 2013).

From observation of the patient sessions, a variety of equipment and lifting aids were used to assist or support the patients. The physiotherapists were often therapeutically handling the patient in addition to the equipment or aids. There is therefore a compromise between patient safety, physiotherapist safety and therapeutic benefit related to the use of equipment in physiotherapy. It is unlikely that lifting aids used in clinical settings will suit the range of specific and varied patient needs within neurological rehabilitation; suggesting that therapeutic handling may not always be reduced through the use of equipment. In addition, if little is known about potential benefits or suggested use of equipment for rehabilitation, physiotherapists may continue to manually facilitate these treatments. Further research on physiotherapists' perceptions of lifting aids and investigation of the feasibility of developing therapeutic aids could benefit patient rehabilitation while reducing the loading experienced by physiotherapists.

6.1.4 Materials

Xsens MTw Awinda System

Full body movement of the physiotherapists was measured using the Xsens MTw Awinda system. Xsens has been used in sporting and industrial settings previously (Roetenberg et al. 2013). A strength of the Xsens systems is the additional freedom of data capture in a larger area of the room, and out of laboratory settings (Pedro et al. 2021; Schepers et al. 2018). Recently, Xsens has been used in healthcare settings to investigate movement of nurses (Callihan et al. 2021). Callihan et al. (2021) tested the feasibility of a patient handling intervention, with the Xsens system used to measure the lever arm distance rather than full body motion. Callihan et al. (2021) investigated nursing students in a laboratory setting with a mannequin as the patient. They stated that future research would benefit from using a live patient and qualified nurses.

Xsens has also been used to investigate the difference in handler shoulder and trunk position when using a glide sheet to assist a patient's movement in bed (Amini Pay et al. 2021). Amini Pay et al. (2021) investigated informal carers performing patient handling tasks in a laboratory environment with a volunteer patient. Amini Pay et al. (2021) and Callihan et al. (2021) both successfully measured handler movement during patient handling tasks with the Xsens system in a laboratory setting. Xsens MTw Awinda has been used to measure HCP movement previously but has not been used in the clinical environment until the current study which measured physiotherapist movement. Xsens MTw Awinda is portable and minimally invasive for both handler and patient, allowing for measurement of physiotherapist movement during patient treatments. For future research, it would be beneficial to explore if there is a more secure method of positioning or attaching the knee and ankle tracker units. These tracker units were vulnerable to being slightly moved or knocked due to the frequent kneeling positions used by the physiotherapists in the neurological setting.

Rapid Upper Limb Assessment Tool

The RULA ergonomic tool has been used for assessment of a variety of healthcare workers previously (Kakaraparthi et al. 2022). Dentists were identified as higher risk, with pharmacists' lower risk of WRMSD when assessed with the RULA. The RULA has been used to investigate nurses and nursing assistants in the Philippines (Robielos et al. 2018). However, many of the patient handling tasks performed in Robielos et al's (2018) research, such as Australian shoulder lift and underarm drag lift, are strongly discouraged in the UK due to the risk of injury for both patient and staff (Chadwick and Titcomb 2008; Chell 2003). Robielos et al. (2018) also found that six of the nine hospital units assessed scored highly with the tool and recommended that changes were implemented.

Although not used in its intended manner, the RULA allowed for a crude assessment of the risk involved in the tasks and physiotherapist positions observed in this research. An effective ergonomic assessment tool in physiotherapy would need to be sensitive to the diversity of positions and the dynamic nature of patient handling. If an ergonomic assessment tool appreciated the diversity of patient handling in physiotherapy, the positions, postures and tasks performed could be more accurately assessed for risk of WRMSD.

The materials used for this study allowed for the first ward-based measurement of physiotherapist movement with patients. The Xsens MTw Awinda system is appropriate for further investigation of patient handling in the clinical setting. For future research, investigating a method of attaching the trackers to the lower leg and foot to reduce their movement during kneeling positions would improve the recording of the lower leg. Further research on therapeutic handling performed in different clinical settings is required with patients on active treatment. The recent availability of accurate portable motion analysis systems, such as Xsens MTw Awinda, now allows for this.

6.2 Strengths and Limitations

The main strength of this research was the use of a portable motion analysis system in the clinical environment with physiotherapists and patients. The Xsens MTw Awinda system allowed for measurement of physiotherapist movement in the clinical setting with real patients. This allowed for a more naturalistic investigation of patient handling during treatments as there was minimal influence on the tasks being performed during recording. Xsens is not the gold-standard for motion analysis; optoelectronic systems such as Vicon are. There was, therefore, less control over external variables than a laboratory-based study. However, in a laboratory setting, physiotherapists would be instructed to perform certain tasks. These laboratory tasks would allow for accurate measurement of physiotherapist movement. However, there is the potential for increased observer bias, increased awareness of the task being performed and the likely use of a simulated patients in the laboratory setting.

Measurement in the clinical setting allowed for a more realistic representation of the range of patient handling treatments, durations they were performed for, handling and positioning used. The Xsens MTw Awinda system was appropriate for use in the clinical setting as it was quick to set up and calibrate and had minimal impact on movement and positioning. These factors also allowed for minimal impact to the physiotherapist's clinical day and the patients' treatment sessions. Xsens MTw Awinda allowed for live recording of physiotherapist movement, with only small portions of data affected by tracker displacement at the knee and foot. If the trackers were affected, it was when the physiotherapists were kneeling or half-kneeling. The physiotherapist's foot position when kneeling often affected the tracker unit, as the dorsal surface of the foot was on the plinth or floor. The knee tracker was moved less often than the foot and was often dependent on how the physiotherapist was kneeling. For this study, the ankle was excluded due to the lower incidence of injury found in the cohort and the wider evidence base (Glover et al. 2005), in addition to the affected data. The knee data could still be included as fewer trials were affected by the tracker displacement.

Another strength of the system and data collection was that physiotherapist movement could be measured in the clinical setting despite the ongoing COVID-19 pandemic. The data was collected during the summer months of 2021 when lockdown measures were still in place and socialisation limited. The system could be worn under PPE and allowed the researcher to adhere to strict social distancing measures after placing the system on the participant. These measures allowed for COVID-safe data collection for the researcher, participants and patients.

When the physiotherapists were kneeling, occasionally the tracker units moved or were knocked. This was difficult to avoid due to the locations they were attached to. When the trackers were significantly knocked and the resulting data were affected, the time of recording was noted in the field notes by the researcher. Noting the time when data was affected allowed for removal of erroneous data before processing. However, the risk of trackers or reflective markers being knocked or occluded would arguably remain with other motion analysis systems. When using an optoelectronic motion analysis system, such as Vicon, the ASIS markers are often occluded (McClelland et al. 2010). Marker occlusion has been found to affect the accuracy of movement recorded (Conconi et al. 2021). The Xsens trackers could be moved when the physiotherapist was kneeling. To reduce tracker movement, the lower leg trackers could be secured further with wider straps, or by padding round the sensor to limit the impact if knocked. This is something that could be piloted before future research to investigate the most secure method.

A limitation related to the method of data processing was defining the start and end points for separation of patient treatments. The treatment sessions were observed, and field notes of the task and estimated start and end frame counts taken during each session. However, the recording rate was 60fps which meant noting the exact frame count was difficult due to the speed of recording. The frame count was used in combination with physiotherapist movement viewed in the Xsens MVN Analyze software to define each treatment's start and end frames. This may have created some inaccuracies as only the physiotherapist could be seen in the Xsens MVN Analyze software. Concurrent Video recording of the treatment sessions would arguably improve the accuracy of defining start and end times of tasks. However, video recording may arguably have impacted staff and patient participation as they may not have felt comfortable with this. Video recording research has been found to impact participant behaviours, with communication and performance improving due to awareness of being recorded (Haidet et al. 2009; Happ et al. 2008). Filming the sessions may be more at risk of a safety observer effect for both physiotherapists and patients. Participants may change treatments or handling practices to ones deemed 'safer' by the participant, and these practices may not be reflective of normal practice (Alvero et al. 2008). A period of acclimatisation has been found to reduce the awareness of being recorded (Happ et al. 2008).

Another method to indicate the start and stop times of the task could be to use external devices such as a switch or pressure sensor. These systems could be used to automatically note the time when weight is placed onto or removed from the device. These devices could either be placed under the patient, controlled by the physiotherapist, or by an external observer. If the start and end times were automatically recorded, these values could be used with Xsens to identify the individual tasks and would likely be more accurate than manually noting the frame count. Pressure switches have been used to indicate task start and end times by Harbert et al. (2012).

Although not formally investigated, it was hoped the system had minimal impact on physiotherapist movement during the data collection day. The participants did not state that the trackers were uncomfortable or limited certain positions or tasks during the sessions. The number of trackers is limited compared to other motion analysis systems, such as Vicon, and the trackers were attached with unobtrusive straps. The physiotherapists did dislodge the sensors occasionally which could suggest they felt comfortable wearing the system and they were focused on the treatment rather than the system. At the start of the data collection day the physiotherapists were encouraged to perform their patient treatments as normal. After this, the researcher observed and noted patient tasks and physiotherapist positioning and was not involved in any aspect of the patient treatments. There may have been a small element of change in physiotherapist handling and posture due to awareness of being measured (Hawthorne effect) (Oswald et al. 2014; Sedgwick and Greenwood 2015). It was hoped that the physiotherapist would focus on the patient interaction and reduce any observer effect. The physiotherapists may have become more comfortable wearing the system over the duration of the data collection day, this could allow for more realistic patient-provider interactions and movements.

Another method of identifying each patient treatment in the data could be to individually record each specific patient treatment as it happened in the session (e.g., record only a sit-to-stand task). However, there is potential for a substantial number of recordings, and this may not be feasible if treatments are performed quickly in succession. In addition, it may be difficult to decide when one treatment starts without interacting with the physiotherapist which could impact their practice. The method of treatment organisation worked for this research due to the exploratory nature. It allowed for more flexibility of task separation as the full range of patient tasks was not known in advance as they happened organically during patient treatments.

Movement and variation was found between physiotherapist positions during patient treatments. To allow feasible processing of data the position most of the task was performed in was used as the physiotherapist position. However, occasionally they would move from standing to squatting or kneeling temporarily. This may affect the overall presentation of percentage time of task in joint ranges.

Due to the variation of specific treatments included in some tasks, not all data could be time-normalised. Lie-to-sit and sit-to-stand have more defined start and end points based on the position of the patient, allowing comparison between all physiotherapists. Walking was not included in time-normalised analysis as amount of walking performed varied depending on ability of the patient. Some treatments consisted of a few steps whilst others walked the length of the ward (~50 metres). The time normalised data was a strength of this study as it allowed for additional descriptive analysis of the physiotherapists with specific movements identified during the patient handling tasks. The time normalised data allowed for description of physiotherapist position and movement over the duration of the task, in addition to proportion time spent in joint positions.

Ten physiotherapists were included in this research. The scoping review identified 12 records that investigated kinematics during patient handling. The average sample size of these studies was 25.25 (SD 16.41), with a range of 2-45. The studies with a larger sample size measured kinematics with tools such as inclinometers or goniometers (Hodder et al. 2010; Holmes et al. 2010; Larouche et al. 2019; Vieira and Kumar 2009). Three of these studies were observational studies and Vieira and Kumar (2009) was a cross-sectional study design. All four of these studies investigated trunk motion rather than full body motion, therefore a larger sample size may have been more feasible to analyse. The sample size of this research fits within the range reported by the previous research and allowed for in-depth exploration of movement as a large volume of data was collected despite the relatively small sample size. A larger sample size would provide more movement data and potentially highlight similarities and differences between positions and tasks. However, the volume of data would be more time-consuming to process and analyse. As this study was exploratory, the sample size was large enough to demonstrate variations in physiotherapist positions, patient tasks and postures, while remaining manageable for data processing.

Ergonomics literature stated an increased risk of WRMSD when 10% of the working day was spent over 90° shoulder flexion (Punnett et al. 2000). Due to the method of data processing and analysis, the 10% threshold was adapted to 10% of the patient handling task to provide an indication of tasks that required a greater duration of shoulder flexion. It would not be feasible to process the quantity of data recorded over the day as one single recording. Future research into the potential risks involved with shoulder flexion would be beneficial. Investigating the sustained and repetitions of shoulder flexion could provide more detailed information on potential risk factors during therapeutic handling.

There are many ergonomic assessment tools available for analysis of working postures. The RULA was chosen as it has shown good inter and intra-rater reliability, has been used within the healthcare setting and has been found to be more sensitive to predicting WRMSD when compared with other ergonomic tools (Kee 2022; Robielos et al. 2018). However, the RULA is used to assess static postures. The nature of the physiotherapist positioning during patient treatment sessions is dynamic; however, the RULA was used to provide an indication of how physiotherapists could score against the set thresholds and provide more clinically applicable descriptions of movement. To adequately and accurately assess the risk of WRMSD to physiotherapists, a tool with the ability to assess more dynamic and varied postures is required. As highlighted in this research, the physiotherapists positioned themselves in kneeling and half-kneeling positions, which ergonomics literature and tools rarely consider. The RULA tool and shoulder thresholds still allowed for identification of tasks and positions that could potentially increase the risk of WRMSD related to therapeutic handling.

The ergonomic assessment of physiotherapist position also potentially identified treatments and positions that deserve further investigation and consideration.

Much of the literature and guidelines used within moving and handling in healthcare has not been published or updated recently. This may have affected the positioning of the research findings within the wider literature as moving and handling has changed in recent years (Wanless 2016). It appears much of moving and handling is based on experience or historic methods which have a poor base of evidence to support them.

6.3 Recommendations for Future Research

The scoping review and subsequent exploratory research has identified a large range of potential future research. This was the first research using the Xsens MTw Awinda system to investigate physiotherapist movement during neurological rehabilitation. Xsens MTw Awinda was shown to be a feasible and appropriate system for measuring movement in a clinical setting and should be used for future research in the healthcare setting. The directions for future research are discussed in three areas, 1) physiotherapist movement and loading; 2) qualitative research into therapeutic handling; 3) ergonomics and WRMSD.

6.3.1 Physiotherapist Movement and Loading

Future research into therapeutic handling could investigate physiotherapist movement and/or loading with a variation of physiotherapy staff populations, tasks or movements involved.

Xsens System to Measure Movement

Further use of Xsens, or similar portable motion analysis systems, could expand on this research with a larger number of participants. A larger sample size would allow the findings to be more applicable to the wider physiotherapy population and allow for analysis of subgroups for each physiotherapist position and patient handling task.

Physiotherapy Clinical Areas and Health Boards

Neurological rehabilitation is a manually intensive area of physiotherapy due to the commonly used treatment techniques. It would be beneficial to investigate in detail if patient handling varies in different clinical areas, and if so, any potential positions or tasks that increase risk in those specific areas. Other clinical areas that would benefit from investigation include outpatient musculoskeletal, frailty, orthopaedics, and paediatrics, as these have been found to have a higher incidence of WRMSD (Glover et al. 2005). These clinical specialties involve different patient populations, types of injury presentation and potentially methods of treatment. More needs to be known in all areas of physiotherapy to develop effective guidance and reduce risk of injury.

The way physiotherapists position themselves and utilise therapeutic handling, as well as the uniformity of general moving and handling practices across clinical areas of health boards needs further investigation. Manual handling training may vary depending on whether the moving and handling passport is used a particular health board (HSE 2014). However, individual variation and preference for lifting techniques should be appreciated when developing guidelines or training. Considering the large variation in treatments, facilitation and physiotherapist positions seen throughout a working day, investigating methods that streamline and speed up data processing would allow for efficient analysis of larger cohorts.

Physiotherapy Staff Populations

Newly qualified physiotherapists are found to have increased incidence of WRMSD (Glover et al. 2005; Graham and Grey 2005). Investigating kinematics and kinetics to explore whether they move and handle patients differently to experienced staff could help reduce the risk of injury early in their careers. Movements or techniques used by more junior physiotherapists to facilitate patients that require more extreme postures or loading could be identified and training developed to avoid these postures.

Investigation of healthcare support workers would also provide valuable information in this field. These staff members are also required to complete manual handling training and, despite not having formal physiotherapy training, are still involved with patients therapeutically.

Therapeutic Handling Tasks and Physiotherapist Position

Further investigation of all patient handling tasks will likely be required due to the small sample size in this research. However, sit-to-stand, trunk, standing and walking treatments showed more variation between physiotherapist positions and identified that they had the potential to result in higher injury risk scores with ergonomic assessments. A study with a larger cohort would allow for investigation of specific physiotherapist positions and also of their position in relation to the patient. This could identify whether physiotherapists have a preference in position in relation to patients due to their handedness. Another factor involved in physiotherapist positioning could be the patient's affected side. More patients had left sided weakness in this study which could have impacted how the physiotherapists positioned themselves. A larger cohort with analysis focused on one position or patient task could also provide more detailed analysis of movement. Combining kinematics with physiotherapist perceptions and experiences could allow for a comprehensive understanding of therapeutic handling.

Further investigation of patient handling from positions other than standing would be beneficial to the area. These positions are rarely considered in the literature and manual handling training. Much of the literature has investigated industrial sectors and provides a useful basis for research. However, patient handling performed while in kneeling, half-kneeling, and sitting is likely to be unique to healthcare. More needs to be understood about any potential risks or benefits of performing patient treatments in these positions.

Kinetics

Future research investigating the kinetics during therapeutic handling is required. Investigating this in the laboratory setting would allow for the use of force plates to investigate the loading and ground reaction forces involved with each physiotherapist position. In addition, investigation of the spinal loading could identify positions or tasks which increase the risk of WRMSD to the handler.

6.3.2 Qualitative Research into Therapeutic Handling

Quantitative research, in combination with, qualitative investigation into physiotherapist experiences and opinions could provide a comprehensive understanding of therapeutic handling by physiotherapists.

Perceptions and Beliefs

Investigation of physiotherapists' perceptions and beliefs, following or in combination with kinematics, could provide insight into whether patient handling changes with experience or professional qualification. Focus groups or interviews could be conducted to gain insight into tasks and to explore whether experience changes physiotherapists' perceptions. If physiotherapists are shown photographs of video recordings of patient handling manoeuvres, their perceptions of the handling being performed could be investigated. Greater understanding into what is perceived as good or poor handling and why could allow for improved development of guidelines or training.

Focus groups or interviews with physiotherapists could investigate the culture of moving and handling within physiotherapy. Investigation of opinions on application of moving and handling guidance would allow for identification of areas of strength or weakness. If guidance is not applicable clinically, there is a risk that is will not be followed. Patient handling is varied, and many tasks could depend on both patient and external factors, such as setting, availability of staff and equipment. If guidelines or risk assessments were created with external factors considered, there is potential they will be more clinically relevant. Additionally, if physiotherapists feel they are less at risk of injury due to age or increased knowledge of human movement they are potentially unlikely to change their practice. Therefore, clear and practical advice would be required for potential culture change towards safer patient handling.

Ethnographic Research

The scoping review identified the requirement for ethnographic research into patient handling in healthcare as this could provide beneficial information to the evidence base. More needs to be known about what tasks physiotherapists find manually intensive or uncomfortable, use of equipment therapeutically, and barriers or facilitators to following safe patient handling principles. Qualitative investigation of patient handling accompanied by biomechanical analysis of physiotherapist movement could enhance the knowledge base. It could also provide a comprehensive investigation with potential for improved guidance and training. If physiotherapists perceive guidance as not applicable to their practice, they may not follow it; therefore understanding barriers and facilitators could allow for guidance that is applicable clinically. Physiotherapist perceptions of physical effort during patient handling tasks could be compared against physiotherapist movements, muscle activity, or loading. This data could then investigate if tasks physiotherapists perceive as easier or more difficult match with the biomechanical analysis. If a mismatch between actual and perceived effort is evident it could result in more risky positioning and patient handling tasks. However, physiotherapist behaviour may change when being directly observed in this manner.

Clinical Reasoning or Personal Preferences

Correct principles of moving and handling is introduced to physiotherapy students at university. A disconnect between what is taught at university and what is used in practice has been identified (Kneafsey et al. 2012; Mc Grath et al. 2015). Unsafe moving and handling practices were found to occur in clinical settings by Kneafsy et al. (2012) and McGrath et al. (2015), with students often not challenging the qualified staff (Kneafsey et al. 2012). If the clinical reasoning behind choices of treatments, positioning and facilitation areas performed by qualified physiotherapists is investigated, training for student physiotherapists could also be improved. This may additionally improve student physiotherapists' confidence with patient treatments and handling in the clinical setting. However, if the students are on clinical placement and the physiotherapists they work with do not adhere to safe moving and handling, they may not use the skills in practice.

Moving and Handling Training

Focus groups or interviews with manual handling trainers would also provide a useful perspective into moving and handling in healthcare. These teams are often consulted for complex moving and handling issues in healthcare (communication with manual handling advisor). Focus groups could include only moving and handling trainers. However, a multi-disciplinary group could stimulate more discussion and potentially identification of barriers and facilitators and how these differ between departments. Moreover, further clarity of the justification behind moving and handling principles and training are required. To allow manual handling to follow evidence-based practice, a large enough and appropriate evidence base is required.

6.3.3 Ergonomics and WRMSD

Future research surrounding the risk of WRMSD related to therapeutic handling could allow interventions into reducing the risk of injury to be investigated.

Positions of Increased Risk of WRMSD

Another position identified as increasing risk of discomfort for the physiotherapists was neck extension. Research could be conducted to investigate a time limit for extension, positions of comfort, stretches or interventions, training the individual to meet the work demands and reduce discomfort during patient tasks. It is unlikely that neck extension can be avoided during these tasks; therefore, research aiming to reduce the adverse effects may be more clinically relevant and beneficial.

WRMSD and Presenteeism

As found in this research, the physiotherapists had not taken sick leave due to their WRMSD. In future research, accessing occupational health referrals may provide a useful insight into staff who adapt roles rather than take sick leave. This may provide a more accurate incidence of WRMSD within healthcare populations.

Real-Time Ergonomic Assessment

With the improvement of motion capture systems and the portability of Xsens MTw Awinda, more research should be conducted in the healthcare setting. To improve the use of the system clinically, results need to be quick and easy to understand and apply to practice. A potential way to measure and assess physiotherapist movement in this way could be to link the Xsens MTw Awinda system with an online ergonomic assessment tool. This could allow for assessment of postures and flag specific tasks, or positions based on the joint measurements. This could provide clinically relevant and specific data to the area while appreciating the dynamic and varied nature of therapeutic handling. If certain ranges of joint angles individually, or combined (e.g., the trunk) were known, they could be applied automatically to the avatar created in Xsens MVN Analyze. This would allow for flagging of dangerous postures as they occur and also in-depth analysis after data recording was completed. This would allow identification of physiotherapist positions or movements that are higher risk of discomfort.

6.3.4 Recommended Research Summary

This study identified many possibilities for future research into therapeutic handling. Some potential priorities for future research include:

- Investigation of therapeutic handling from sitting or kneeling positions.

- Investigation of sit-to-stand, trunk, standing and walking facilitation tasks.
- Ethnographic research with or without biomechanical analysis of physiotherapist movement.
- Calculation of loading experienced during therapeutic handling.

6.3.5 Recommendations for Practice

Due to the exploratory nature of this research, making recommendations for practice are difficult. However, this research did identify that physiotherapists perform a large variety of therapeutic handling tasks from sitting or kneeling positions. A large number of patient handling tasks were performed in sitting or kneeling. Manual handling training teaches you safe handling principles from a standing position, however, it may be more challenging to apply these principles from different positions. The risk of injury in positions such as sitting or kneeling is not known in a physiotherapy context. However, previous ergonomic research has identified possible risk of injury related to maintaining a position or how loading changes. To develop training and guidelines that improve safety during therapeutic handling, more needs to be understood around the positions, tasks, forces and demands involved. Work-related musculoskeletal disorders are multifactorial, therefore, interventions to reduce these will also likely require multiple aspects to be effective.

7 CONCLUSION

This doctoral thesis has investigated manual patient handling by physiotherapists in the clinical setting. The scoping review (Chapter 2) identified several gaps in the literature surrounding manual handling and in particular therapeutic handling by physiotherapists. One gap that was identified was the lack of research exploring therapeutic handling by physiotherapists in the clinical setting. This research aimed to address the gap of limited primary research investigating physiotherapists in the clinical setting while performing therapeutic handling. A portable 3D motion analysis system, Xsens MTw Awinda, was used to measure full body movement of physiotherapists during patient handling tasks in the clinical setting with patients on active treatment. This is the first study, to the author's knowledge, that has measured full body movement in the clinical setting. Conducting the research in the clinical setting allowed for a more naturalistic exploration of therapeutic handling in the neurological setting. The findings of this study identified eight frequently performed tasks performed by physiotherapists during neurological rehabilitation. The physiotherapists' adopted four common positions during each of the eight patient handling tasks and identified which positions that potentially increased risk of WRMSD.

The key findings from the research were that therapeutic handling tasks were often performed from kneeling or sitting positions rather than in standing. This is in contrast with moving and handling guidance and training, which generally assumes the person performing patient handling is in a standing position. Future guidance and training should consider the variation of positions that are actually used by physiotherapists during therapeutic handling.

The physiotherapists were found to extend their neck to look up to the patients when in kneeling, half-kneeling and sitting positions. Neck extension scored highly with the RULA and suggests an increased risk of WRMSD associated with conducting therapeutic handling in kneeling and sitting positions.

Standing demonstrated greater cervicothoracic flexion during therapeutic handling than kneeling or sitting, both of which demonstrated a more neutral cervicothoracic posture. However, kneeling and sitting demonstrated greater lumbosacral flexion during therapeutic handling than standing which was closer to neutral posture. The RULA considers the trunk as one segment, whereas this research analysed the trunk as three separate segments. Differences in cervicothoracic and lumbosacral postures were found to be dependent on the physiotherapist position. Future research around ergonomic assessment of physiotherapist movement would benefit from considering the trunk into different segments.

Sit-to-stand, trunk, standing and walking tasks scored highly with the RULA, indicating an increased risk of developing WRMSD, and would benefit from further detailed investigation into the movement, loading and physical demands involved. The physiotherapist’s position in relation to the patient (e.g., to the right, or behind the patient) and any impact on the movements and postures involved during therapeutic handling could also be investigated.

The lumbosacral region was the area with the highest incidence of WRMSD within the physiotherapist cohort. Other areas of WRMSD included the shoulders, upper back, elbows, hips, and knees. Physiotherapists had altered their duties previously, sought professional advice and taken medication as a result of their WRMSD. However, none of the participants had taken sick leave in the last 12 months. These findings are congruent with the wider body of literature surrounding WRMSD in physiotherapist populations, suggesting there is a culture within physiotherapy of poorly reporting injuries at work. As identified from the scoping review, qualitative research to explore physiotherapists’ experiences and perceptions of moving and handling and current training provision needs to be investigated. Future research on specific patient tasks, physiotherapist positions, and different specialties would be beneficial to further understand the movements and postures involved with therapeutic handling. Understanding more about the movements, postures, barriers and facilitators to safe patient handling will aid development of effective training and guidelines for physiotherapists.

This study has comprehensively quantified, described, and ergonomically assessed physiotherapist movement during therapeutic handling. In addition, the incidence of WRMSD within the physiotherapy cohort was investigated and potential tasks of increased risk or WRMSD hypothesised. This study found that physiotherapists adopt a variety of positions to perform therapeutic handling from. Positions such as kneeling and sitting could increase risk of WRMSD due to postures that are discouraged in ergonomics. This new knowledge needs to be used to guide future research into movement, loading and perceptions; ultimately allowing for development and implementation of effective training and guidance for physiotherapists.

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APPENDIX

1 Full Search Strategy

AMED (via EBSCOhost)

Search conducted 12 August 2020

Search	Query	Records retrieved
#1	TX moving and handling OR KW manual handling OR TX manual handling OR KW (moving and lifting patients) OR TX (moving and lifting patients) OR TX patient handling OR TX patient moving and handling OR TX patient positioning	399
#2	KW nurse OR TX nurs* OR KW physiotherapy OR KW physiotherapist TX physiotherap* OR KW physical therapy OR TX physical therap* OR KW allied health personnel OR TX allied health* OR TX support staff OR KW rehabilitation OR TX rehabilitation OR KW occupational therapist OR KW occupational therapy OR TX occupational therap*	127601
#3	#1 AND #2	319
Limited to English language		

AMED (via EBSCOhost)

Updated search conducted 10 November 2021

Search	Query	Records retrieved
#1	TX moving and handling OR KW manual handling OR TX manual handling OR KW (moving and lifting patients) OR TX (moving and lifting patients) OR TX patient handling OR TX patient moving and handling OR TX patient positioning	408
#2	KW nurse OR TX nurs* OR KW physiotherapy OR KW physiotherapist TX physiotherap* OR KW physical therapy OR TX physical therap* OR KW allied health personnel OR TX allied health* OR TX support staff OR KW rehabilitation OR TX rehabilitation OR KW occupational therapist OR KW occupational therapy OR TX occupational therap*	131747
#3	#1 AND #2	347
#4	#1 AND #2 (Limited to literature since August 2020)	0
Limited to English language		

CINAHL (via EBSCOhost)

Search conducted 10 November 2021

Search	Query	Records retrieved
#1	TX moving and handling OR TX patient moving and handling OR MH patient positioning OR TX patient positioning OR TX transfer* technique* OR TX manual handling OR TX moving and lifting patients	24460
#2	MH nurses OR TX nurs* OR TX physiotherap* OR MH physical therapy OR TX physical therap* OR MH rehabilitation OR TX rehabilitation OR MH allied health personnel OR TX allied health* OR TX support staff OR MH occupational therapy OR TX occupational therap*	3052157
#3	#1 AND #2	17814
#4	TX guidance OR TX guidelines OR TX practice guidelines OR TX clinical practice guidelines OR TX protocol OR TX regulation	800153
#5	#3 AND #4	8317
#6	MH ergonomics OR TX ergonomic* OR TX human factors	19336
#7	#5 AND #6	1304
Limited to English language		

EMBASE (via Ovid)

Search conducted 12 August 2020

Search	Query	Records retrieved
#1	KW moving and handling OR TX moving and handling OR KW moving and lifting patients OR TX moving and lifting patients OR KW manual handling OR TX manual handling OR KW patient handling OR TX patient handling OR KW patient moving and handling OR TX patient moving and handling OR KW patient positioning OR TX patient positioning	9542
#2	KW nurse OR TX nurs* OR KW physiotherapist OR KW physiotherapy OR TX physiotherap* OR KW physical therapy OR KW physical therapist OR TX physical therap* OR KW allied health personnel OR KW allied health professional OR TW allied health* OR KW support staff OR TX support staff OR KW rehabilitation OR TX rehabilitation OR KW occupational therapist OR KW occupational therapy OR TX occupational therap*	805052
#3	#1 AND #2	892

EMBASE (via Ovid)

Updated search conducted 10 November 2021

Search	Query	Records retrieved
#1	KW moving and handling OR TX moving and handling OR KW moving and lifting patients OR TX moving and lifting patients OR KW manual handling OR TX manual handling OR KW patient handling OR TX patient handling OR KW patient moving and handling OR TX patient moving and handling OR KW patient positioning OR TX patient positioning	7765
#2	KW nurse OR TX nurs* OR KW physiotherapist OR KW physiotherapy OR TX physiotherap* OR KW physical therapy OR KW physical therapist OR TX physical therap* OR KW allied health personnel OR KW allied health professional OR TW allied health* OR KW support staff OR TX support staff OR KW rehabilitation OR TX rehabilitation OR KW occupational therapist OR KW occupational therapy OR TX occupational therap*	879357
#3	#1 AND #2	881
#3	#1 AND #2 (Limited to literature since August 2020)	112

MEDLINE (via EBSCOhost)

Search conducted 12 August 2020

Search	Query	Records retrieved
#1	TX moving and handling OR TX moving and lifting patients OR TX manual handling OR TX patient handling OR TX patient moving and handling OR MH patient positioning OR TX patient positioning	16766
#2	MH nurses OR TX nurs* OR TX physiotherap* OR TX physical therap* OR MH allied health personnel OR TX allied health* OR TX support staff OR MH rehabilitation OR TX rehabilitation OR MH occupational therapy OR TX occupational therap*	1773156
#3	#1 AND #2	2735
Limited to English language		

MEDLINE (via EBSCOhost)

Updated search conducted 10 November 2021

Search	Query	Records retrieved
#1	TX moving and handling OR TX moving and lifting patients OR TX manual handling OR TX patient handling OR TX patient moving and handling OR MH patient positioning OR TX patient positioning	19413
#2	MH nurses OR TX nurs* OR TX physiotherap* OR TX physical therap* OR MH allied health personnel OR TX allied health* OR TX support staff OR MH rehabilitation OR TX rehabilitation OR MH occupational therapy OR TX occupational therap*	1979659
#3	#1 AND #2	3725
#3	#1 AND #2 (Limited to literature since August 2020)	551
Limited to English language		

SPORTDiscus (via EBSCOhost)

Search conducted 10 November 2021

Search	Query	Records retrieved
#1	KW moving and handling OR TX moving and handling OR KW patient moving and handling OR TX patient moving and handling OR KW moving and lifting patients OR TX moving and lifting patients OR KW manual handling OR TX manual handling OR KW patient handling OR TX patient handling OR KW patient positioning OR TX patient positioning OR TX transfer* technique*	8977

#2	KW nurse OR TX nurs* OR KW physiotherapist OR KW physiotherapy OR TX physiotherap* OR KW physical therapist OR KW physical therapy OR TX physical therap* OR KW allied health personnel OR KW allied health professional OR TX allied health* OR KW support staff OR TX support staff OR KW rehabilitation OR TX rehabilitation OR KW occupational therapy OR KW occupational therapist OR TX occupational therap*	242724
#3	#1 AND #2	3144
#3	#1 AND #2 (Limited to literature published after 2002)	2725
Limited to English language		

Google Scholar

Search conducted 12 August 2020

Search	Query	Records retrieved
#1	"Patient handling" AND "healthcare"	150
#2	"Moving and handling" AND "healthcare"	150
#3	"Moving and handling" AND "patients"	150
#4	"Manual handling" AND "healthcare"	150
#5	"Manual handling" AND "patients"	150
Records hand selected for screening		

ETHOS

Search conducted 12 August 2020

Search	Query	Records retrieved
#1	Moving and handling in healthcare	10
#2	Moving and handling of patients	14
#3	Manual handling in healthcare	12
#4	Manual handling of patients	7
Records hand selected for screening		

Open Grey

Search conducted 12 August 2020

Search	Query	Records retrieved
#1	Moving and handling in healthcare	1
#2	Moving and handling of patients	2
#3	Manual handling in healthcare	1
#4	Manual handling of patients	1

HSE

Search conducted 12 August 2020

Search	Query	Records retrieved
#1	Moving and handling in healthcare	260

Records hand selected for screening	

NIOSH

Search conducted 12 August 2020

Search	Query	Records retrieved
#1	Moving and handling in healthcare	390
Records hand selected for screening		

Safe Work Australia

Search conducted 7 July 2021

Search	Query	Records retrieved
#1	Moving and handling in healthcare	236
#2	Safe patient handling	715
#3	Moving and handling of patients	234
Records hand selected for screening		

Canadian Centre of Occupational Health and Safety

Search conducted 7 July 2021

Search	Query	Records retrieved
#1	Moving and handling in healthcare	3986

#2	Safe patient handling	3014
#3	Moving and handling of patients	3983
Records hand selected for screening		

Worksafe New Zealand

Search conducted 7 July 2021

Search	**Query**	**Records retrieved**
#1	Moving and handling in healthcare	1000
#2	Safe patient handling	1000
#3	Moving and handling of patients	1000
Records hand selected for screening		

2 Full Text Excluded and Reasons for Exclusion

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3 Primary Research Aspects References

Questions Addressed by the Research (n = 36)	
Physical demands during manual patient handling	(Cantarella et al. 2020; Garzillo et al. 2020; Howard et al. 2013; Kang et al. 2013; Kurowski et al. 2012; Larouche et al. 2019; McCoskey 2007; Stringer and Rice 2014; Vieira and Kumar 2009; Wångblad et al. 2009)
Patient handling practice and tasks performed	(Chen et al. 2014; de Ruiter and Liaschenko 2011; Fiedler et al. 2012; Hodder et al. 2010; Holmes et al. 2010; Kim et al. 2015; Kjellberg et al. 2003; Kurowski et al. 2012; Kyriakidis et al. 2021; Larouche et al. 2019; McCoskey, 2007; Newton et al. 2020; Nikolajsen and Nielsen 2015)
Improving safety of patient handling	(Brusco et al. 2007; Fragala 2011; Garzillo et al. 2020; Hodder et al. 2010; Kurowski et al. 2012; Theis and Finkelstein 2014; Vieira and Kumar 2009)
Risk assessment of patient handling tasks	(Brusco et al. 2007; Cantarella et al. 2020; Carneiro et al. 2015; Fragala, 2011; Kim et al. 2015; Larouche et al. 2019; Larouche et al. 2019; Maekawa et al. 2009)
Investigation of kinetics (loading) experienced by the HCP	(Baptiste 2011; Holmes et al. 2010; Jordan et al. 2011; Lavender et al. 2016; Maekawa et al. 2009; Skotte and Fallentin 2008; Skotte et al. 2002)
Investigation of the kinematics (joint motion)	(Arias et al. 2017; Hodder et al. 2010; Hodder et al. 2010; Hye-Knudsen et al. 2004; Kang et al. 2013; Kim et al. 2015; Larouche et al. 2019)
Personal factors affecting patient handling	(Kang et al. 2013; Kjellberg et al. 2003; Kyriakidis et al. 2021; Larouche et al. 2019; Osborne et al. 2021; Skotte and Fallentin 2008; Stringer and Rice 2014; Wade et al. 2017; Wångblad et al. 2009)

4 Outcome Measure References

Outcome Measures used in the Research (n = 36)	
Kinematics	(Arias et al. 2017; Hodder et al. 2010; Hodder et al. 2010; Holmes et al. 2010; Hye-Knudsen et al. 2004; Jordan et al. 2011; Kang et al. 2013; Kim et al. 2015; Kurowski et al. 2012; Larouche et al. 2019; Maekawa et al. 2009; Vieira and Kumar 2009)
Physical Demands	(Arias et al. 2017; Chen et al. 2014; Garzillo et al. 2020; Hodder et al. 2010; Howard et al. 2013; Hye-Knudsen et al. 2004; Kang et al. 2013; Larouche et al. 2019; Maekawa et al. 2009; McCoskey 2007; Skotte et al. 2002; Wångblad et al. 2009)
Tasks Performed	(Cantarella et al. 2020; Chen et al. 2014; de Ruiter and Liaschenko 2011; Fiedler et al. 2012; Hodder et al. 2010; Holmes et al. 2010; Kjellberg et al. 2003; Kurowski et al. 2012; Kyriakidis et al. 2021; Larouche et al. 2019; McCoskey 2007; Nikolajsen and Aagaard Nielsen 2015)
Kinetics	(Baptiste 2011; Fragala 2011; Jordan et al. 2011; Kurowski et al. 2012; Lavender et al. 2016; Skotte and Fallentin 2008; Skotte et al. 2002; Stringer and Rice 2014; Vieira and Kumar 2009)
Staff Perceptions or Opinions	(de Ruiter and Liaschenko 2011; Kjellberg et al. 2003; Larouche et al. 2019; McCoskey 2007; Osborne et al. 2021; Wade et al. 2017; Wångblad et al. 2009)
Safety During Manual Patient Handling	(Brusco et al. 2007; Cantarella et al. 2020; Carneiro et al. 2015; Kjellberg et al. 2003; Larouche et al. 2019; Larouche et al. 2019; Newton et al. 2020; Vieira and Kumar 2009; Wade et al. 2017)
WRMSD	(Brusco et al. 2007; Carneiro et al. 2015; Theis and Finkelstein 2014)

5 School of Health Sciences Ethics

SCHOOL OF HEALTH SCIENCES
The Ishbel Gordon Building
Robert Gordon University
Garthdee Road
Aberdeen
AB10 7QG
United Kingdom
Tel: 01224 263250
www.rgu.ac.uk

SHS Ethics

30th November 2020

Dear Kay,

Re: School of Health Sciences Research Ethics Committee Application

Study Title: An exploration of movement and handling by physiotherapists in a rehabilitation setting: a motion analysis study

Reference Number: IRAS 286201

Thank you for submitting the above study to this committee, and for addressing any points raised. I am pleased to inform you that you now have been given approval by the School Research Ethics Committee, and am happy for you to begin the IRAS process in relation to recruitment of participants and/or data from the NHS.

As you know, where research involves NHS staff or patients, approval should be sought via the IRAS system. Please email a copy of this approval letter along with your study protocol to Jill Johnston (j.johnston4@rgu.ac.uk) who tracks NHS IRAS applications on behalf of Sponsor Paul Hagan.

I wish you every success with this project.

Kind regards,

Dr Lyndsay Alexander

Deputy Convenor

School of Health Sciences Research Ethics Committee

Acting Head of School

Laura Binnie

MSc BSc FHEA

INVESTOR IN PEOPLE

Robert Gordon University, a Scottish charity registered under charity number SC013781

6 Health Research Authority Ethics

London - Riverside Research Ethics Committee

Ground Floor

Temple Quay House

2 The Square

Bristol

BS1 6PN

Telephone: 02071048199

07 January 2021

Professor Kay Cooper
School of Health Sciences
Robert Gordon University
Aberdeen
AB10 7QG

Dear Professor Cooper

Study title:	**An exploration of movement and handling by physiotherapists in a rehabilitation setting: a motion analysis study.**
REC reference:	**20/PR/0999**
Protocol number:	**286201**
IRAS project ID:	**286201**

The Proportionate Review Sub-committee of the London - Riverside Research Ethics Committee reviewed the above application on 07 January 2021.

Ethical opinion

The PR Sub-committee queried whether the applicant had experience of using the Xsens system and if they could comment on how/if wearing the device might affect the movements or ability of the physio at work. The PR Sub-committee required knowledge as to whether the system is light and easy to wear or if it would restrict movement through the working day.

The applicant responded that they had received training in using the Xsens system by RGU

School of Health Sciences applications supervisor and their Doctoral supervisor (Dr Paul Swinton), both of whom had extensive experience of using it in the field. The applicant clarified they had personally piloted use of the system on themselves and volunteered for the past

3-months. This was done in order to refine the protocol for the current study, ensuring that the use of Xsens was feasible in a clinical setting. The applicant assured the Sub-committee that physios would not be restricted by the system and confirmed that the sensors were small and lightweight, and attached to the physio using a lightweight vest (worn over their clothing) and Velcro straps (arms and legs).

Following this pilot work, the applicant decided not to use the hand sensor (which was attached using a glove), as this could interfere with the physio's movement and wrist/hand analysis was not essential for this study. The applicant went on to clarify that pilot work involved testing the system on a series of mock treatment sessions, replicating as closely as possible the movements involved in typical rehabilitation. The applicant was confident that the Xsens would not restrict the physio's movement and provided the PR Sub-committee with a link to the Xsens website which helped the PR Sub-committee with the visualisation of the system.

The PR Sub-committee noted the references in the IRAS form and protocol to a member of a patient's family providing consent on their behalf, however, it was not indicated on the IRAS project filter page that any adults lacking the capacity to consent will be recruited to the study. The PR Sub-committee sought confirmation as to whether this group would be included.

The applicant confirmed that they would now only include patients on the ward who could provide consent themselves. The number of patients who lacked consent would have been a small number. Therefore, it would not be necessary to involve them in the study as there would be enough potential participants with the capacity to consent to obtain data from.

On behalf of the Research Ethics Committee (REC), the sub-committee gave a favourable ethical opinion of the above research on the basis described in the application form, protocol and supporting documentation, subject to the conditions specified below. This was on the basis that adults lacking the capacity to consent for themselves would not be included in this study.

Good practice principles and responsibilities

The UK Policy Framework for Health and Social Care Research sets out principles of good practice in the management and conduct of health and social care research. It also outlines the responsibilities of individuals and organisations, including those related to the four elements of research transparency:

1. registering research studies
2. reporting results
3. informing participants
4. sharing study data and tissue

Conditions of the favourable opinion

The REC favourable opinion is subject to the following conditions being met prior to the start of the study.

Confirmation of Capacity and Capability (in England, Northern Ireland and Wales) or NHS management permission (in Scotland) should be sought from all NHS organisations involved in the study in accordance with NHS research governance arrangements. Each NHS organisation must confirm through the signing of agreements and/or other documents that it has given permission for the research to proceed (except where explicitly specified otherwise).

Guidance on applying for HRA and HCRW Approval (England and Wales)/ NHS permission for research is available in the Integrated Research Application System.

For non-NHS sites, site management permission should be obtained in accordance with the procedures of the relevant host organisation.

Sponsors are not required to notify the Committee of management permissions from host organisations.

Registration of Clinical Trials

All research should be registered in a publicly accessible database and we expect all researchers, research sponsors and others to meet this fundamental best practice standard.

It is a condition of the REC favourable opinion that **all clinical trials are registered** on a publicly accessible database within six weeks of recruiting the first research participant. For this purpose, 'clinical trials' are defined as the first four project categories in IRAS project filter question 2. Failure to register is a breach of these approval conditions, unless a deferral has been agreed by or on behalf of the Research Ethics Committee (see here for more information on requesting a deferral:

https://www.hra.nhs.uk/planning-and-improving-research/research-planning/research-registratio n-research-project-identifiers/

If you have not already included registration details in your IRAS application form, you should notify the REC of the registration details as soon as possible.

Publication of Your Research Summary

We will publish your research summary for the above study on the research summaries section of our website, together with your contact details, no earlier than three months from the date of this favourable opinion letter.

Should you wish to provide a substitute contact point, make a request to defer, or require further information, please visit:

https://www.hra.nhs.uk/planning-and-improving-research/application-summaries/research-sum maries/

N.B. If your study is related to COVID-19 we will aim to publish your research summary within 3 days rather than three months.

During this public health emergency, it is vital that everyone can promptly identify all relevant research related to COVID-19 that is taking place globally. If you haven't already done so, please register your study on a public registry as soon as possible and provide the REC with the registration detail, which will be posted alongside other information relating to your project. We are also asking sponsors not to request deferral of publication of research summary for any projects relating to COVID-19. In addition, to facilitate finding and extracting studies related to COVID-19 from public databases, please enter the WHO official acronym for the coronavirus disease (COVID-19) in the full title of your study. Approved COVID-19 studies can be found at:

https://www.hra.nhs.uk/covid-19-research/approved-covid-19-research/

It is the responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

After ethical review: Reporting requirements

The attached document "After ethical review – guidance for researchers" gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Notification of serious breaches of the protocol
- Progress and safety reports
- Notifying the end of the study, including early termination of the study
- Final report
- Reporting results

The latest guidance on these topics can be found at https://www.hra.nhs.uk/approvals-amendments/managing-your-approval/.

Ethical review of research sites

The favourable opinion applies to all NHS sites taking part in the study, subject to management permission being obtained from the NHS/HSC RandD office prior to the start of the study (see "Conditions of the favourable opinion").

Approved documents

The documents reviewed and approved were:

Document	*Version*	*Date*
Covering letter on headed paper [Covering letter 17th December]	1.0	17 December 2020
Evidence of Sponsor insurance or indemnity (non NHS Sponsors only) [insurance Cover EL-PL to 31-7-2021]	1.0	01 August 2020
IRAS Application Form [IRAS_Form_18122020]		18 December 2020
Letters of invitation to participant [Recruitment email for staff]	v1.0	28 September 2020
Participant consent form [Participant consent form]	1.0	01 December 2020
Participant consent form [Patient consent form]	1.0	01 December 2020
Participant information sheet (PIS) [Participant informtion sheet]	v1.0	23 September 2020
Participant information sheet (PIS) [Patient information document]	1.0	01 December 2020
Referee's report or other scientific critique report [SHS REC IRAS Approval]	1.0	30 November 2020
Research protocol or project proposal [Xsens project proposal]	v1.0	28 September 2020
Sample diary card/patient card [Xsens subject data sheet]	v1.0	24 September 2020
Sample diary card/patient card [Patient handling task form]	v1.0	28 September 2020
Summary CV for Chief Investigator (CI) [KC CV IRAS]	1.0	09 November 2020
Summary CV for student [Katie Johnson CV]	1.0	09 November 2020
Summary CV for supervisor (student research) [KC CV IRAS]	1.0	09 November 2020
Summary CV for supervisor (student research) [IRAS CV PS]	1.0	09 November 2020
Validated questionnaire [Nordic musculoskeletal questionnaire extended]		

Membership of the Proportionate Review Sub-Committee

The members of the Sub-Committee who took part in the review are listed on the attached sheet.

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

User Feedback

The Health Research Authority is continually striving to provide a high quality service to all applicants and sponsors. You are invited to give your view of the service you have received and the application procedure. If you wish to make your views known please use the feedback form available on the HRA website:

http://www.hra.nhs.uk/about-the-hra/governance/quality-assurance/

HRA Learning

We are pleased to welcome researchers and research staff to our HRA Learning Events and online learning opportunities– see details at:

https://www.hra.nhs.uk/planning-and-improving-research/learning/

With the Committee’s best wishes for the success of this project.

IRAS project ID: 286201	**Please quote this number on all correspondence**

Yours sincerely

pp Dr Margaret Jones Chair

Email: riverside.rec@hra.nhs.uk

Copy to: Ms Jill Johnston

Lead Nation:

Scotland nhsg.NRSPCC@nhs.net

London - Riverside Research Ethics Committee

Attendance at PRS Sub-Committee of the REC meeting held via correspondence on 07 January 2021.

Committee Members:

Name	*Profession*	*Present*	*Notes*
Dr Nuria Gonzalez-Cinca	Clinical Study Manager	Yes	
Dr Margaret Jones	Retired General Practitioner	Yes	Chaired the meeting.
Dr Mark Weeks	Respiratory Hub Manager	Yes	

Also in attendance:

Name	*Position (or reason for attending)*
Helen Penistone	Approvals Manager

7 Research and Development Ethics

Research and Development Foresterhill House Annexe
Foresterhill
ABERDEEN
AB25 2ZB

Lesley Stables		Date	12/02/2021
NHS Grampian		Project No	2020RG007E
Dept of Physiotherapy			
Aberdeen Royal Infirmary		Enquiries to	Louise/Rituka
Aberdeen		Extension	53846 01224 553846
AB25 2ZN		Direct Line	gram.randdpermissions@nhs.scot
		Email	

Dear Stables

Management Permission for Non-Commercial Research

STUDY TITLE:	An exploration of movement and handling by physiotherapists in a rehabilitation setting: a motion analysis study
PROTOCOL NO:	v1, 28/09/20
REC REF:	20/PR/0999
IRAS REF:	286201

Thank you very much for sending all relevant documentation. I am pleased to confirm that the project is now registered with the NHS Grampian Research and Development Office. The project now has R and D Management Permission to proceed locally. This is based on the documents received from yourself and the relevant Approvals being in place.

All research with an NHS element is subject to the UK Policy Framework for Health and Social Care Research (2017 v3), and as Chief or Principal Investigator you should be fully committed to your responsibilities associated with this.

RandD Permission is granted on condition that:

1) **The RandD Office will be notified and any relevant documents forwarded to us if any of the following occur:**
   - **Any Serious Breaches in Grampian (Please forward to pharmaco@abdn.ac.uk).**
   - **A change of Principal Investigator in Grampian or Chief Investigator.**
   - **Any change to funding or any additional funding**

2) **When the study ends, the RandD Office will be notified of the study end-date.**

3) **The Sponsor will notify all amendments to the relevant National Co-ordinating centre. For single centre studies, amendments should be notified to the RandD office directly.**

NHSG-RD-DOC-019 – V6 – RandD Management Permission Letter (Non CTIMP)

We hope the project goes well, and if you need any help or advice relating to your RandD Management Permission, please do not hesitate to contact the office.

Yours sincerely

Susan Ridge
Non-Commercial Manager

cc: CI/Sponsor
Research Monitor

Sponsor: RGU

NHSG-RD-DOC-019 – V6 – RandD Management Permission Letter (Non CTIMP)

8 Participant Information Sheet

IRAS ID: 286201

Study title: An exploration of movement and handling by physiotherapists in a rehabilitation setting: a motion analysis study.

Introduction and purpose of study

My name is Katharine Johnson, and I am studying for a Doctorate of Physiotherapy in the School of Health Sciences at Robert Gordon University (RGU), Aberdeen, supervised by Professor Kay Cooper. I would like to invite you to take part in this study but before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please ask us if there is something that is not clear, or you would like more information.

Musculoskeletal pain and injury is a common complaint in the Allied Health Professions (AHP) with patient handling documented as the largest risk factor. Physiotherapists can be heavily involved with manual handling of patients during rehabilitation. Patient handling may require physiotherapists to adopt positions that have been previously reported to increase risk of injury. However, there has been very little research into how physiotherapists move during patient handling tasks. Therefore, I am undertaking a research study to explore how physiotherapists move during patient manual handling within a rehabilitation setting. I will also investigate history of work-related pain and injury through a validated self-complete written questionnaire.

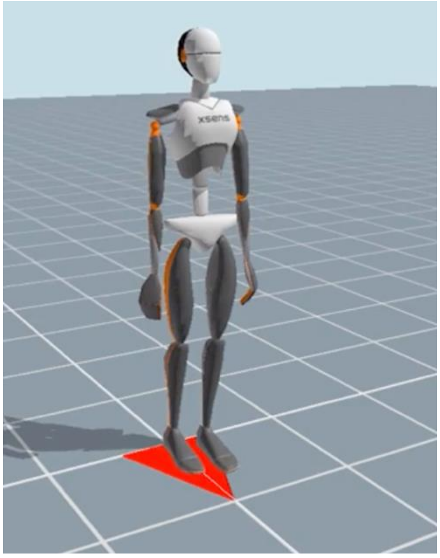
You are being invited to take part because you are an NHS Grampian physiotherapist working within neurological rehabilitation in Woodend Hospital. AHP professional leads have kindly agreed to email these invitation letters out to their staff. This research project has been approved by NHS Grampian RandD department (IRAS: 286201).

Taking part in the study

If you are interested in taking part in the study, I will ask you a few questions to confirm you are eligible to participate. I will then attend the ward you are based in to measure your movement for one day during a morning and afternoon session with a motion analysis system. When I arrive, we will go through this information sheet and I will answer any questions you may have. If you still wish to volunteer for the study, you will be asked to sign a form consenting to take part in the study. You many withdraw from the research at any time without giving a reason.

We will need to place motion analysis markers on you to collect data, the motion analysis system is Xsens and I will need to place trackers on you for data collection. It is a wireless and non-invasive system of accelerometers which measures joint and segment angles during movement. I will measure your height, shoulder height, hip height, hip width, knee height, ankle height, shoulder width, elbow span, wrist span, arm span, and shoe length. The markers will then be attached using straps and a vest, which can go over your clothes. The system will be calibrated and then data collection can start. The patients will be asked if they consent to having treatment while I am collecting your data, but they are not the focus of this research study. You will be asked to perform your patient treatments and handling as normal. I will remain in the physiotherapy gym to observe the patient handling tasks that are taking place and monitor the Xsens system. You will be asked to complete a short written questionnaire about work related pain and injuries, this can be done anytime during your working day. All data recorded during motion analysis and the questionnaire will remain anonymised throughout the study. No payment will be offered for your participation.

Example of tracker placement and screenshot of motion capture recording.

Advantages to participating

There will be no direct advantage to you personally for participating in this study. The findings will improve our understanding of physiotherapists' movement during patient handling. We will be pleased to share the study findings with you.

Disadvantages to participating

There are no anticipated disadvantages to participating in this study. As the nature of patient handling is manual there is a small risk of discomfort or injury. However, this is what you would complete on a normal working day. If you do not wish to take part in the study, there will be no negative effect to you or your position within the physiotherapy team.

Confidentiality and anonymity

If you decide to participate in this study, you will be given a unique anonymous identification number which we will use when collecting your data. Any personal information you share including your name and other details personal to yourself will be kept confidential and stored in a password protected document on a secure server and any paper documents (e.g., signed consent form) will be kept in a locked cabinet only accessible to the research team.

Any questions?

If you have any further questions about this research, please contact me or my academic supervisor using the contact details provided below.

What happens if there is a problem?

Please discuss any problems with me using the contact details given at the end of this letter. If you have a complaint please send details of this to the convenor, School of Health Sciences Research Ethics Panel, Robert Gordon University, Garthdee Road, Aberdeen AB10 7QG SRRG@rgu.ac.uk or to Laura Binnie, Head of School of Health Sciences, Robert Gordon University, Garthdee Road, Aberdeen AB10 7QG, l.m.binnie@rgu.ac.uk.

What will happen to my research data?

A research report and paper will be written as part of this study and may be more widely disseminated in academic and professional journals and conferences. All the data presented will be anonymous and there will be no way to link you to the study. The data we collect from you will be assessed for retention at the end of the research study once all the reporting is complete.

What happens now?

Please take some time to consider this and feel free to discuss this letter with anyone you wish before deciding whether to take part. If you would like to take part in this study, please contact me using any of the contact details listed below.

Thank you for taking the time to read this letter.

Katharine Johnson

Doctorate of Physiotherapy student

Academic Supervisor

Professor Kay Cooper

School of Health Sciences
Robert Gordon University
Garthdee Road
Aberdeen
AB10 7QG
Email: k.johnson6@rgu.ac.uk
Tel: 01224 262677

School of Health Sciences
Robert Gordon University
Garthdee Road
Aberdeen
AB10 7QG
Email: k.cooper@rgu.ac.uk
Tel: 01224 262677

This project is sponsored by the Robert Gordon University.

How we will use information about you?

We (Robert Gordon University) will need to use information from your for this research project. This information will include your age, years of experience as a physiotherapist and various body measurements. People will use this information to do the research. We will keep all information about you safe and secure. Once we have finished the study, we will keep some of the data so we can check the results. We will write out reports in a way that no-one can work out that you took part in the study.

What are your choices about how your information is used?

You can stop being a part of the study at any time, without giving a reason, but we will keep information about you that we already have. We need to manage your records in specific ways for the research to be reliable. This means that we won't be able to let you see or change the data we hold about you.

Where can you find out more about how your information is used?

You can find out more about how we use your information: at www.hra.nhs.uk/information-about-patients/; our leaflet available from www.hra.nhs.uk/patientdataandresearch; by asking one of the research team; by sending an email to dp@rgu.ac.uk; or by ringing us on +44 (0)1224 262076.

9 Participant Consent Form

CONSENT FORM IRAS ID: 286201

Study reference: IRAS ID: 286201 PIN:_______

Study Title: An exploration of movement and handling by physiotherapists in a rehabilitation setting: a motion analysis study.

Name of Researcher: Katharine Johnson Please **initial** box

1. I confirm that I have read the information sheet dated 01.12.20 (Version 1) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected. ☐

3. I understand that data collected during the study will be looked at by individuals from The Robert Gordon University and NHS Grampian where it is relevant to my taking part in this research. I give permission for these individuals to have access to the data. ☐

4. I agree to unidentifiable motion capture data being used in any research output (e.g., academic articles, professional papers, conference presentations) from this study. ☐

5. I give permission for my research data to be used for other similar purposes in the future (e.g., other research projects) on the understanding that it will not be possible to identify me from the data provided ☐

6. I agree to take part in the above study. ☐

Name of Participant Date Signature

Name of Person taking consent Date Signature

When completed: 1 for participant; 1 for researcher site file.

Movement and handling/Participant consent form/V1.0/01.12.20

10 Patient Information Sheet

Your physiotherapist is taking part in a research study.

The study is investigating how physiotherapists move during patient handling tasks. This will be done using a portable motion analysis system. The system will be attached to the physiotherapist and it will record how they move during a day on the ward. A member of the research team will be present in the room during treatment for observation of the physiotherapist and equipment. Your treatment session will go ahead as normal and you will not be asked to do anything for the project. No personal or identifiable data will be taken about yourself.

There will be no benefit or risk to yourself during the study as the treatment you receive will be the same as normal and data is only being collected of your physiotherapist's movement. There will also be no disadvantage if you do not wish to consent to data collection during your treatment session. You will still receive your normal physiotherapy treatment.

Are you happy that your physiotherapist is involved in a research study and that a researcher will be present in the room during your treatment session?

If the answer is YES please sign the consent form.

If the answer is NO you don't need to do anything.

If you have any questions or want to find out more before making a decision, please speak to your physiotherapist, or you can contact the researcher or academic supervisor, using the contact details provided below.

Katharine Johnson **Academic Supervisor**

Doctorate of Physiotherapy student
School of Health Sciences
Robert Gordon University
Garthdee Road
Aberdeen
AB10 7QG
Email: k.johnson6@rgu.ac.uk
Tel: 01224 262677

Professor Kay Cooper
School of Health Sciences
Robert Gordon University
Garthdee Road
Aberdeen
AB10 7QG
Email: k.cooper@rgu.ac.uk
Tel: 01224 262677

The sponsor for this study is Robert Gordon University.

How we will use the information about you?

We (Robert Gordon University) will need to use information from your physiotherapy treatment sessions for this research project. This information will include your weight and the level of assistance you require. We will keep all information about you safe and secure. Once we have finished the study, we will keep some of the data so we can check the results. We will write out reports in a way that no-one can work out that you took part in the study.

What are your choices about how your information is used?

You can stop being a part of the study at any time, without giving a reason, but we will keep information about you that we already have. We need to manage your records in specific ways for the research to be reliable. This means that we won’t be able to let you see or change the data we hold about you.

Where can you find out more about how your information is used?

You can find out more about how we use your information: at www.hra.nhs.uk/information-about-patients/; our leaflet available from www.hra.nhs.uk/patientdataandresearch; by asking one of the research team; by sending an email to dp@rgu.ac.uk; or by ringing us on +44 (0)1224 262076.

11 Patient Consent Form

IRAS ID: 286201

CONSENT FORM

Study Reference: IRAS ID: 286201 PIN:_______

Study Title: An exploration of movement and handling by physiotherapists in a rehabilitation setting: a motion analysis study.

Name of Researcher: Katharine Johnson Please **initial** box

1. I confirm that I have read the patient information sheet dated 01.12.20 (Version 1) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected. ☐

3. I consent to my treatment session being observed by a member of the research team and recording of my physiotherapist during the session. ☐

4. I understand that no data will be collected about me personally as the project is exploring physiotherapist movement. ☐

5. I agree to take part in this study. ☐

________________		________________
Name of Participant	Date	Signature
________________		________________
Name of Person taking consent	Date	Signature

When completed: 1 for participant; 1 for researcher site file.

Movement and handling/Patient consent form/V1.0/01.12.20

11 Treatment Observation Sheet

Treatment session no. and level of assistance required by patient (e.g. single/double)	Time into data collection session	Patient handling task	Physiotherapist position

12 Xsens Measurement Sheet

ROBERT GORDON UNIVERSITY ABERDEEN

IRAS ID: 286201

XSENS SUBJECT DIMENSION MEASUREMENTS

Participant ID:

	Measurement (cm)
Height (with shoes on)	
Shoulder height	
Hip height	
Hip width	
Knee height	
Ankle height	
Shoulder width	
Elbow span	
Wrist span	
Arm span	
Shoe length	

Movement and handling/Xsens data sheet/V1.0/24.09.20

IRAS ID: 286201

Height: Participant is to keep shoes on as they will be wearing them during data collection. Use stadiometer to measure height from top of head to floor.

Shoulder height: Participant is to stand in neutral posture with shoulders relaxed, measure from acromion to floor.

Hip height: Greater trochanter to floor.

Hip width: ASIS width

Knee height: Lateral epicondyle to floor.

Ankle height: Centre of ankle to floor.

Shoulder width: Distance between left and right acromion with relaxed shoulders.

Elbow span: Participant standing in T pose, distance between right and left olecranon.

Wrist span: Participant standing in T pose, distance between right and left ulnar styloid.

Arm span: Distance between right and left middle fingertip.

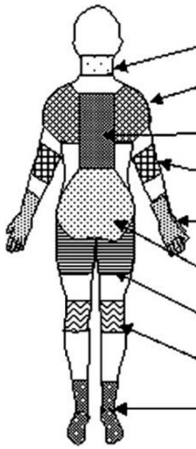
Shoe length: Full length of shoe.

13 NMQ-E

Extended Nordic Musculoskeletal Questionnaire (NMQ-E)

How to answer the questionnaire:

Please answer by putting a cross in the appropriate box - one cross for each question. Answer every question, even if you have never had trouble in any part of your body. Please answer questions from left to right before going down to the next body region. This picture shows how the body has been divided. Limits are not sharply defined and certain parts overlap. You should decide for yourself which part (if any) is or has been affected.



	Have you **ever** had trouble (ache, pain or discomfort) in:	**If 'No', go on to the next body region. If 'Yes', please continue**	At the time of initial onset of the trouble, what was your age?	Have you **ever** been hospitalised because of the trouble?	Have you **ever** had to change jobs or duties (even temporarily) because of the trouble?	Have you had trouble (ache, pain, discomfort) at any time during the **last 12 months?**	**If 'No', go on to the next body region. If 'Yes', please continue**	Have you had trouble (ache, pain, discomfort) at any time during the **last month (4 weeks)?**	Have you had trouble (ache, pain, discomfort) **today?**	During the **last 12 months** have you at any time: been prevented from doing your normal work (at home or away from home) because of the trouble?	seen a doctor, physio-therapist, chiropractor or other such person because of the trouble?	taken medication because of the trouble?	taken sick leave from work/studies because of the trouble?
NECK	□ No □ Yes		___ years	□ No □ Yes	□ No □ Yes	□ No □ Yes		□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes
SHOULDERS	□ No □ Yes		___ years	□ No □ Yes	□ No □ Yes	□ No □ Yes		□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes
UPPER BACK	□ No □ Yes		___ years	□ No □ Yes	□ No □ Yes	□ No □ Yes		□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes
ELBOWS	□ No □ Yes		___ years	□ No □ Yes	□ No □ Yes	□ No □ Yes		□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes
WRISTS/ HANDS	□ No □ Yes		___ years	□ No □ Yes	□ No □ Yes	□ No □ Yes		□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes
LOW BACK	□ No □ Yes		___ years	□ No □ Yes	□ No □ Yes	□ No □ Yes		□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes
HIPS / THIGHS	□ No □ Yes		___ years	□ No □ Yes	□ No □ Yes	□ No □ Yes		□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes
KNEES	□ No □ Yes		___ years	□ No □ Yes	□ No □ Yes	□ No □ Yes		□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes
ANKLES / FEET	□ No □ Yes		___ years	□ No □ Yes	□ No □ Yes	□ No □ Yes		□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes	□ No □ Yes

14 Xsens Segments (Xsens 2021)

Outcome Measures used in the Research (n = 36)	
Pelvis	Segment between both hip joints and joint L5S1
L5	Segment between joints L5S1 and L4L3
L3	Segment between joints L4L3 and L1T12
T12	Segment between joints L1T12 and T9T8
Sternum (T8)	Segment between joints T9T8 and C1Head
Neck	Segment between joints T1C7 and C1Head
Shoulder	Segment between joints C7Shoulder and UpperArm glenohumeral joint
Upper Arm	Segment between joints UpperArm glenohumeral joint and Elbow
Forearm	Segment between joints Elbow and Wrist
Upper leg	Segment between joints Hip and Knee
Lower leg	Segment between joints Knee and Ankle
Foot	Segment between joints Ankle and Toe
Toe	End segment after joint Toe

15 Joint ROM Maximum Values

			Average		SD	
C1Head	Coronal	Left bend	23.8		4.2	
		Right bend	23.8		7.4	
	Transverse	Rotation to right	41.6		4.9	
		Rotation to left	47.5		7.3	
	Sagittal	Extension	46.9		9.3	
		Flexion	26.3		9.4	
C7T1	Coronal	Left bend	13.4		2.4	
		Right bend	13.3		3.1	
	Transverse	Rotation to right	21.2		2.4	
		Rotation to left	24.0		3.7	
	Sagittal	Extension	5.8		5.1	
		Flexion	33.5		5.1	
T12L1	Coronal	Left bend	2.1		0.4	
		Right bend	3.3		1.8	
	Transverse	Rotation to right	7.9		2.7	
		Rotation to left	8.2		3.2	
	Sagittal	Extension	2.8		2.0	
		Flexion	9.8		4.6	
L5S1	Coronal	Left bend	4.9		1.1	
		Right bend	7.5		4.1	
	Transverse	Rotation to right	17.6		6.4	
		Rotation to left	18.4		7.4	
	Sagittal	Extension	6.3		4.5	
		Flexion	22.0		10.3	
			Right	**SD**	**Left**	**SD**
T4Shoulder	Coronal	Retraction	13.8	2.4	13.5	2.0
		Protraction	11.0	4.2	13.9	5.4
	Transverse	Elevation	11.4	4.6	14.1	7.4
		Depression	16.9	5.8	16.3	6.2
Shoulder	Coronal	Adduction	1.8	8.6	18.7	56.3
		Abduction	132.5	21.5	149.9	18.3
	Transverse	External rotation	63.5	19.1	69.7	32.2
		Internal rotation	75.8	20.6	76.8	32.0
	Sagittal	Extension	48.2	10.0	60.3	38.9
		Flexion	120.5	19.9	124.2	20.2
Hip	Coronal	Adduction	11.8	3.1	19.4	8.8
		Abduction	24.4	8.9	18.8	7.0
	Transverse	External rotation	19.1	4.2	21.1	5.0

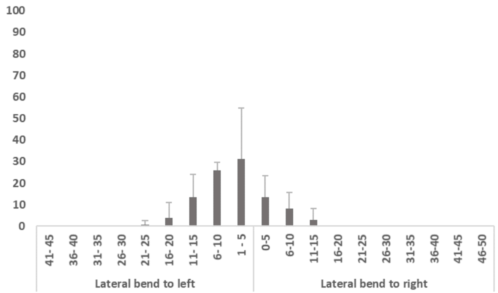
		Internal rotation	18.3	6.2	18.2	4.8
	Sagittal	Extension	11.1	12.3	9.7	9.8
		Flexion	108.9	23.7	110.3	22.9
Knee	Sagittal	Extension	3.3	3.5	3.6	2.6
		Flexion	125.5	9.0	129.0	9.2

16 Other Joint Movement Graphs Not Included in Text

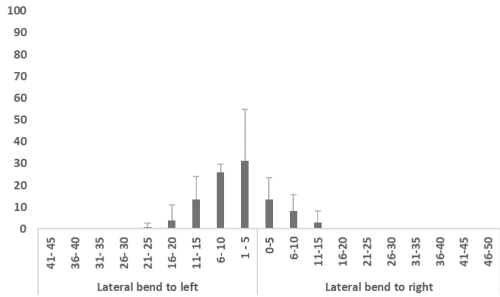
Lie-to-sit

Neck

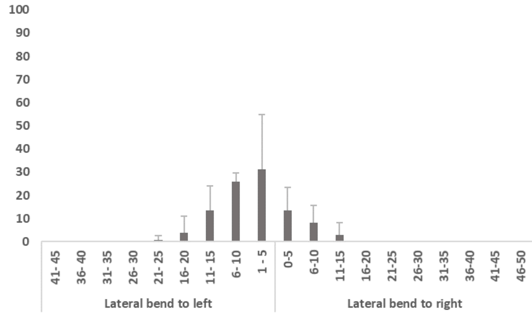
Kneeling



Half-kneeling

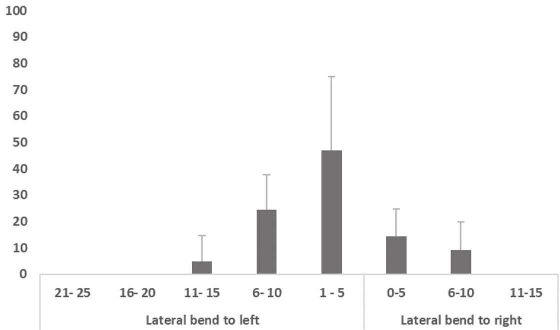


Standing



Cervicothoracic

Kneeling



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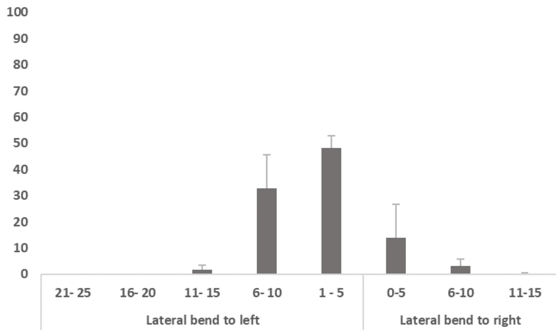

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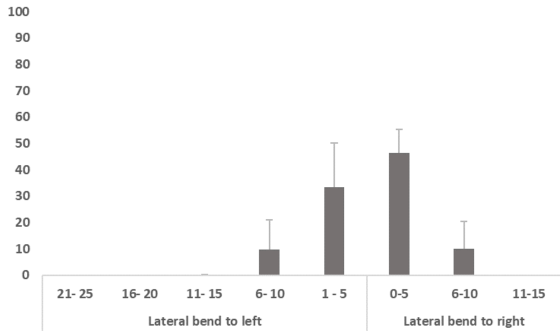
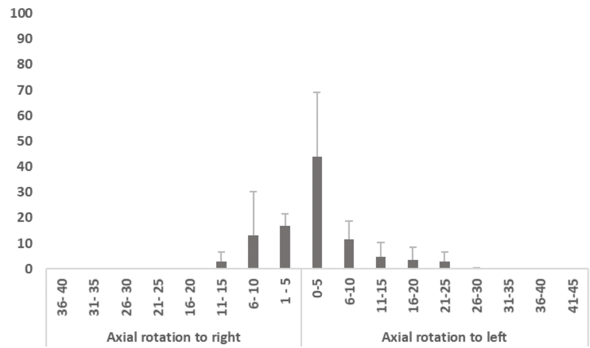


Cervicothoracic

Kneeling



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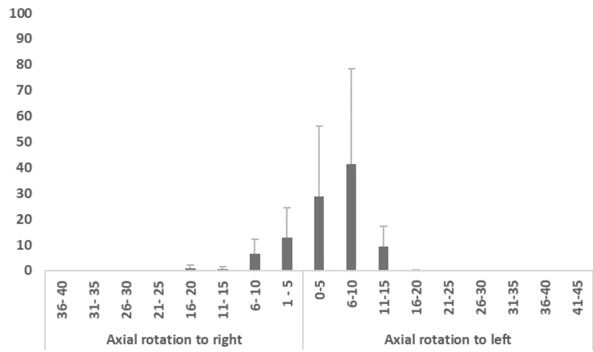

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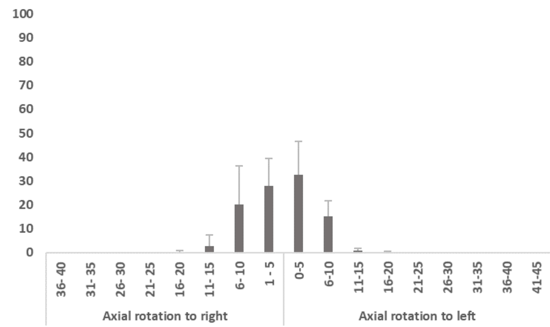
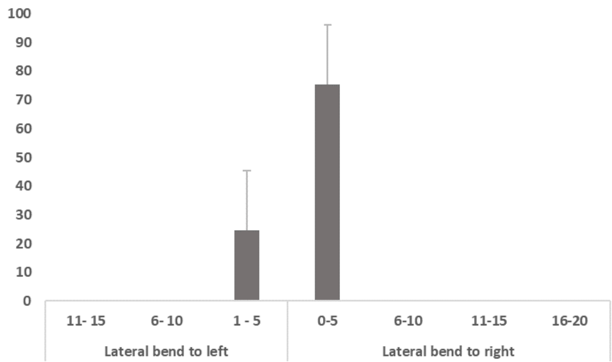


Thoracolumbar

Kneeling



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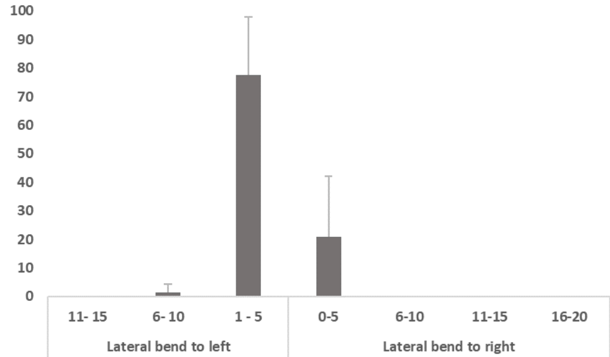

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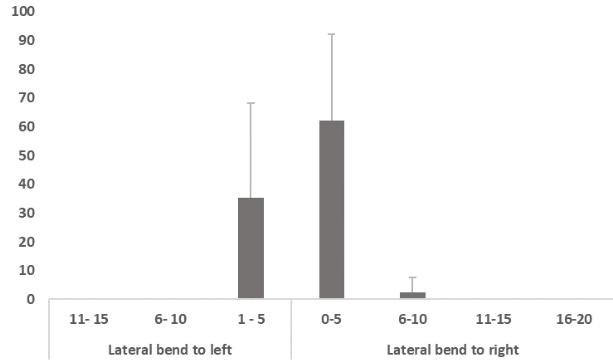
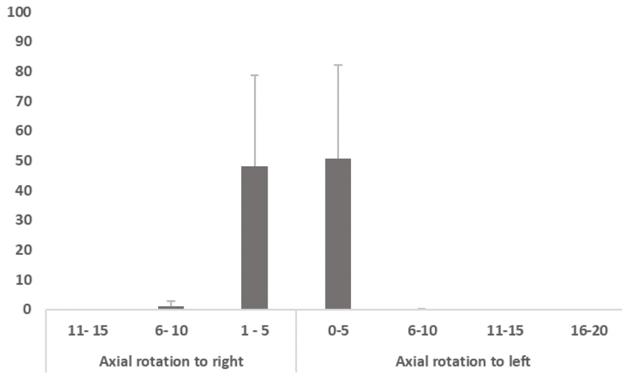


Thoracolumbar

Kneeling



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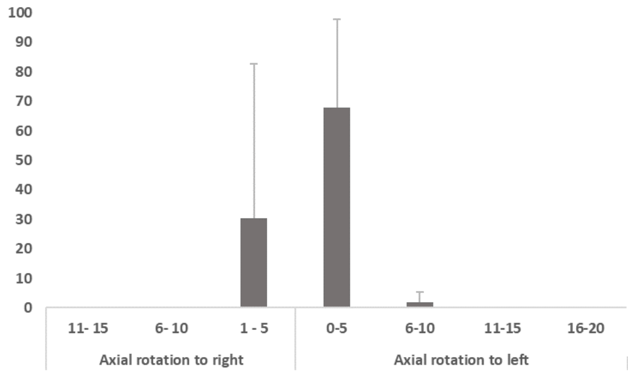
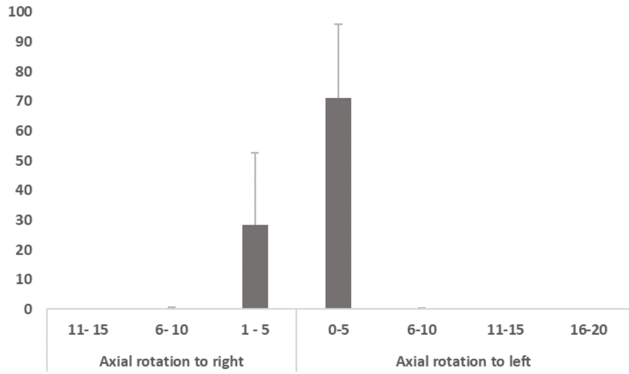
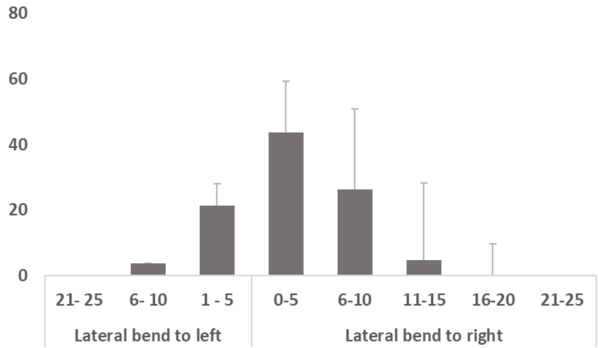


Standing



Lumbosacral

Kneeling



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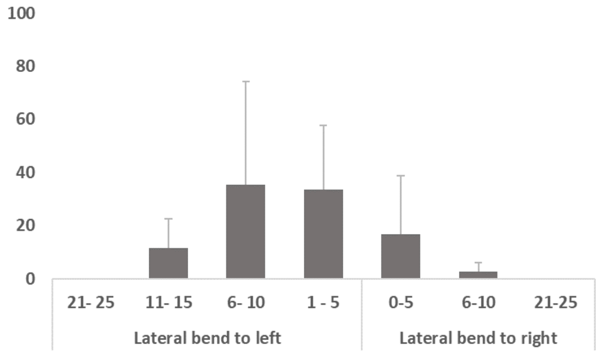

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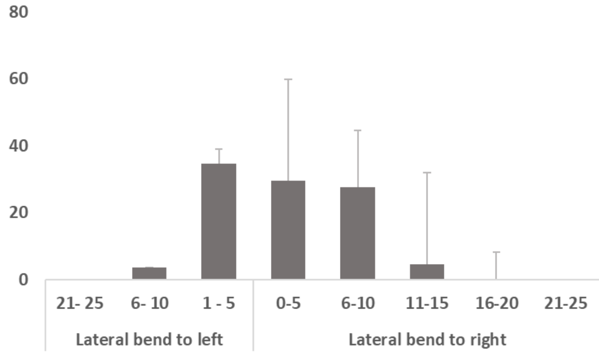
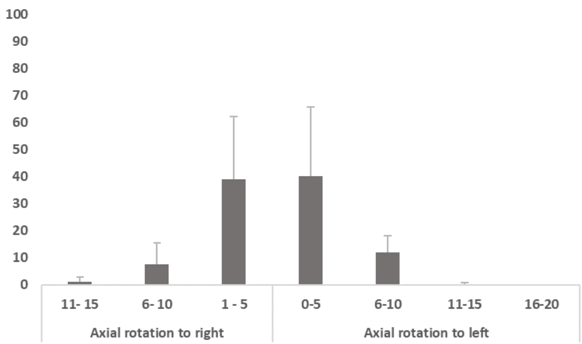
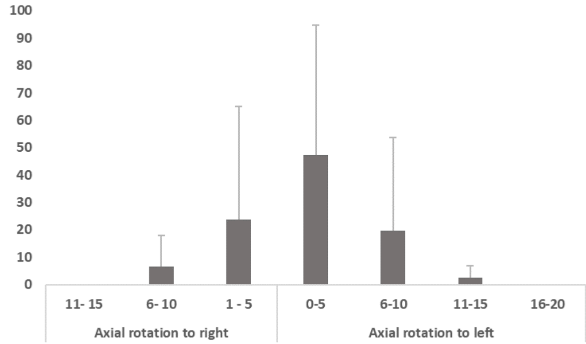


Lumbosacral

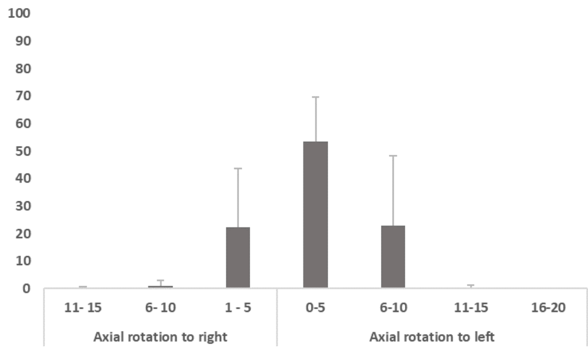
Kneeling



Half-kneeling

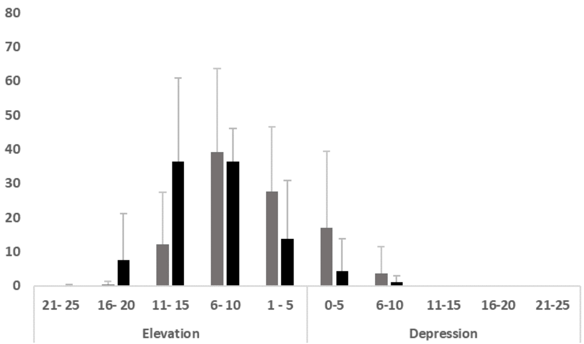


Standing



Shoulder Girdle

Kneeling



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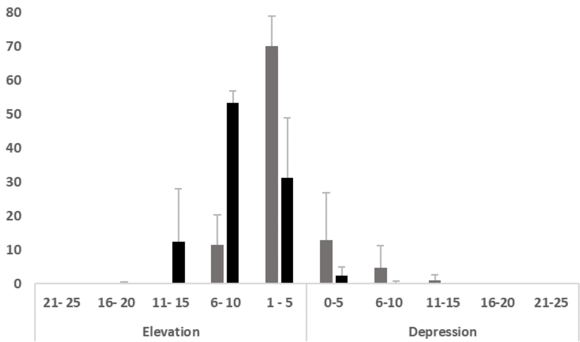
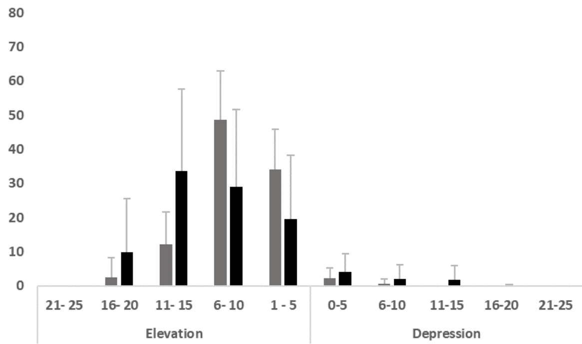
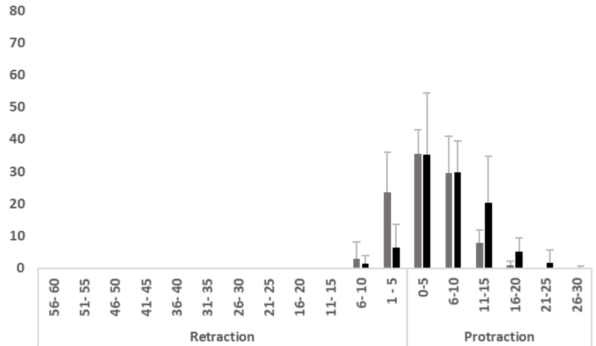


Standing



Shoulder Girdle

Kneeling



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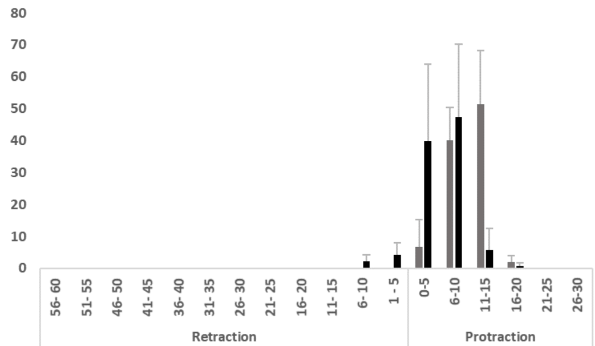

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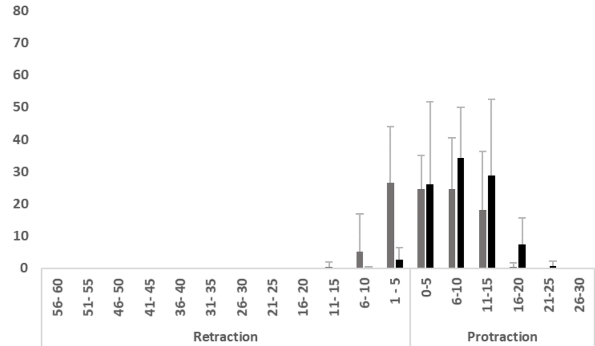
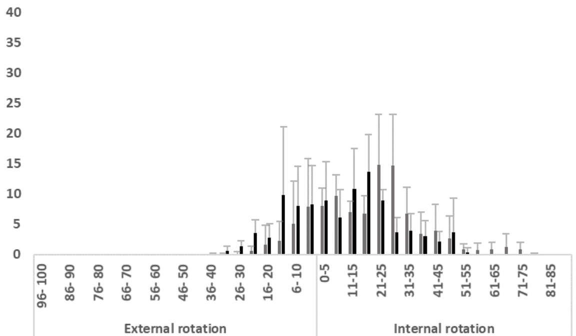


Shoulder

Kneeling



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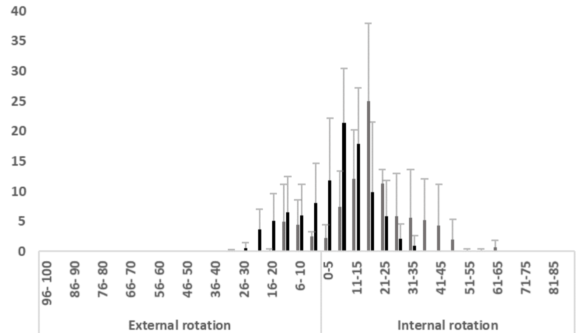
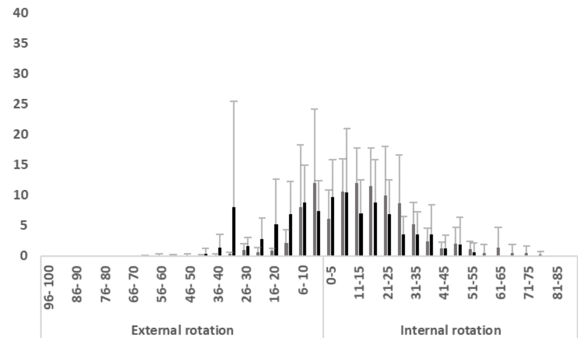
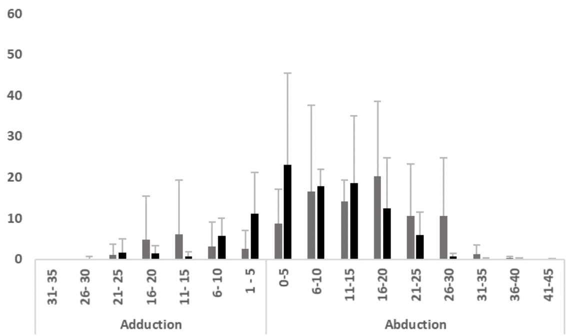


Standing

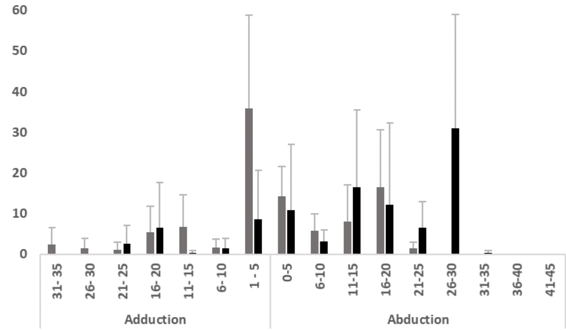


Hip

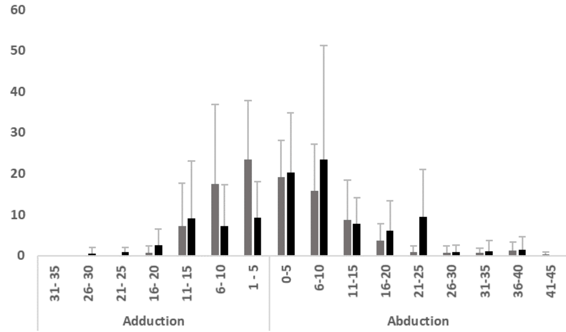
Kneeling



Half-kneeling

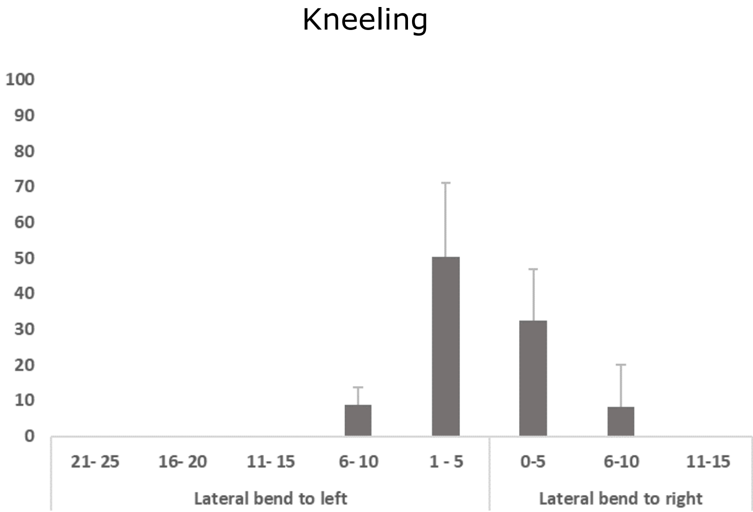


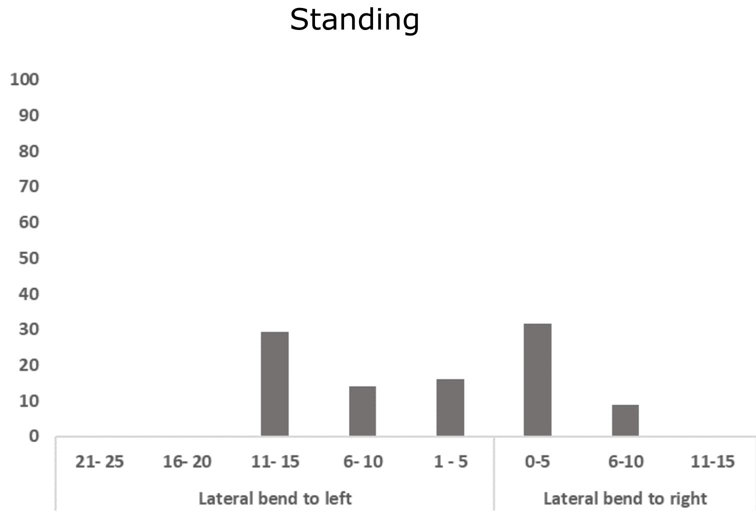
Standing



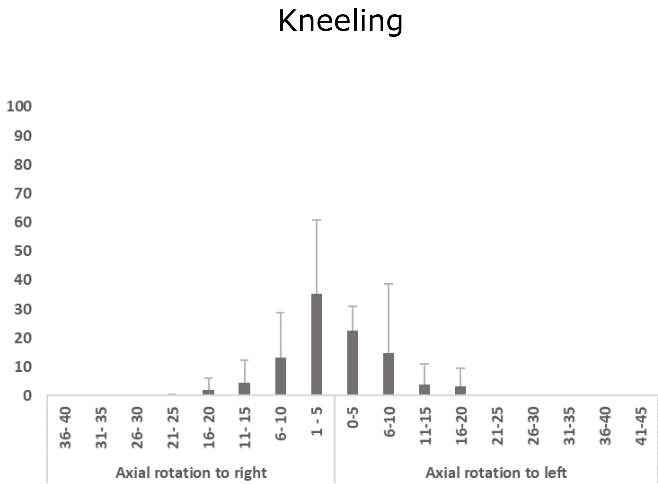
Sit-to-lie

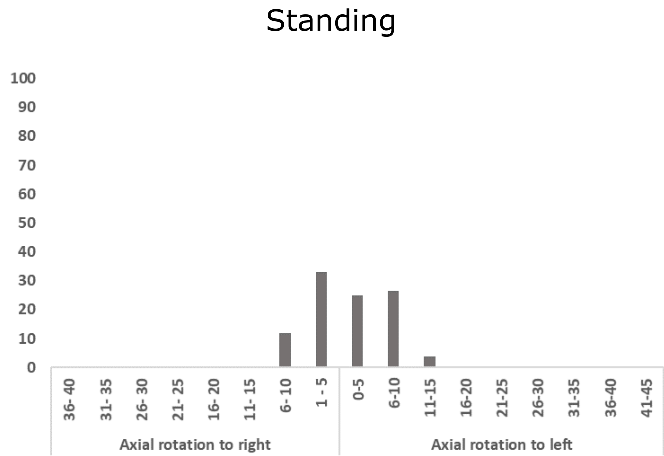
Cervicothoracic



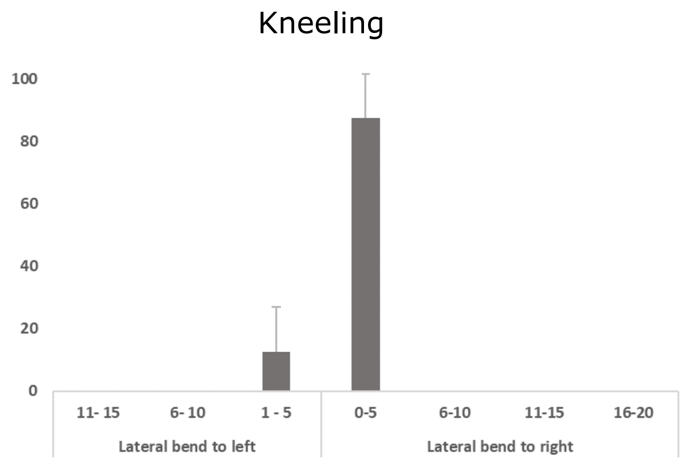


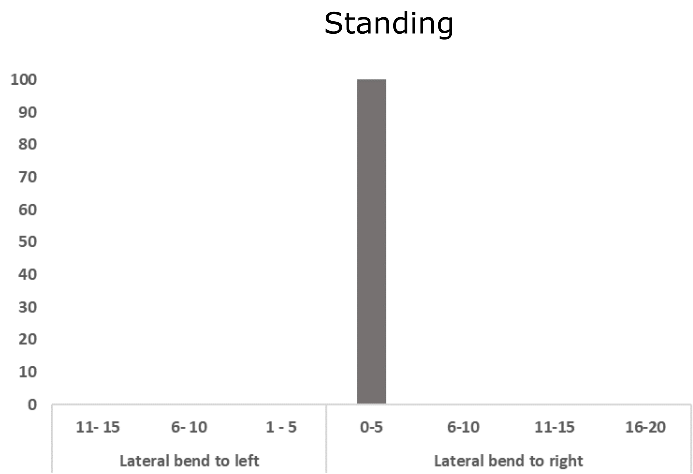
Cervicothoracic





Thoracolumbar





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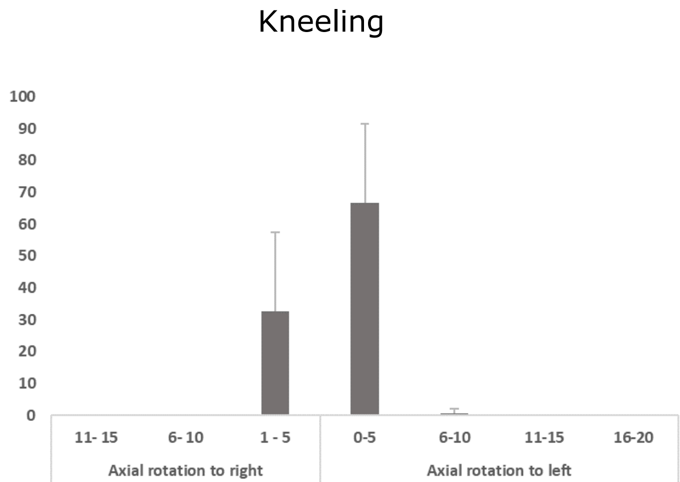
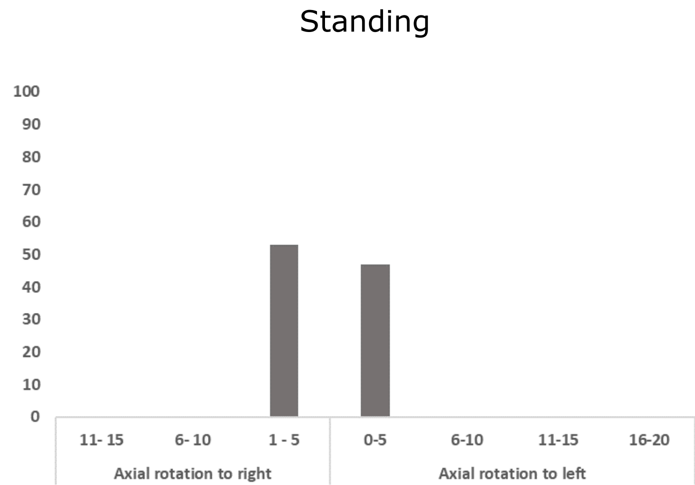
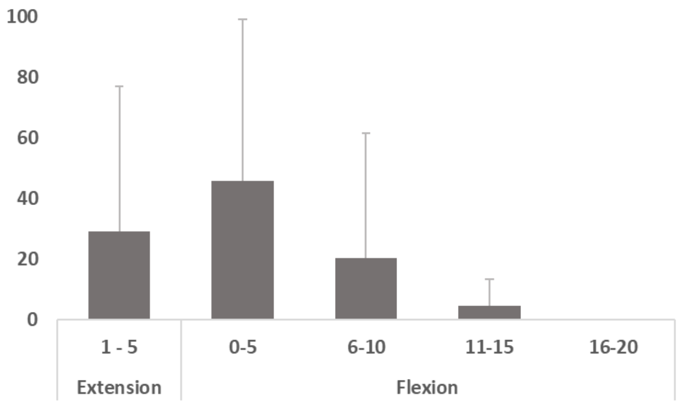


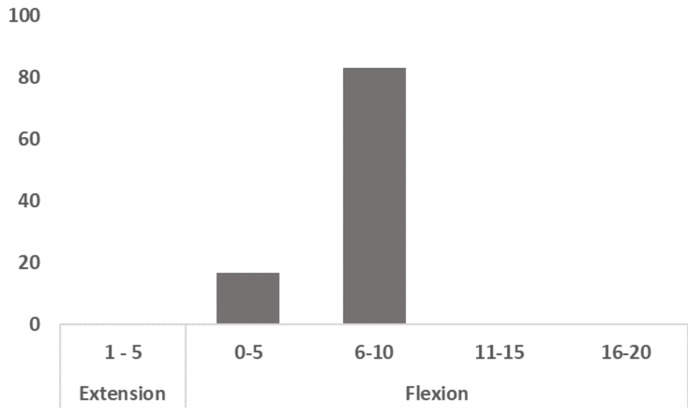


Thoracolumbar

Kneeling

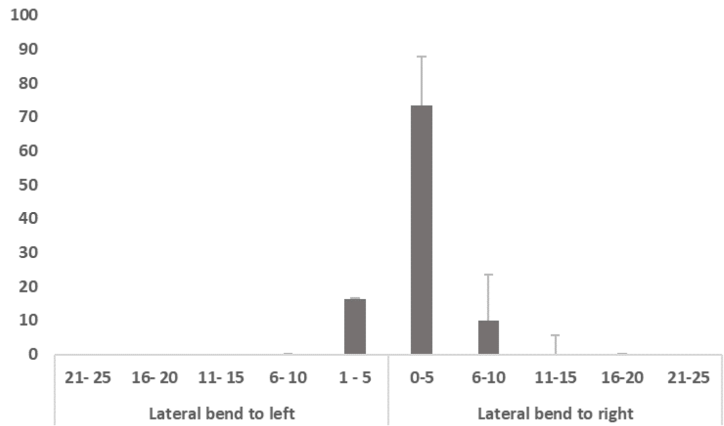


Standing

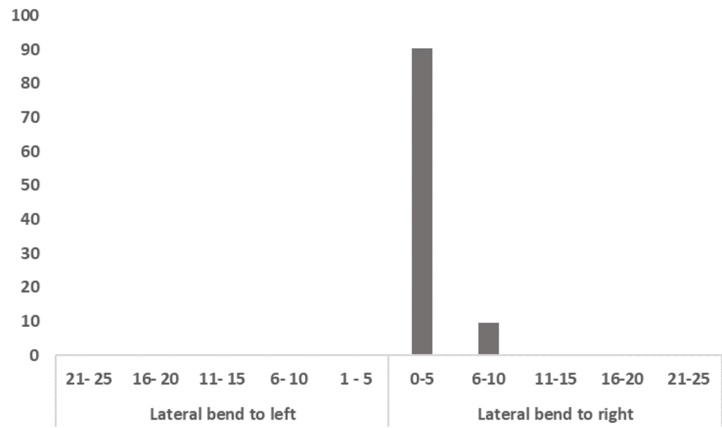


Lumbosacral

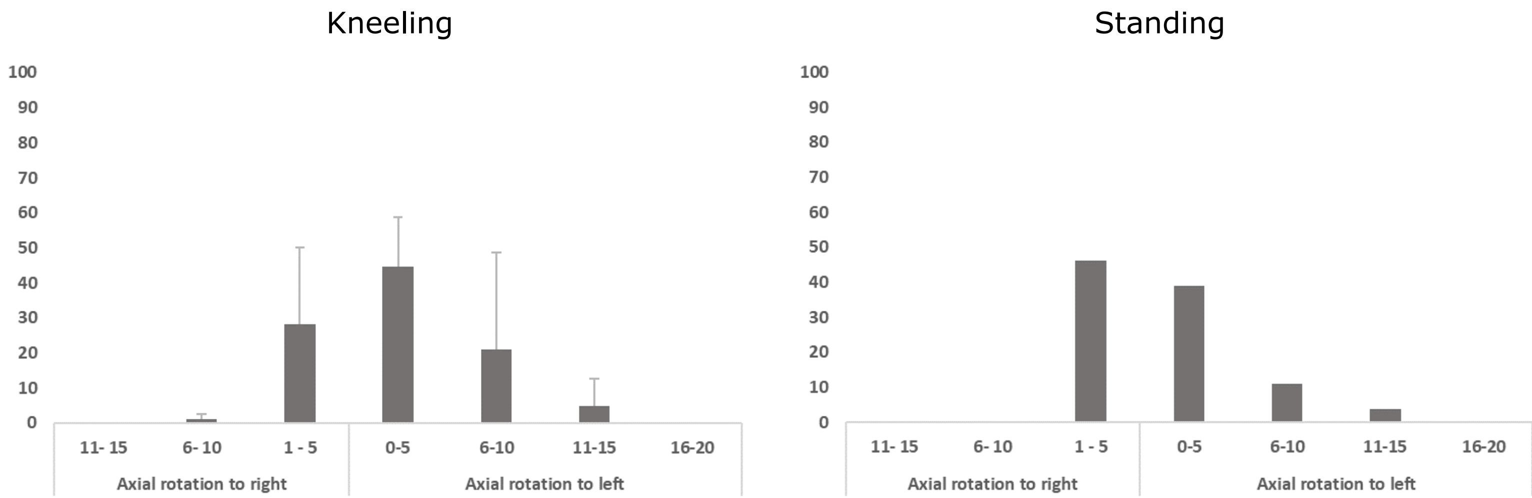
Kneeling



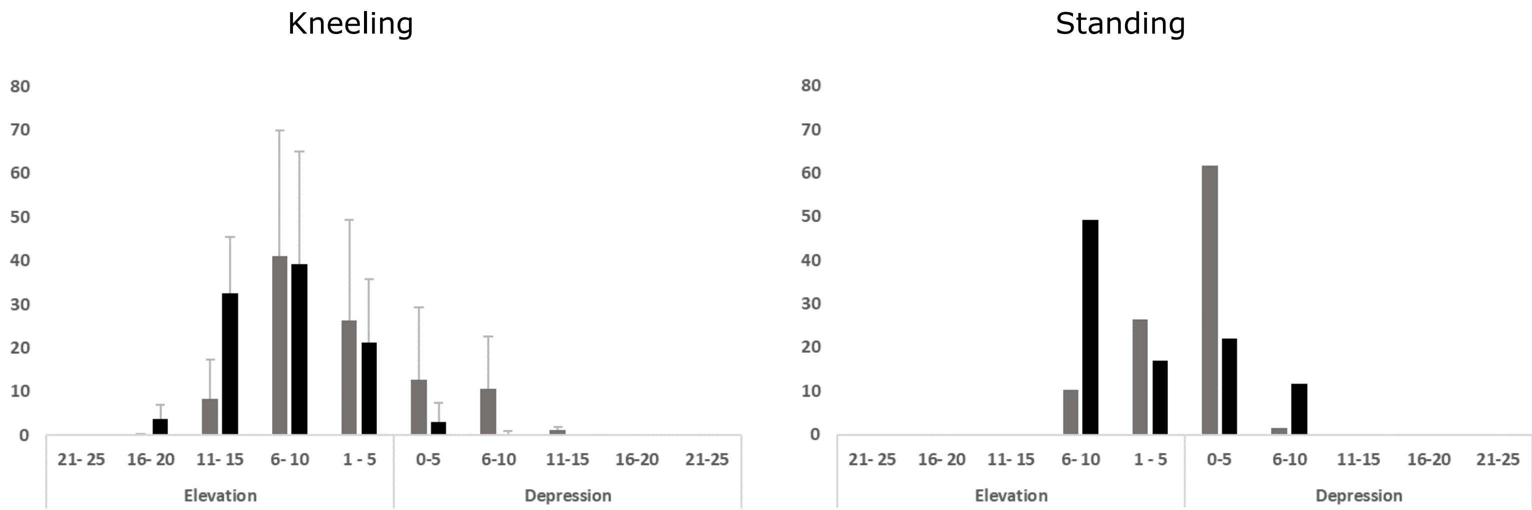
Standing



Lumbosacral

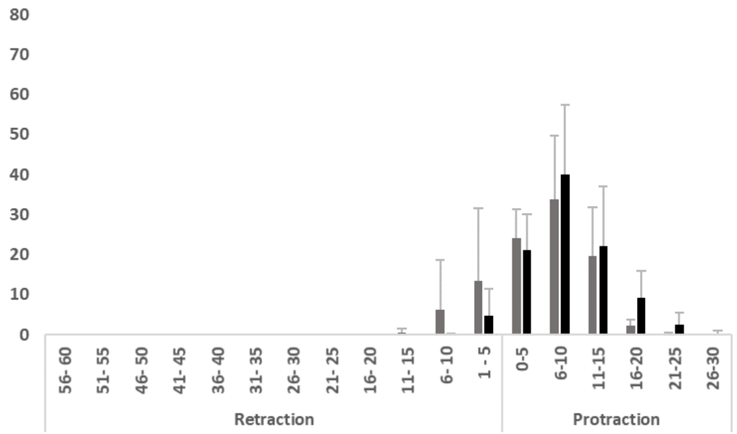


Shoulder Girdle

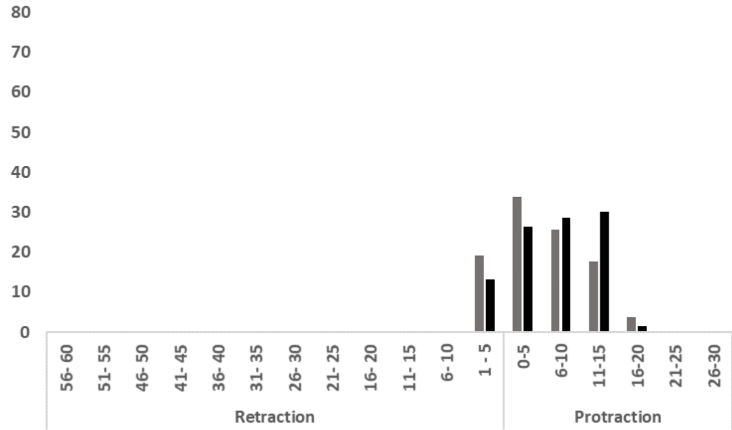


Shoulder Girdle

Kneeling

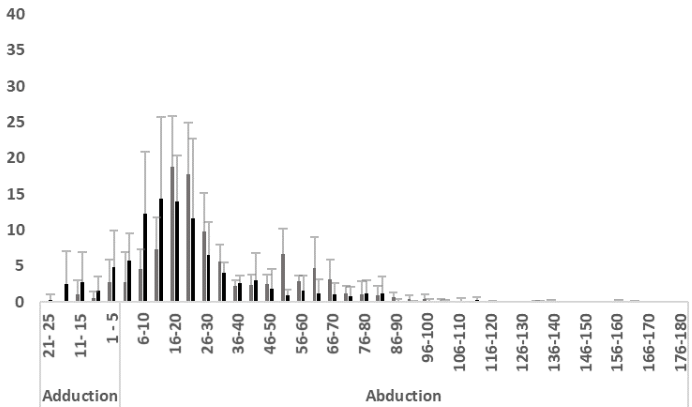


Standing

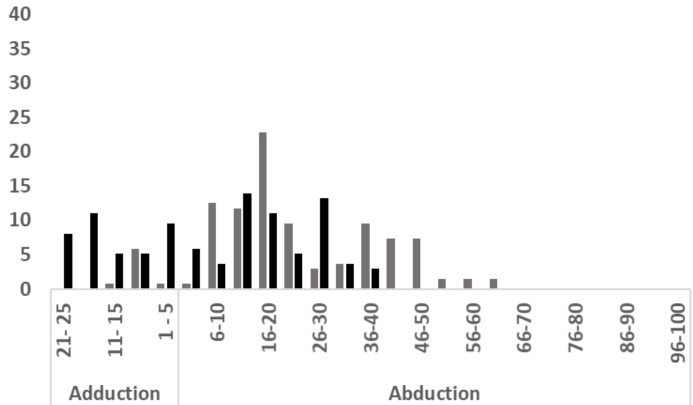


Shoulder

Kneeling

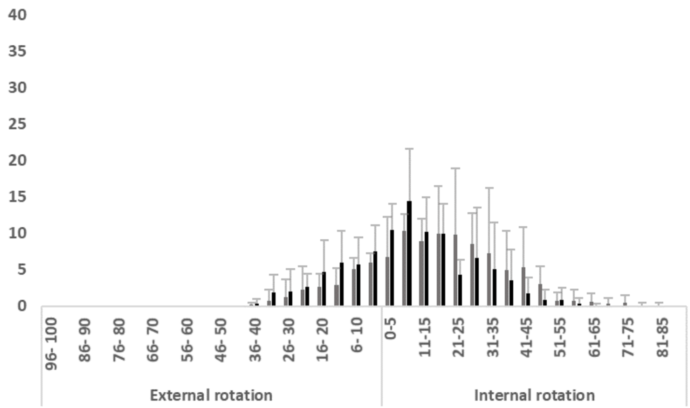


Standing

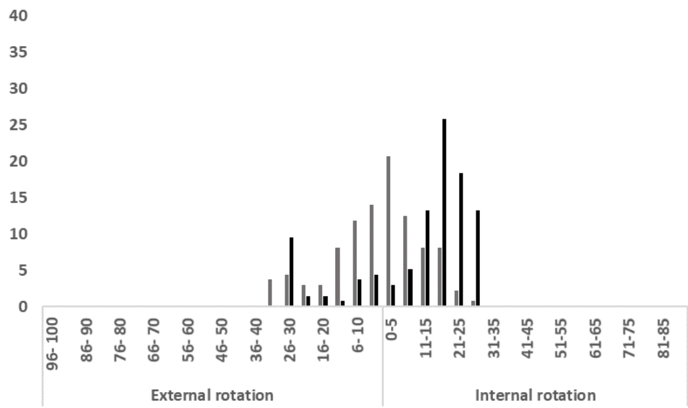


Shoulder

Kneeling

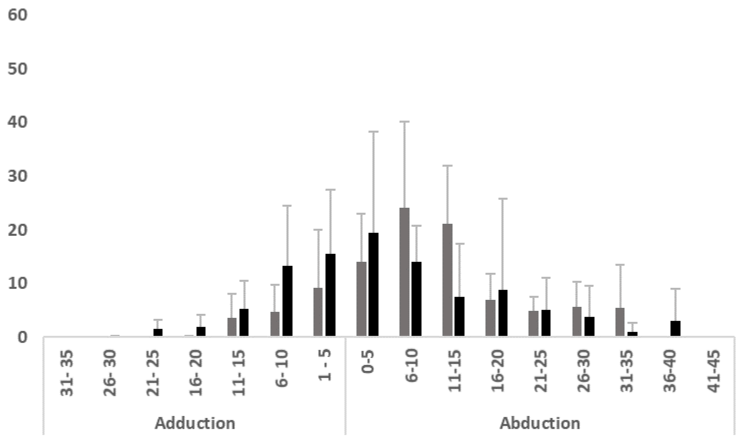


Standing

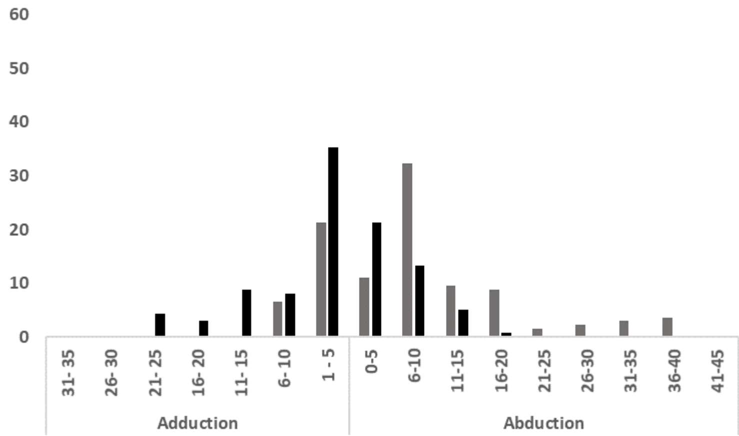


Hip

Kneeling

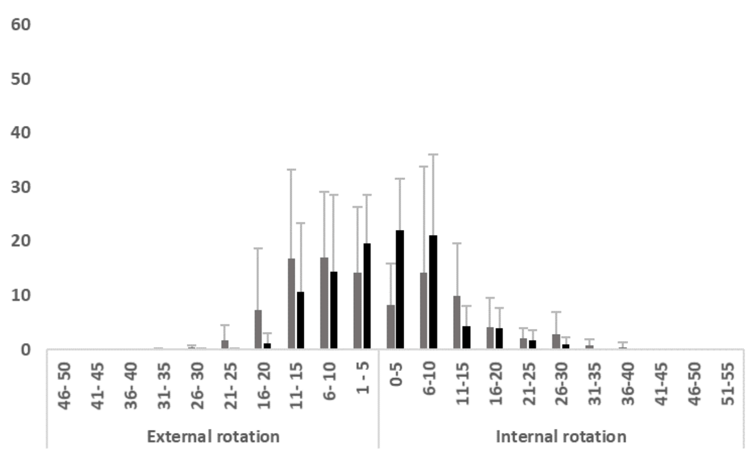


Standing

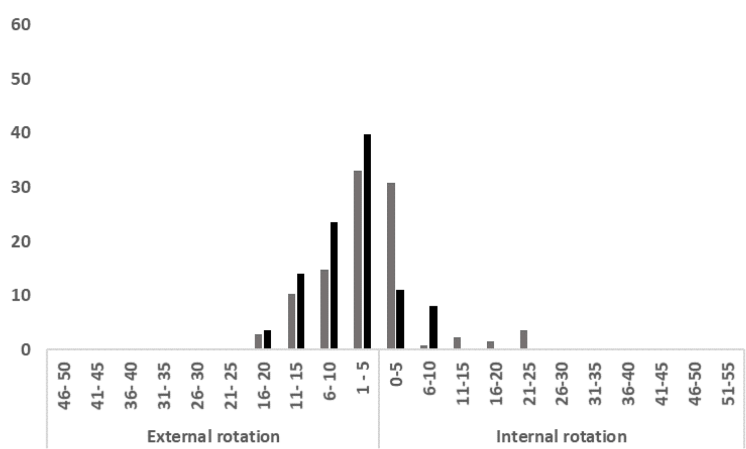


Hip

Kneeling



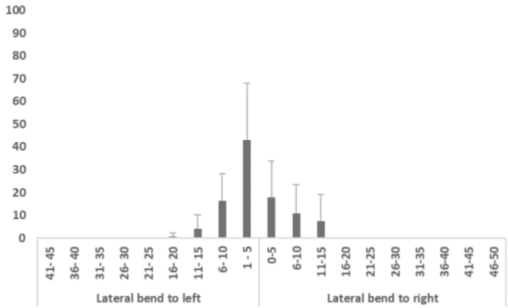
Standing



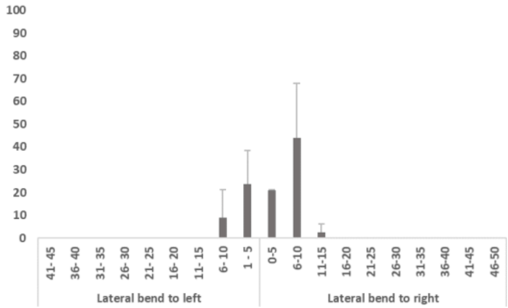
Sit-to-stand

Neck

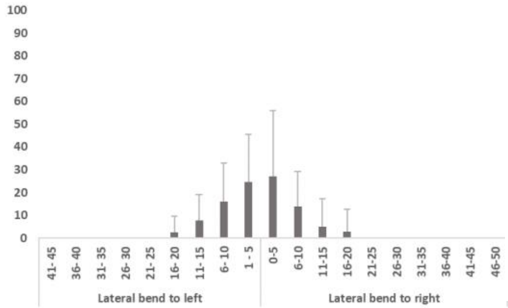
Kneeling



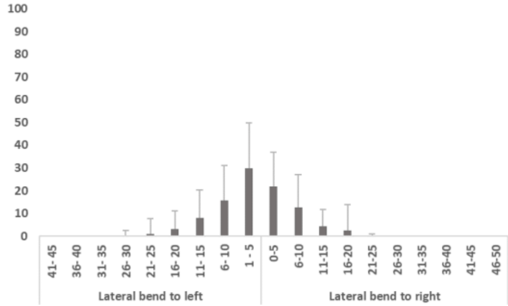
Half-kneeling



Standing

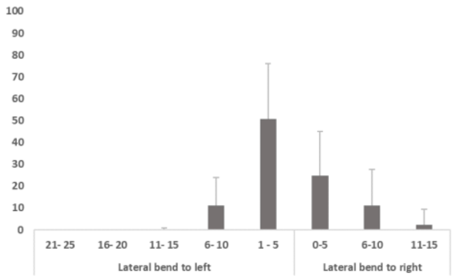


Sitting

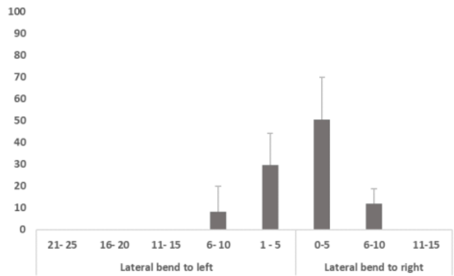


Cervicothoracic

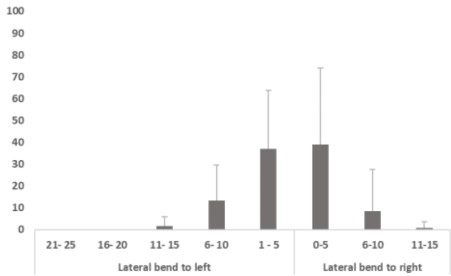
Kneeling



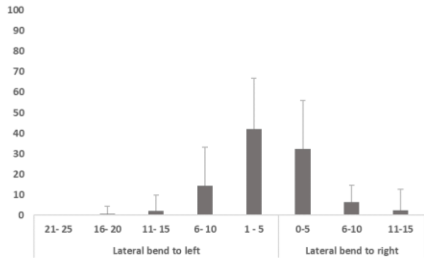
Half-kneeling



Standing

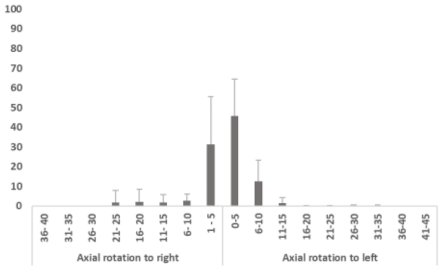


Sitting

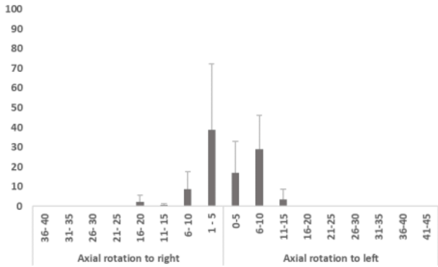


Cervicothoracic

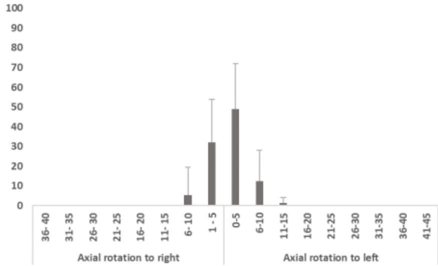
Kneeling



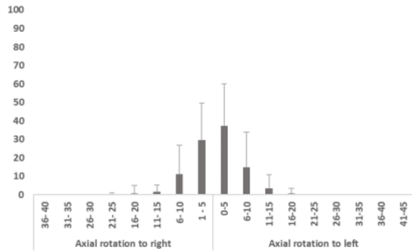
Half-kneeling



Standing

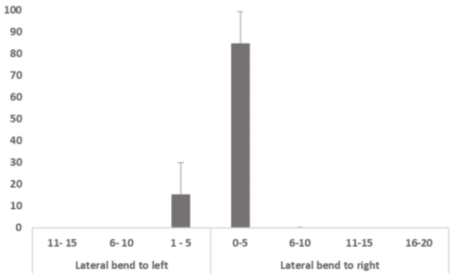


Sitting

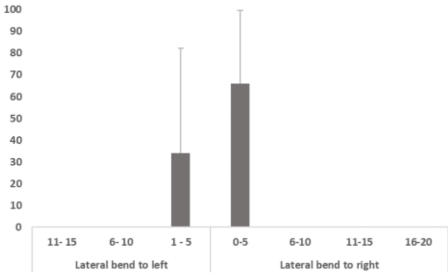


Thoracolumbar

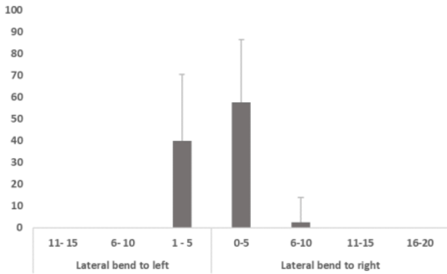
Kneeling



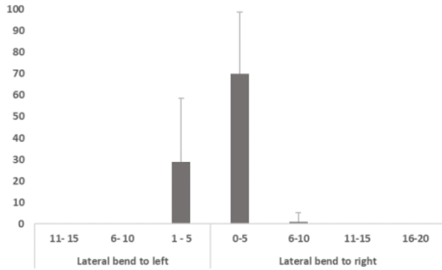
Half-kneeling



Standing

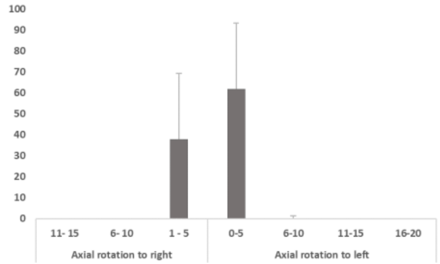


Sitting



Thoracolumbar

Kneeling



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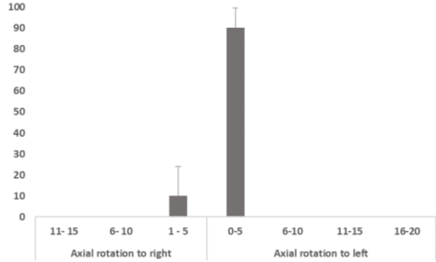
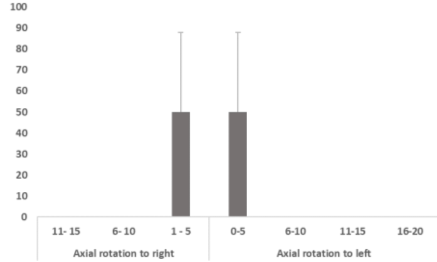
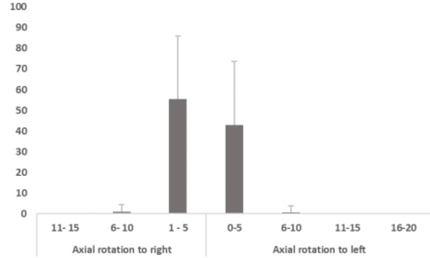


Standing

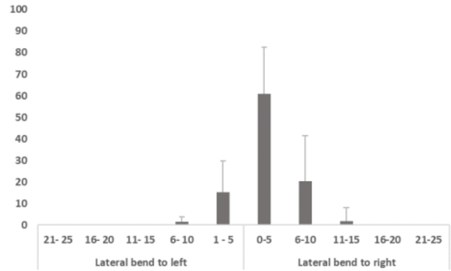


Sitting

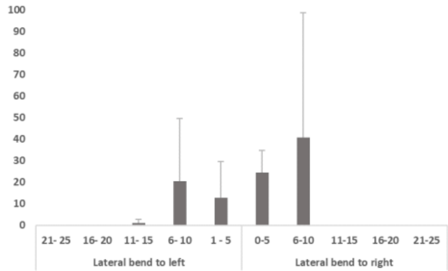


Lumbosacral

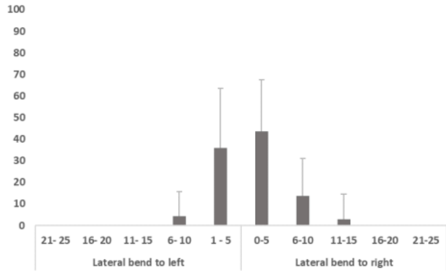
Kneeling



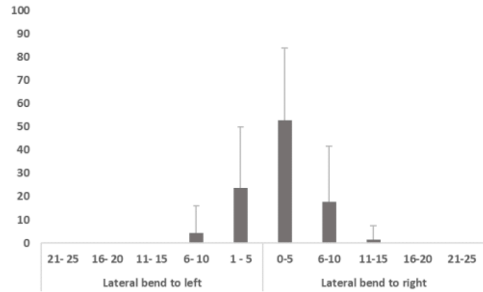
Half-kneeling



Standing

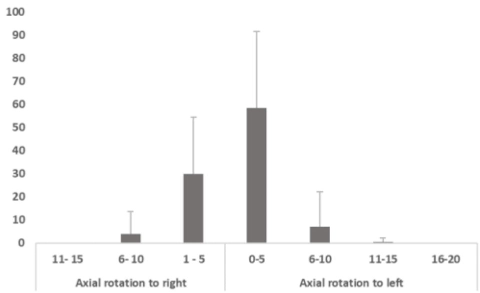


Sitting



Lumbosacral

Kneeling



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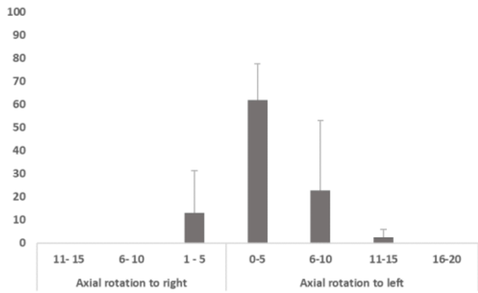

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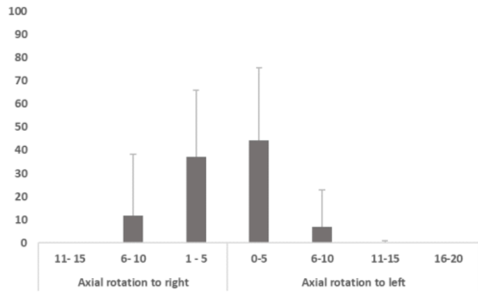
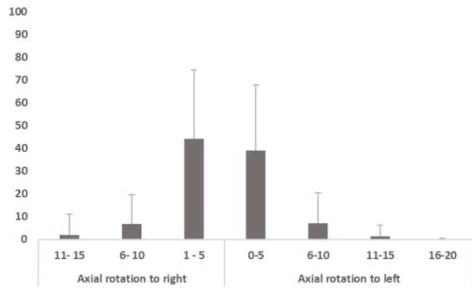
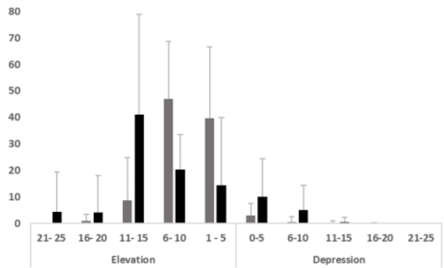


Sitting

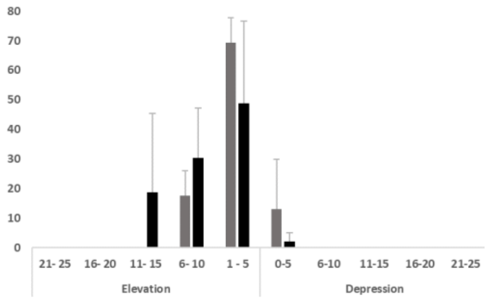


Shoulder Girdle

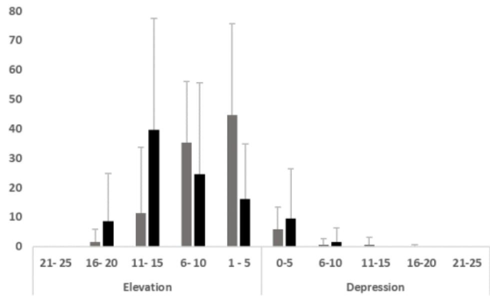
Kneeling



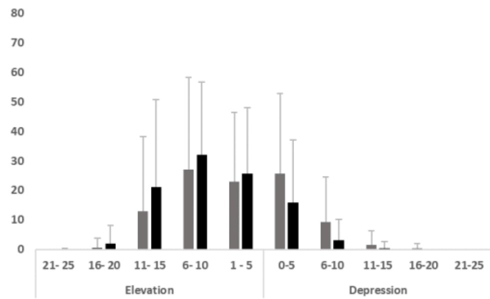
Half-kneeling



Standing

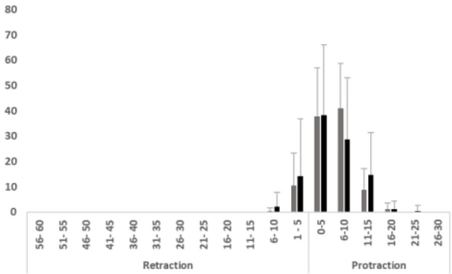


Sitting



Shoulder Girdle

Kneeling



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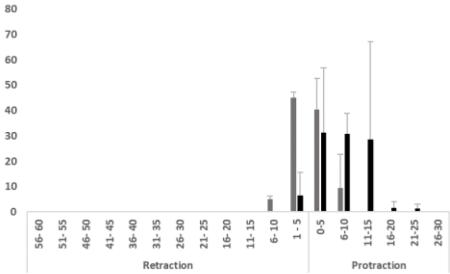

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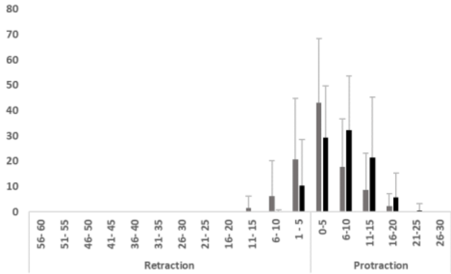

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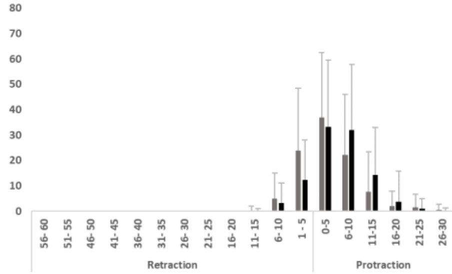
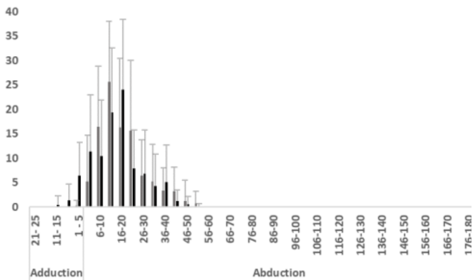


Shoulder

Kneeling



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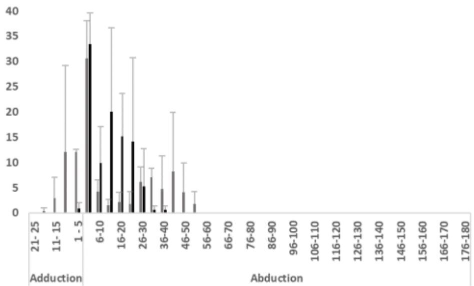
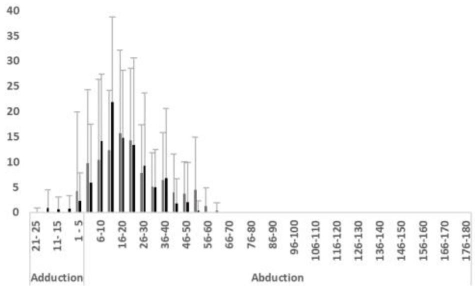
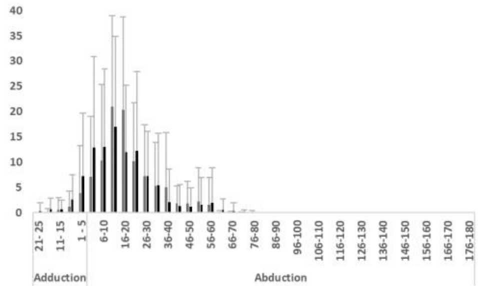


Standing

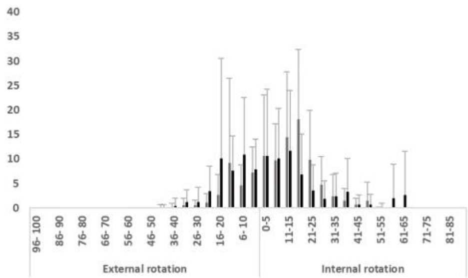


Sitting

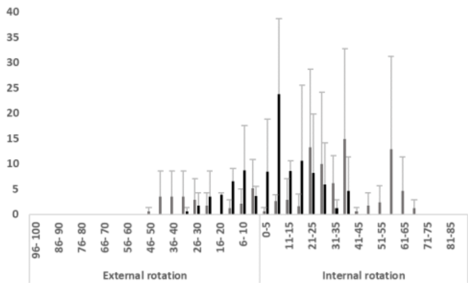


Shoulder

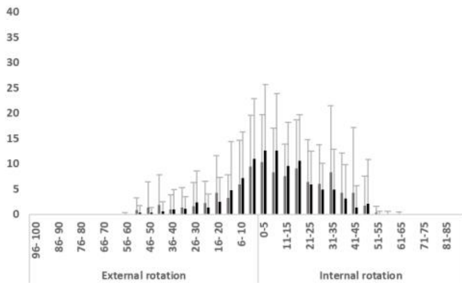
Kneeling



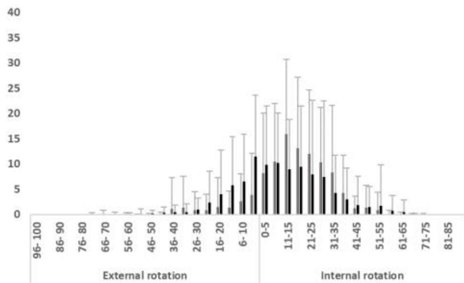
Half-kneeling



Standing

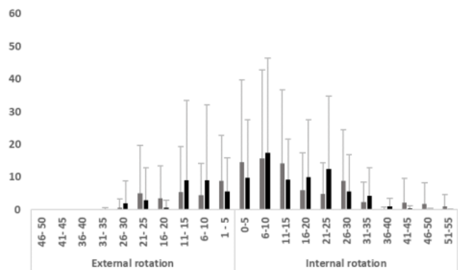


Sitting

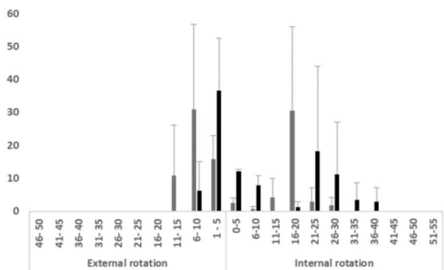


Hip

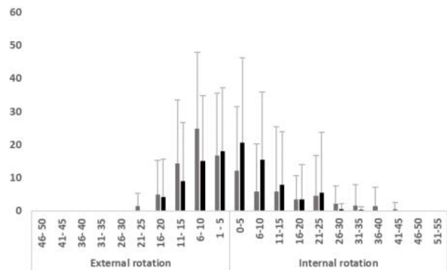
Kneeling



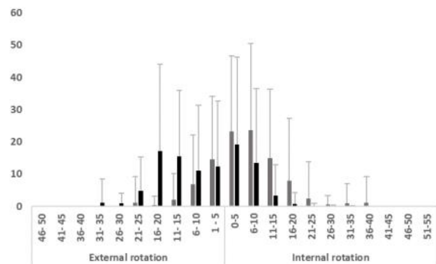
Half-kneeling



Standing



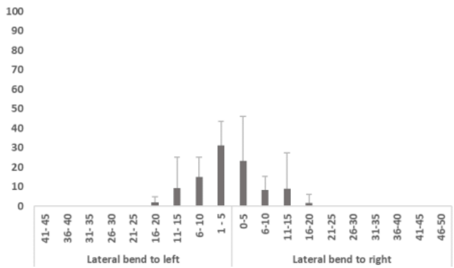
Sitting



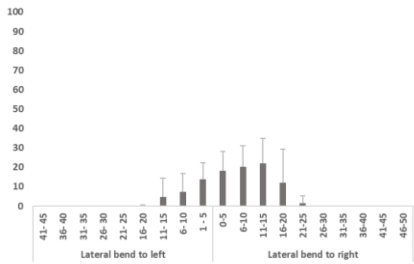
Upper Limb

Neck

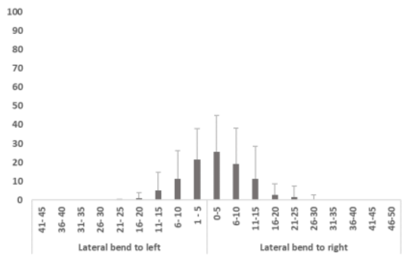
Kneeling



Half-kneeling



Standing



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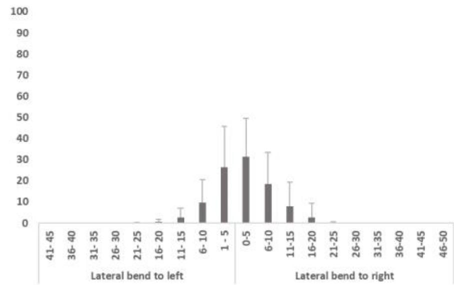
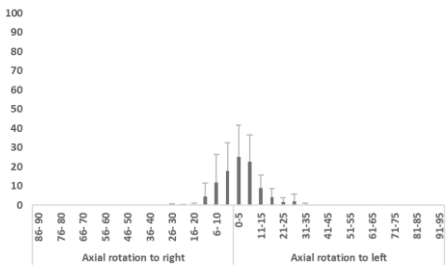
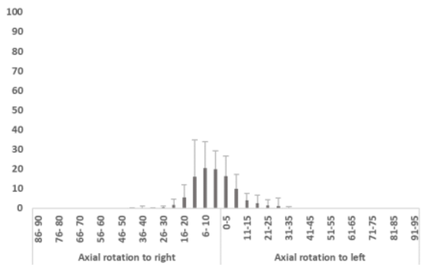


Neck

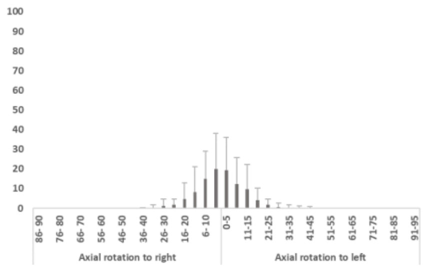
Kneeling



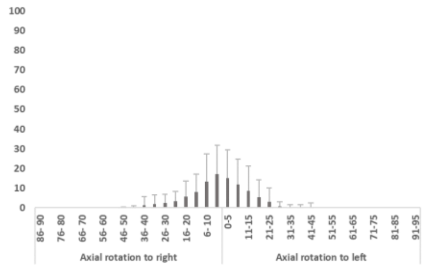
Half-kneeling



Standing

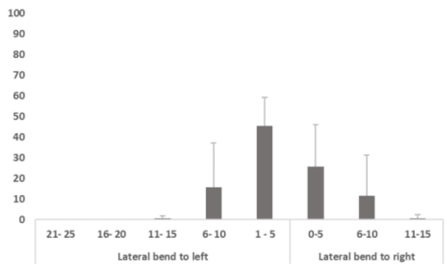


Sitting

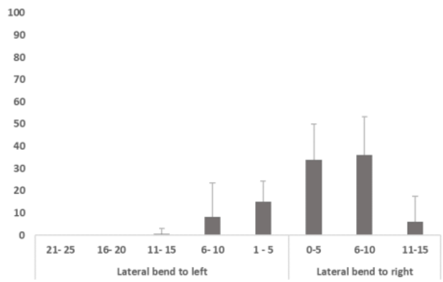


Cervicothoracic

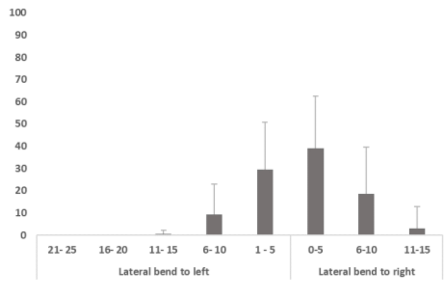
Kneeling



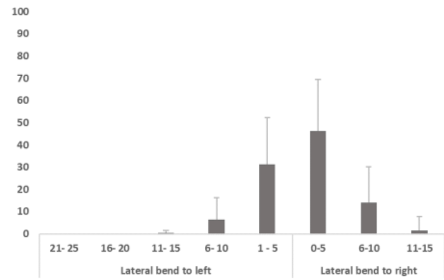
Half-kneeling



Standing

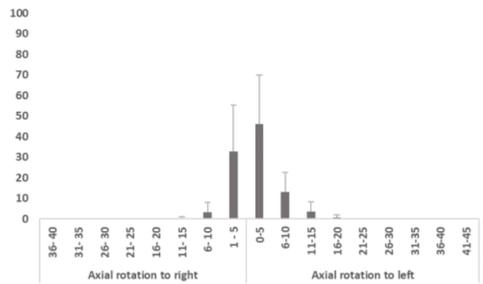


Sitting

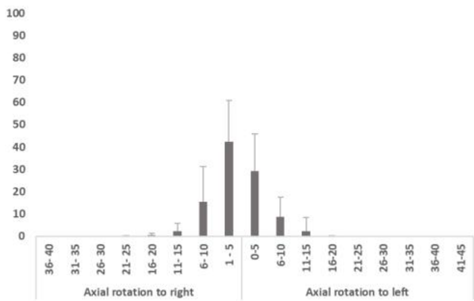


Cervicothoracic

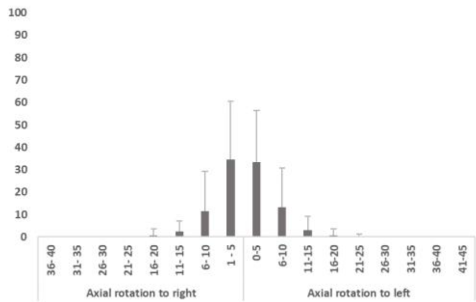
Kneeling



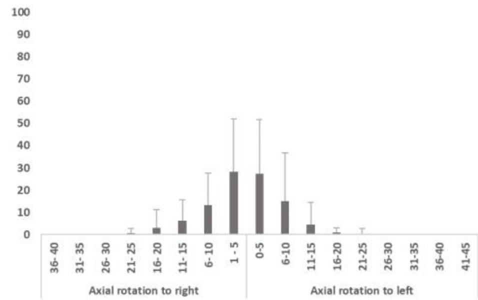
Half-kneeling



Standing

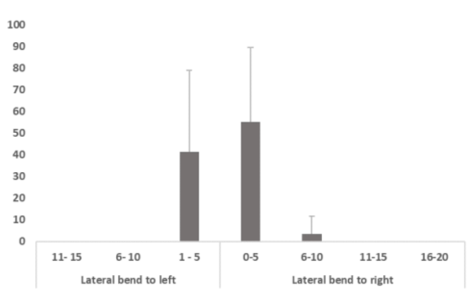


Sitting

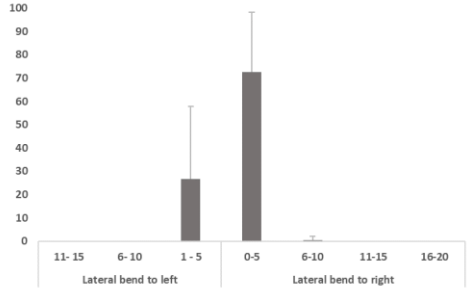


Thoracolumbar

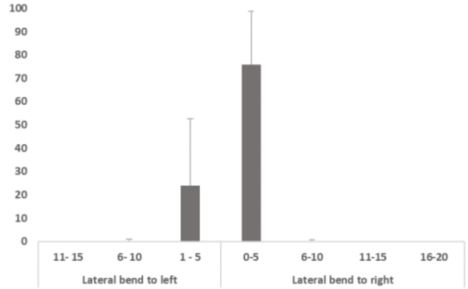
Kneeling



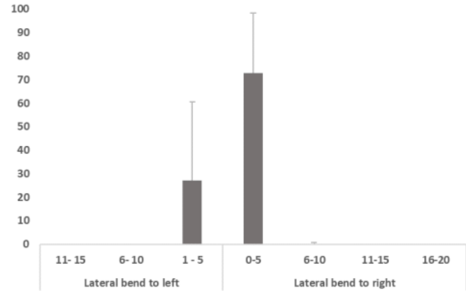
Half-kneeling



Standing

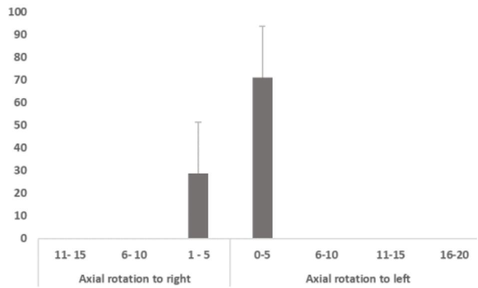


Sitting

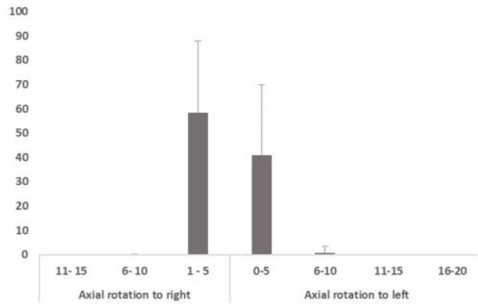


Thoracolumbar

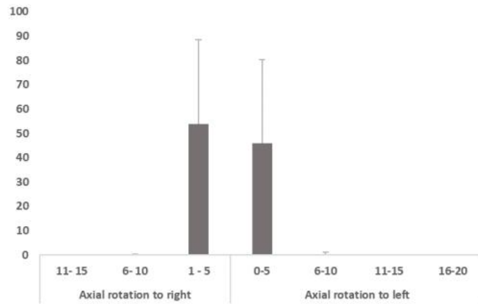
Kneeling



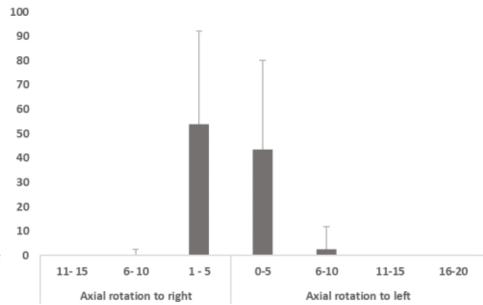
Half-kneeling



Standing

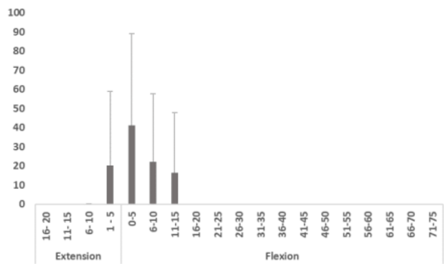


Sitting



Thoracolumbar

Kneeling



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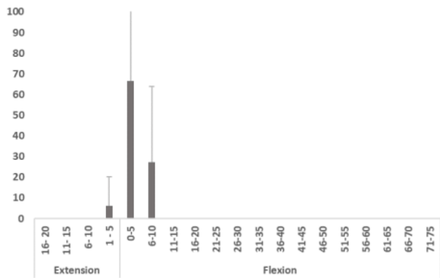

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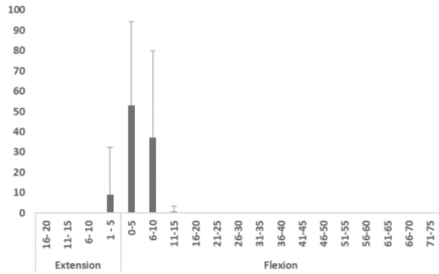

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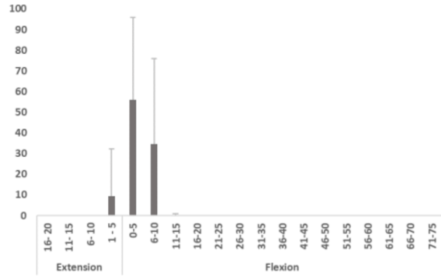
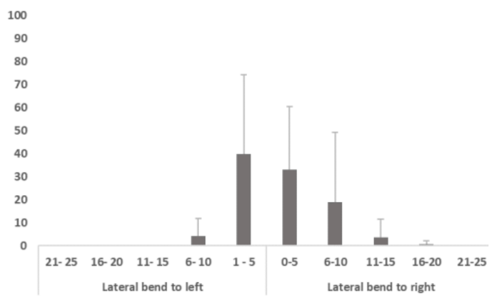


Lumbosacral

Kneeling



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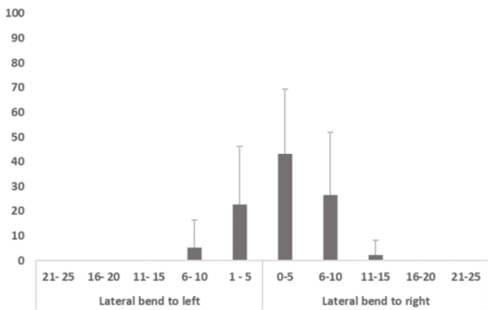
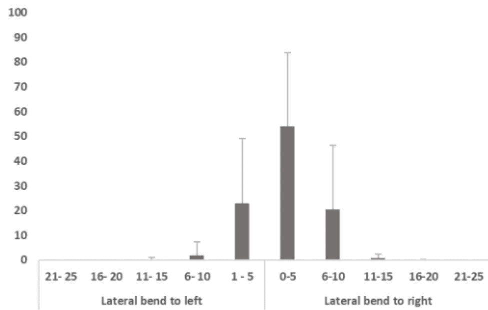
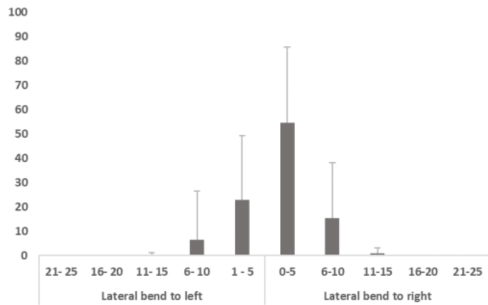


Standing

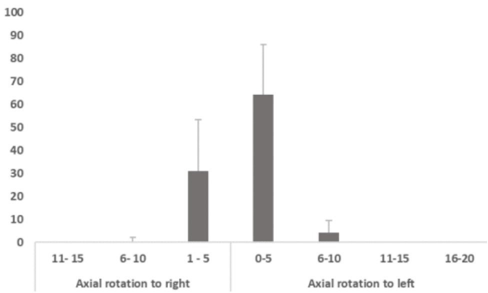


Sitting



Lumbosacral

Kneeling



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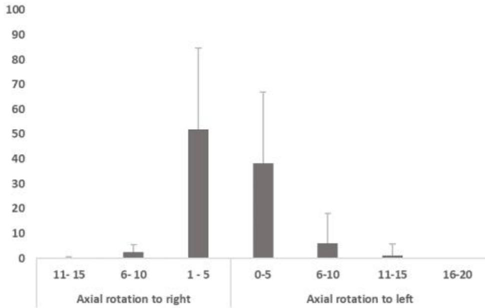

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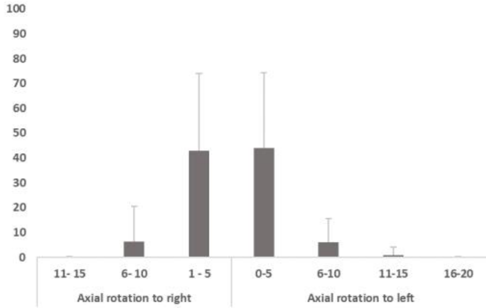

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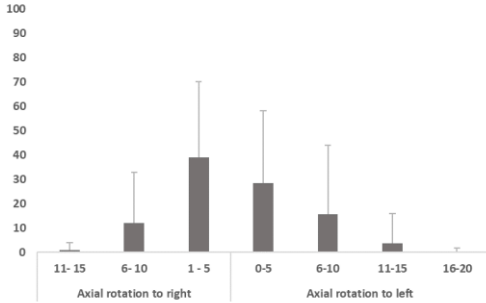
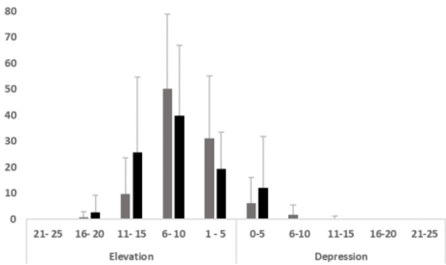
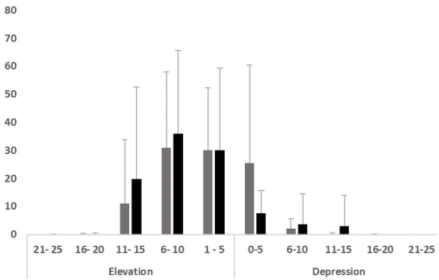


Shoulder Girdle

Kneeling



Half-kneeling



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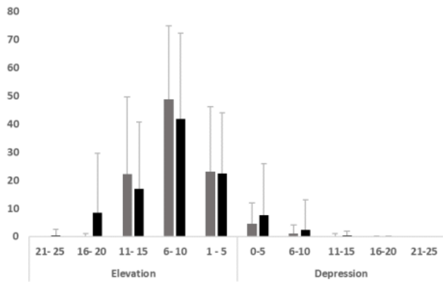

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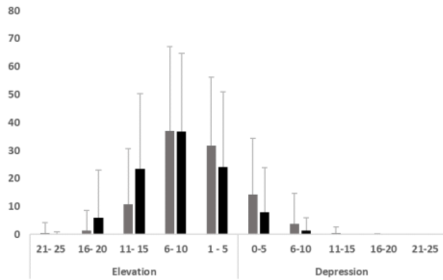
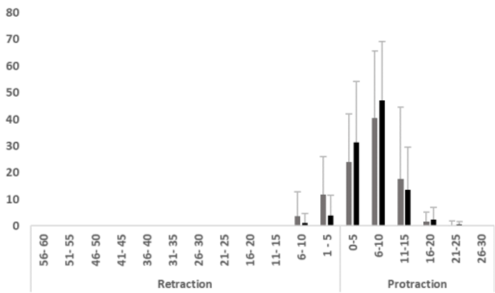


Shoulder Girdle

Kneeling



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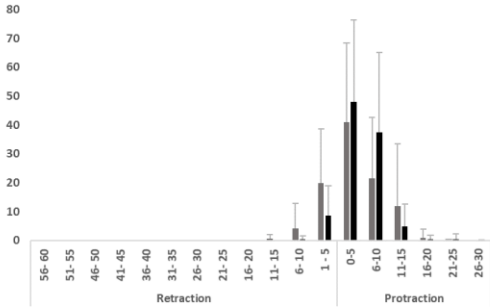

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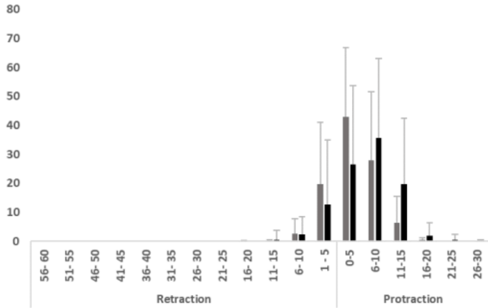

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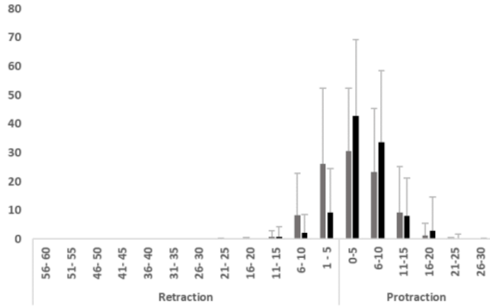
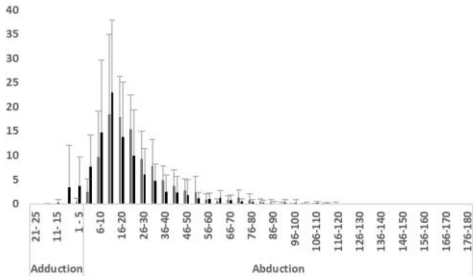


Shoulder

Kneeling



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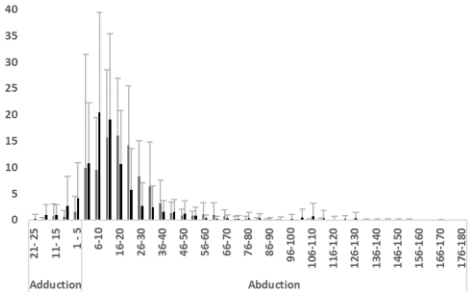

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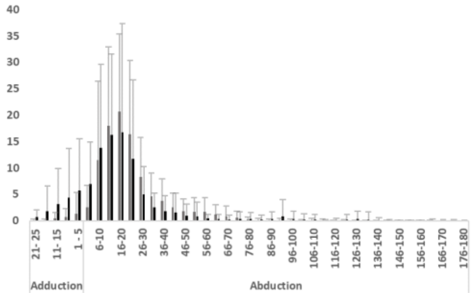

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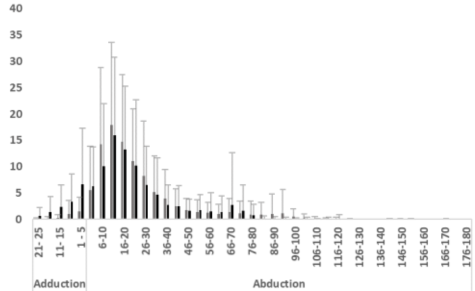
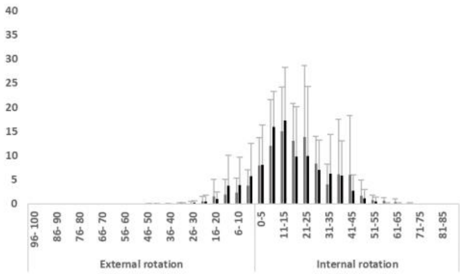


Shoulder

Kneeling



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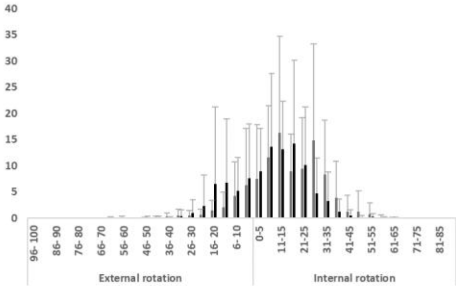

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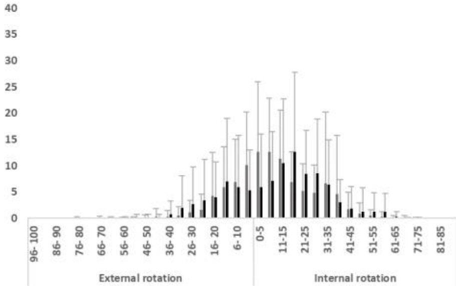

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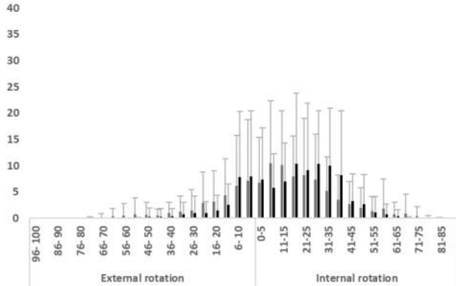
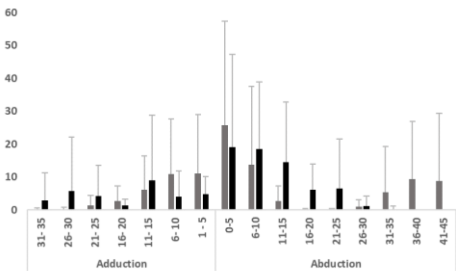


Hip

Kneeling



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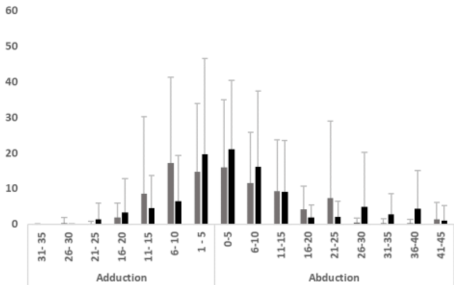

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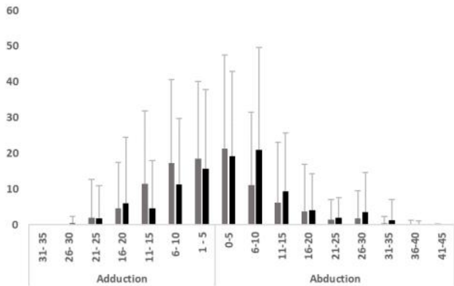

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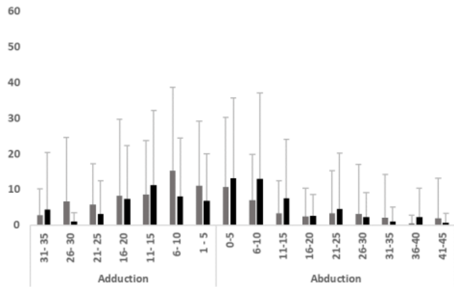
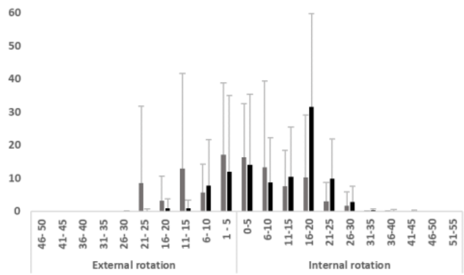


Hip

Kneeling



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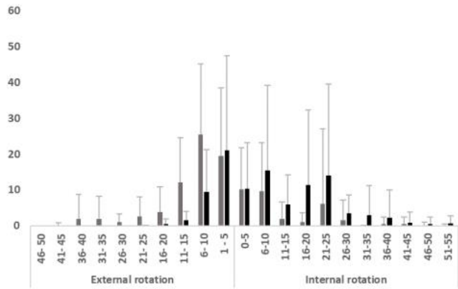

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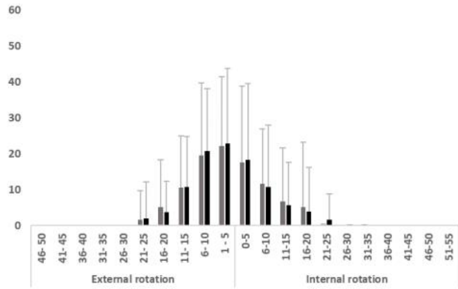

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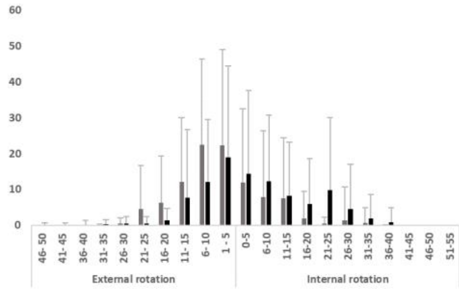
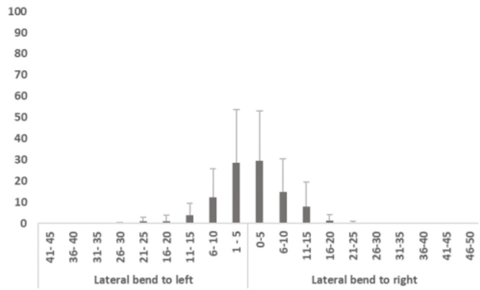


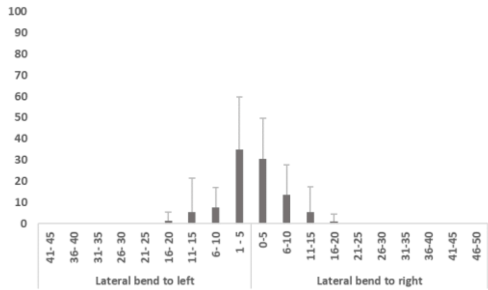
Lower Limb

Neck

Kneeling



Half-kneeling



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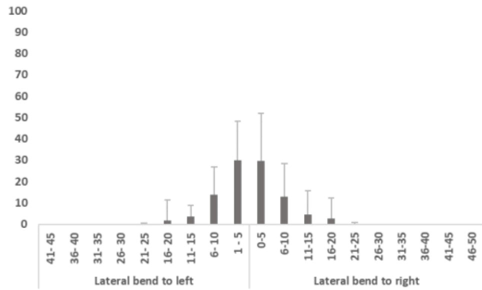

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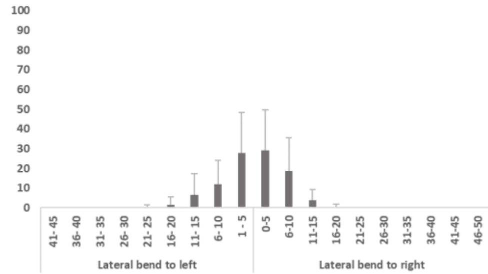
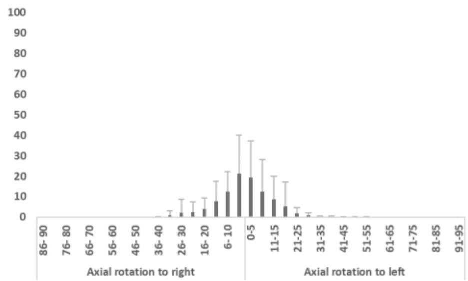


Neck

Kneeling



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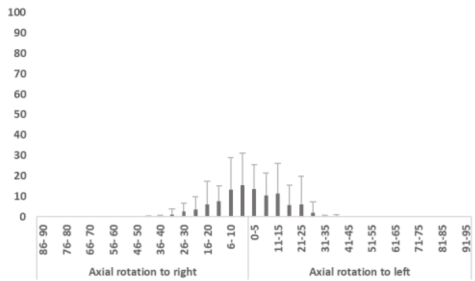
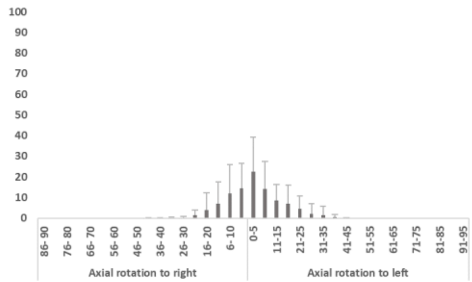


Standing



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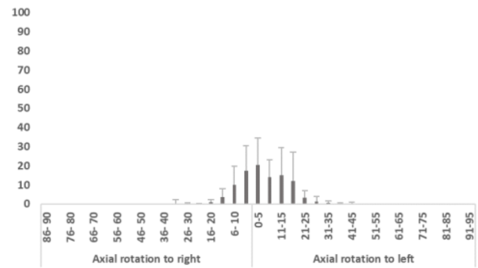
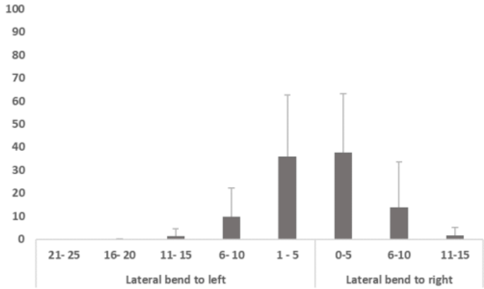
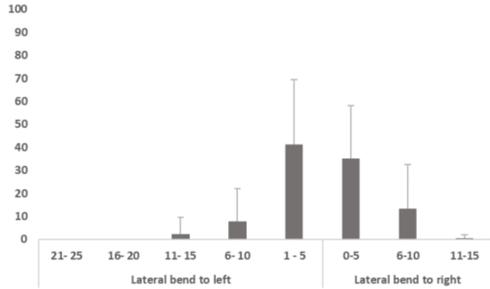


Cervicothoracic

Kneeling



Half-kneeling



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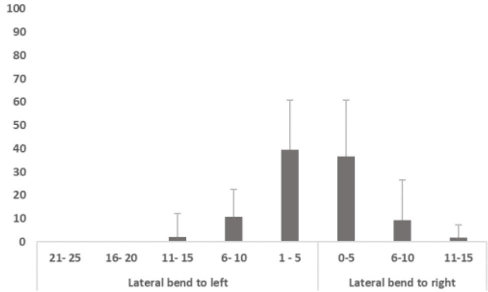

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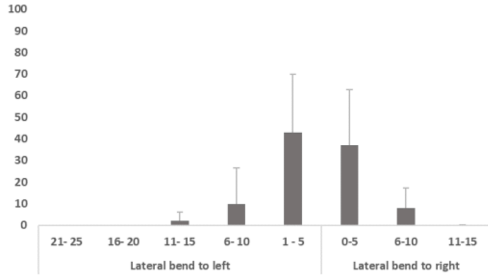
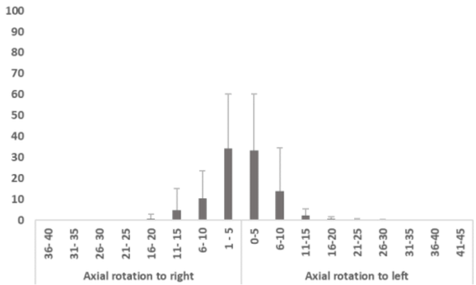


Cervicothoracic

Kneeling



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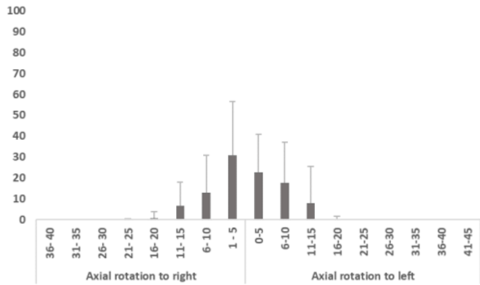

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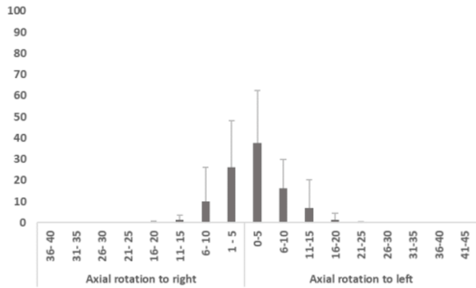

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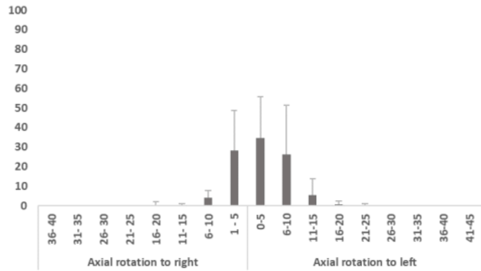
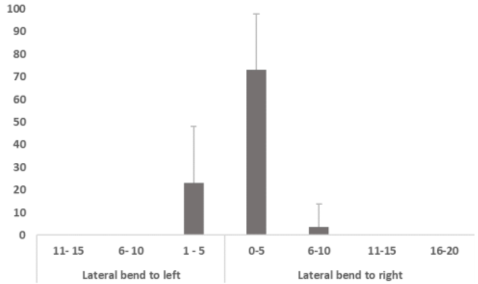


Thoracolumbar

Kneeling



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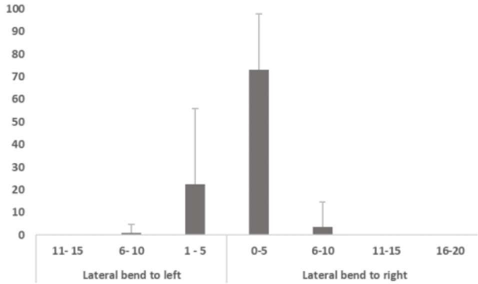

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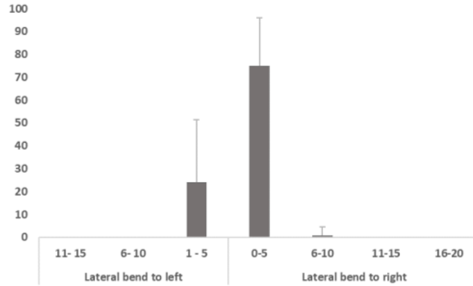

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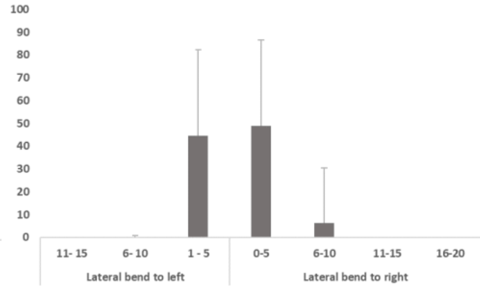
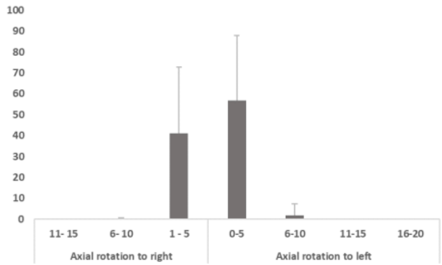


Thoracolumbar

Kneeling



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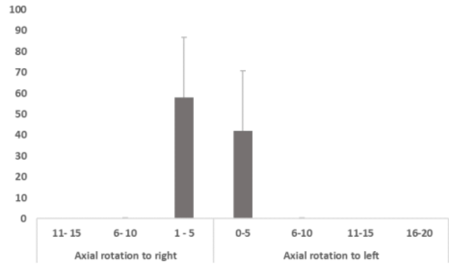

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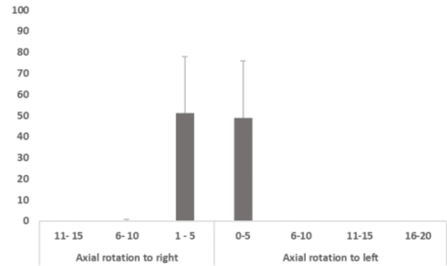

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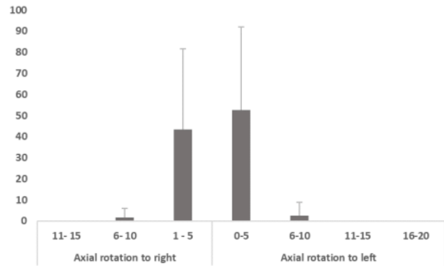
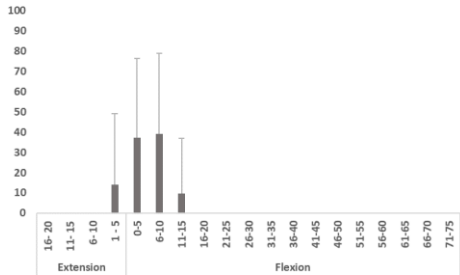


Thoracolumbar

Kneeling



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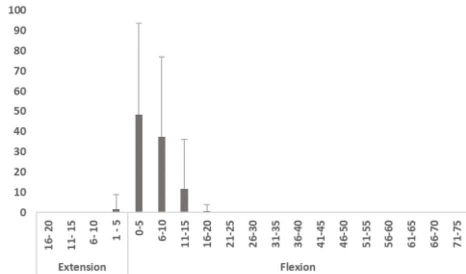
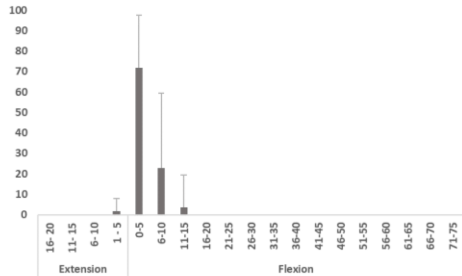


Standing



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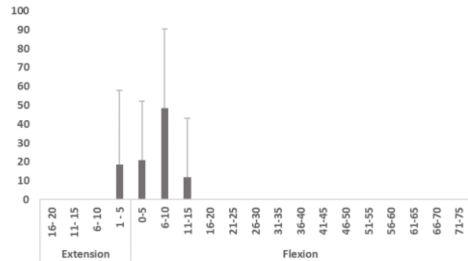
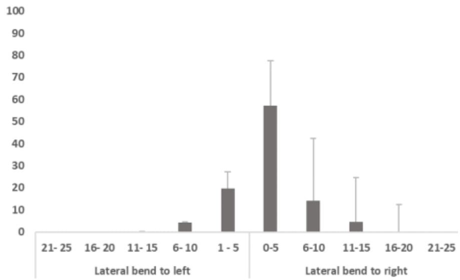
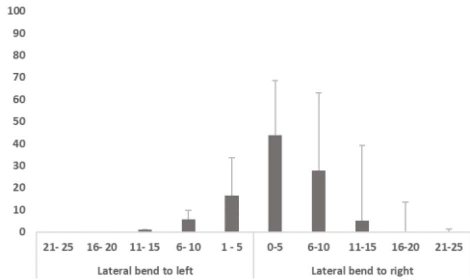


Lumbosacral

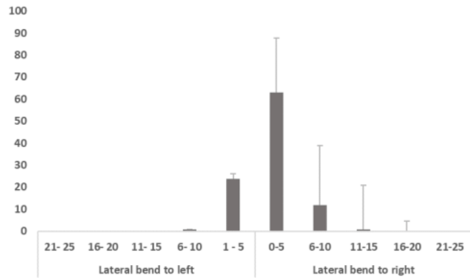
Kneeling



Half-kneeling



Standing



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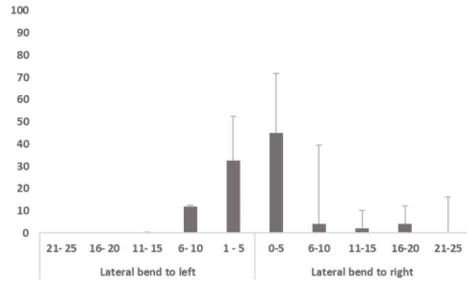
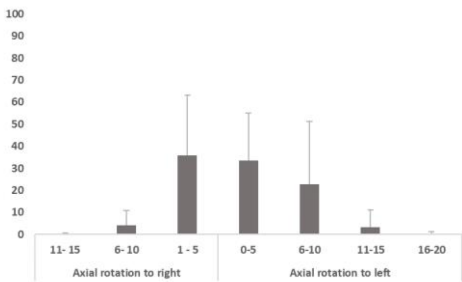
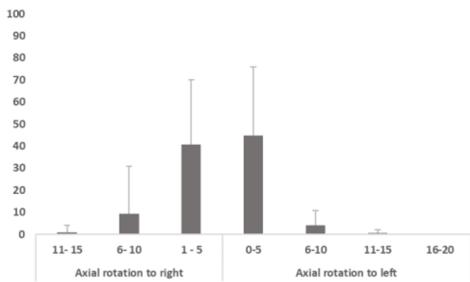


Lumbosacral

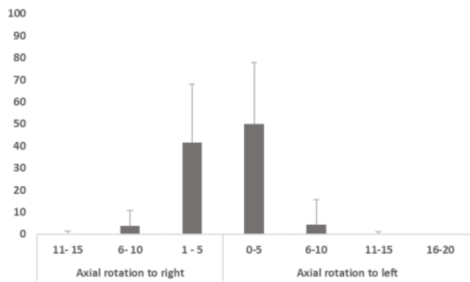
Kneeling



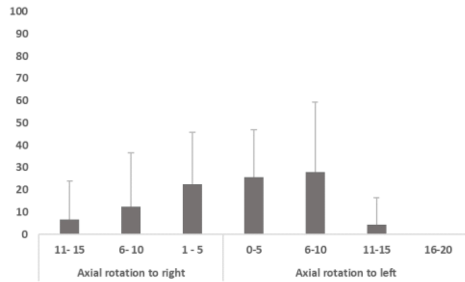
Half-kneeling



Standing

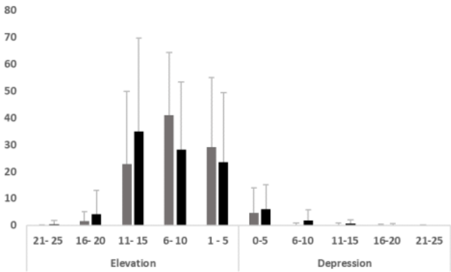


Sitting



Shoulder Girdle

Kneeling



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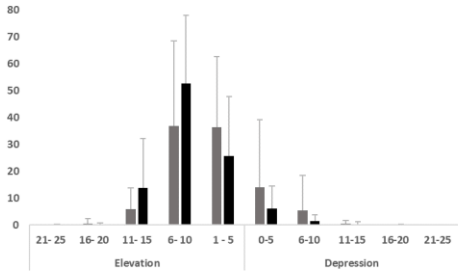

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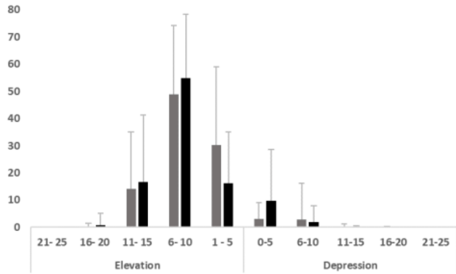

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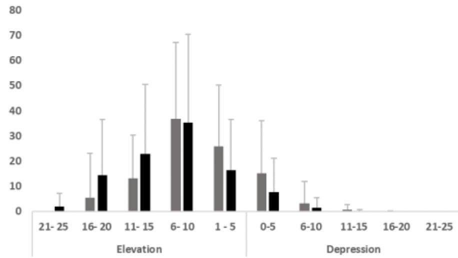
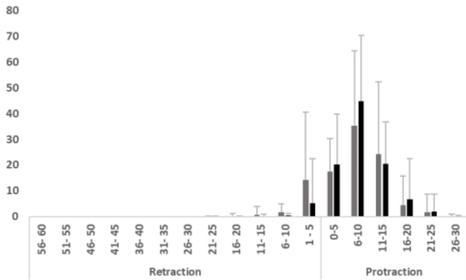


Shoulder Girdle

Kneeling



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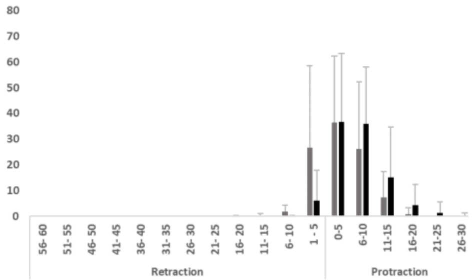

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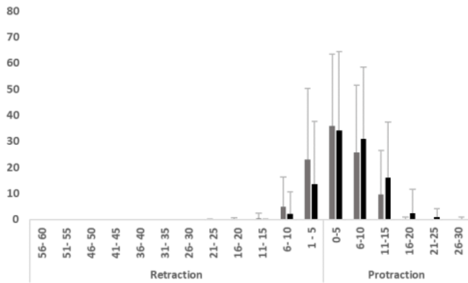

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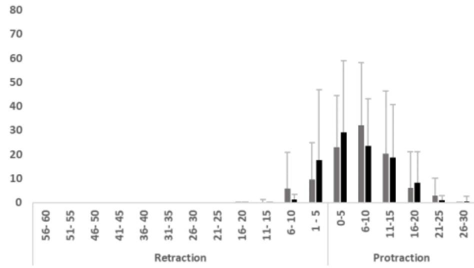
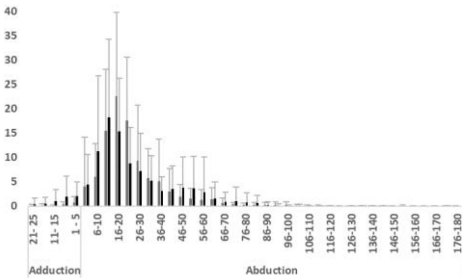


Shoulder

Kneeling



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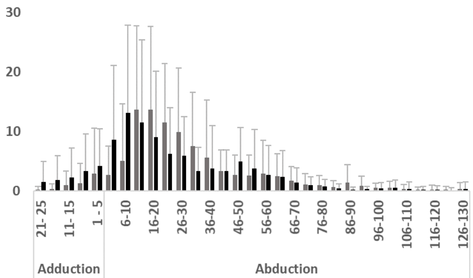

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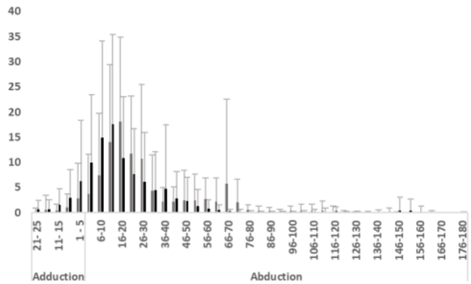

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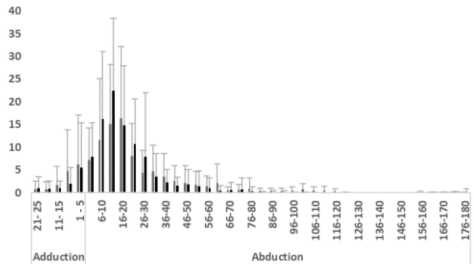

Shoulder

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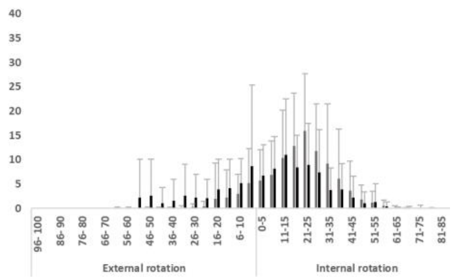

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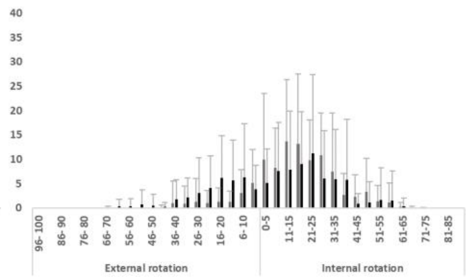

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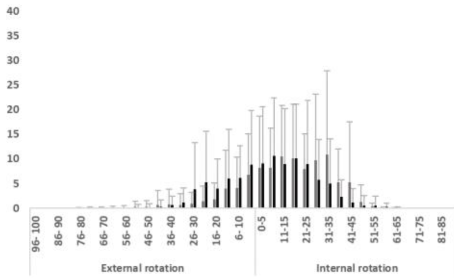

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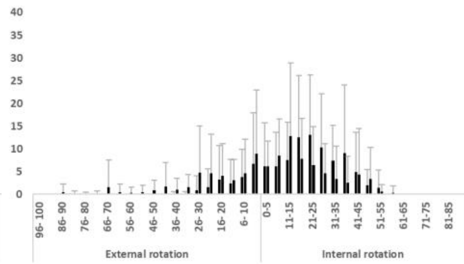
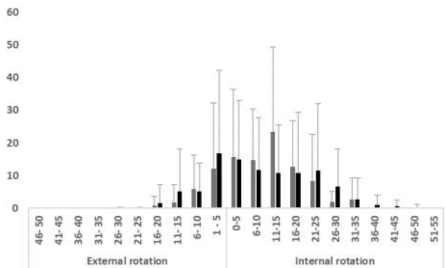


Hip

Kneeling



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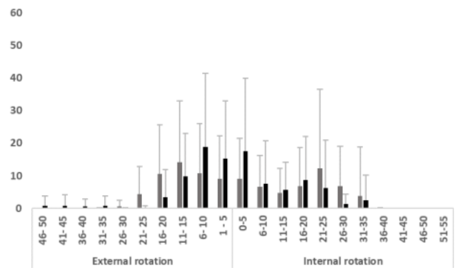

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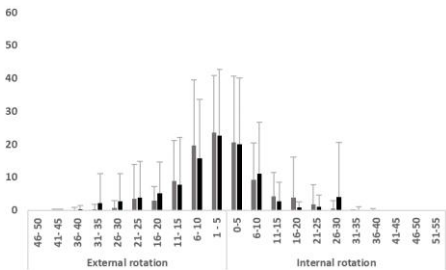

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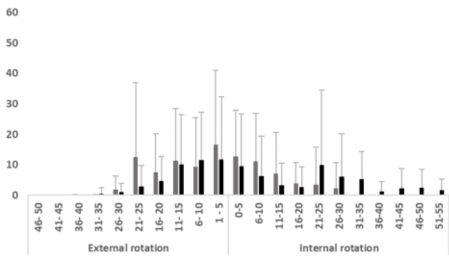
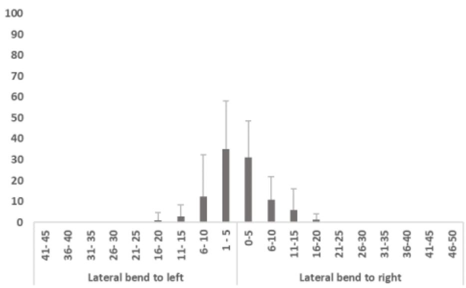


Trunk

Neck

Kneeling



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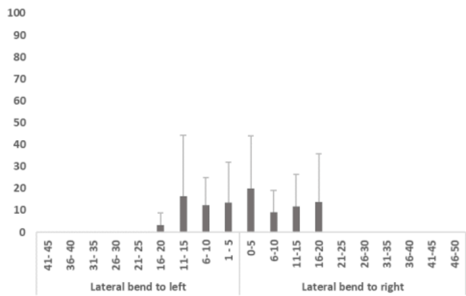

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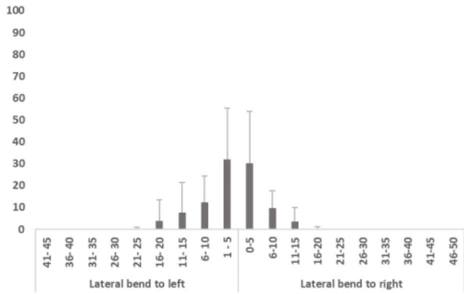

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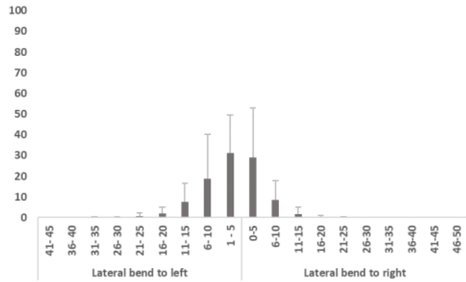
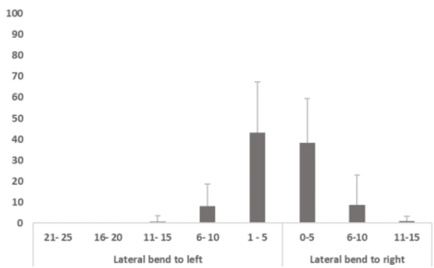


Cervicothoracic

Kneeling



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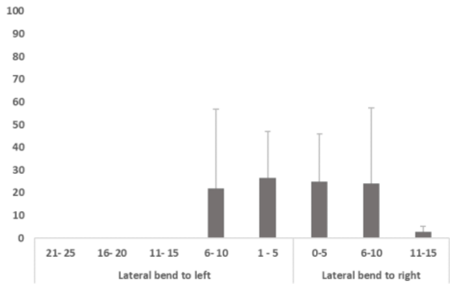

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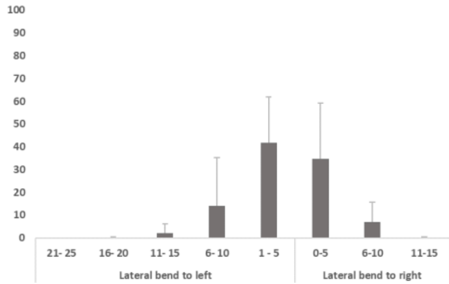

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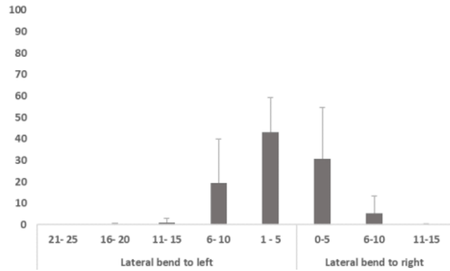
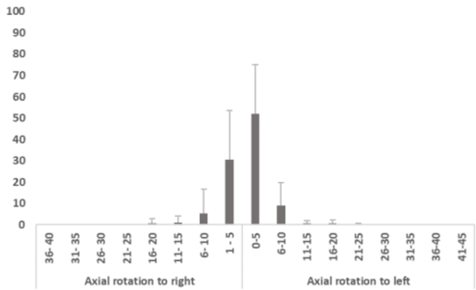


Cervicothoracic

Kneeling



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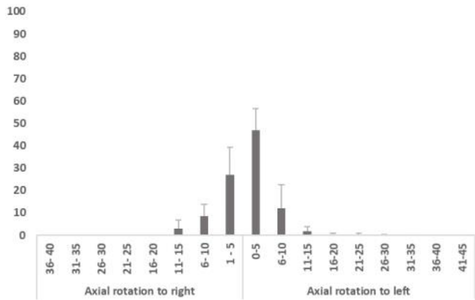

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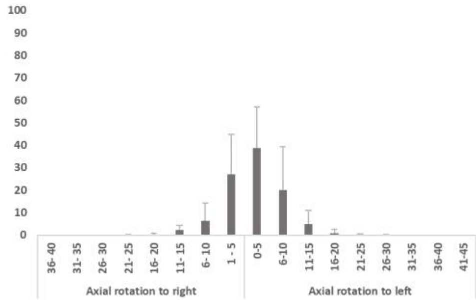

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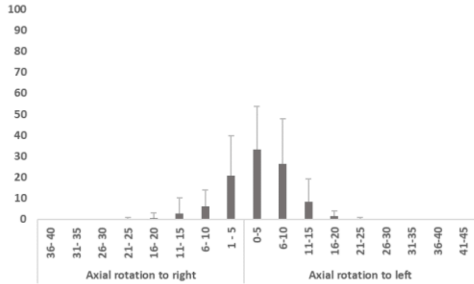
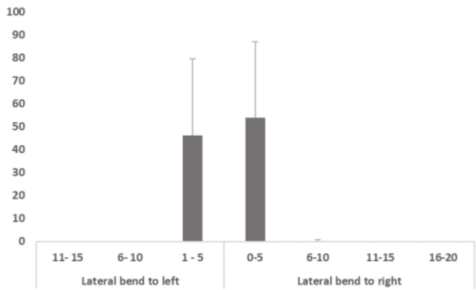


Thoracolumbar

Kneeling



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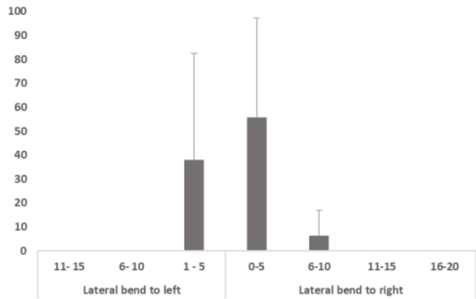

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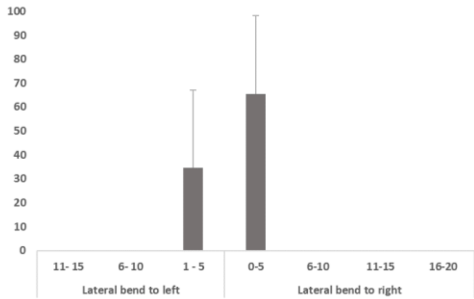

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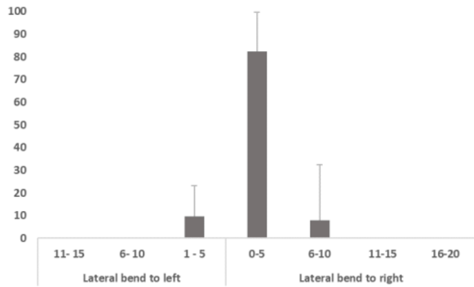
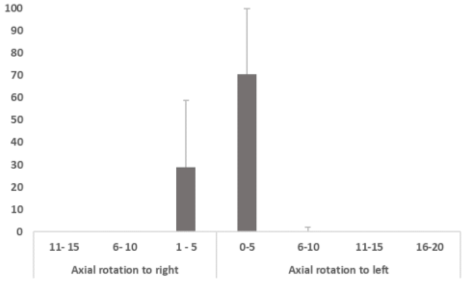


Thoracolumbar

Kneeling



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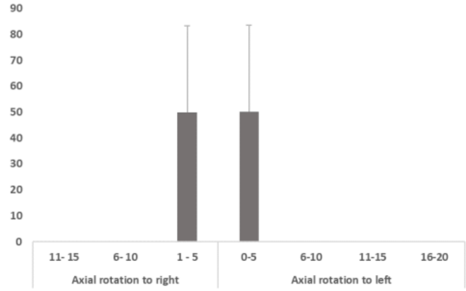

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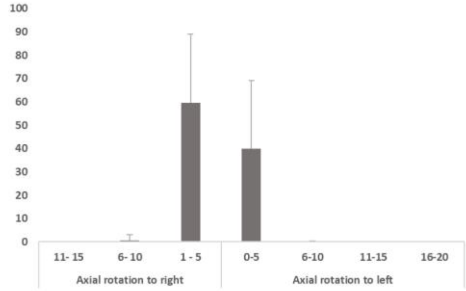

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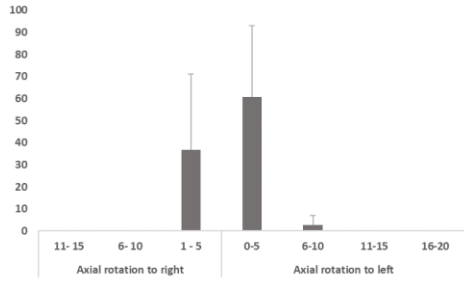
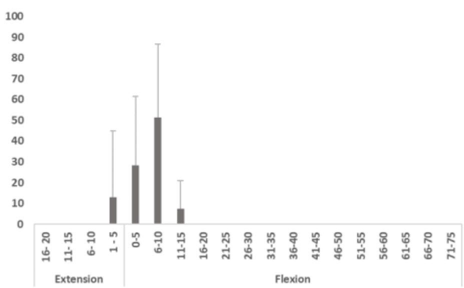


Thoracolumbar

Kneeling



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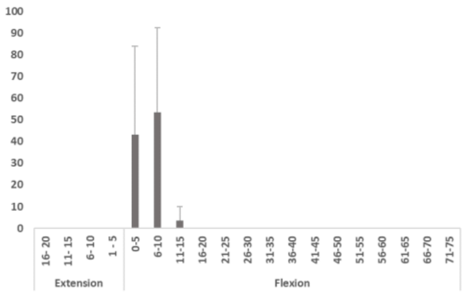

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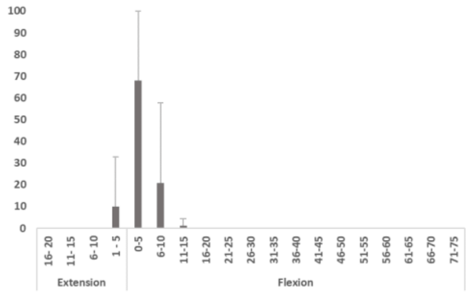

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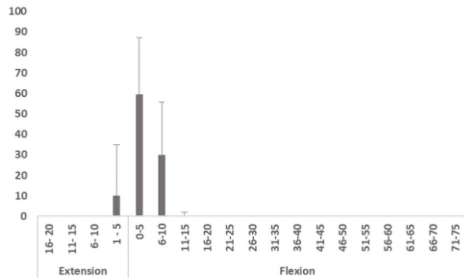
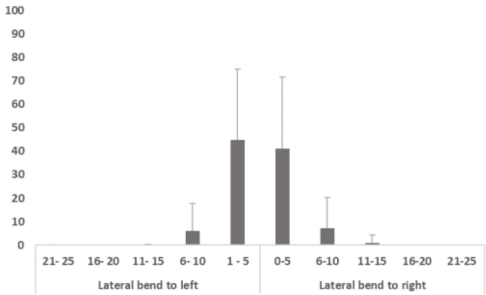


Lumbosacral

Kneeling



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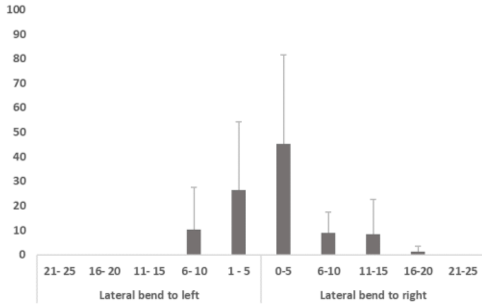

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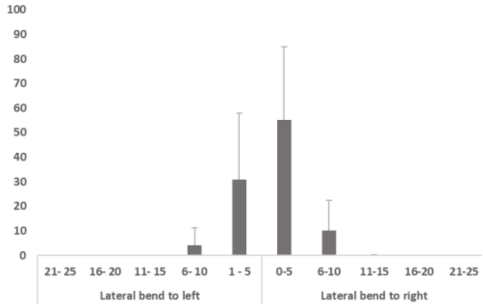

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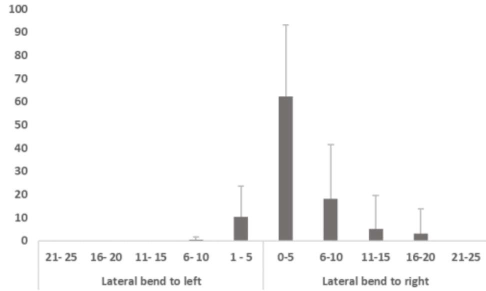
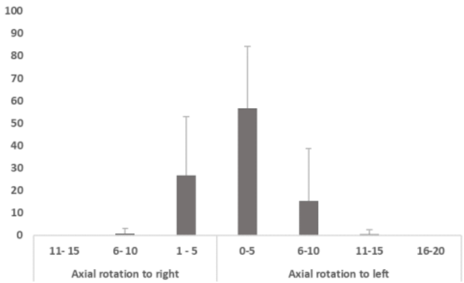


Lumbosacral

Kneeling



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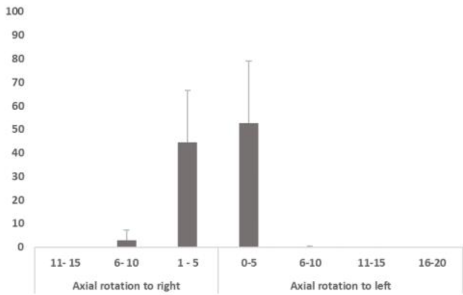

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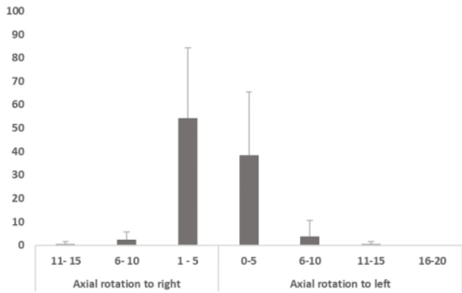

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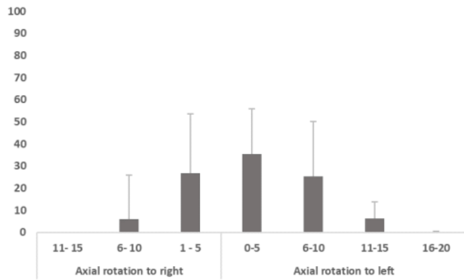
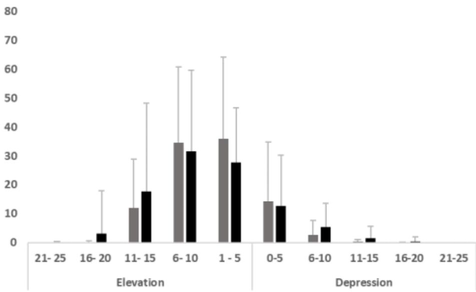
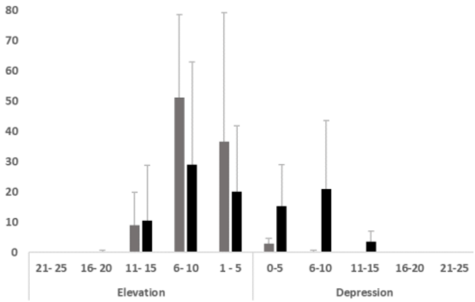


Shoulder Girdle

Kneeling



Half-kneeling



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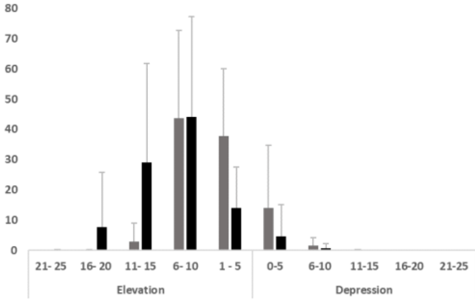

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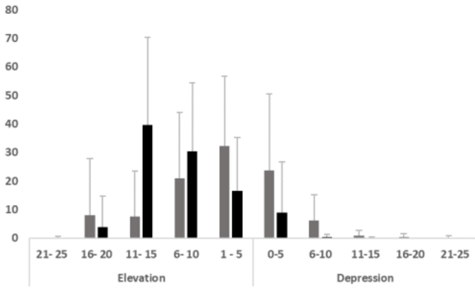

Shoulder Girdle

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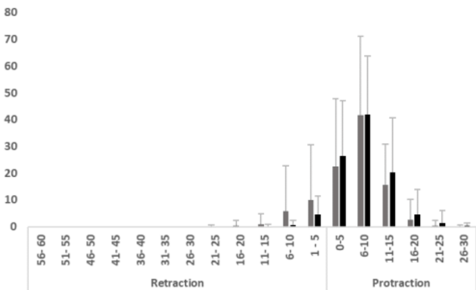

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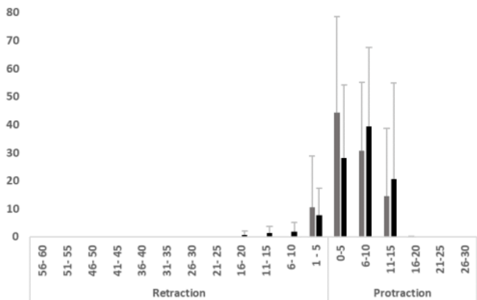

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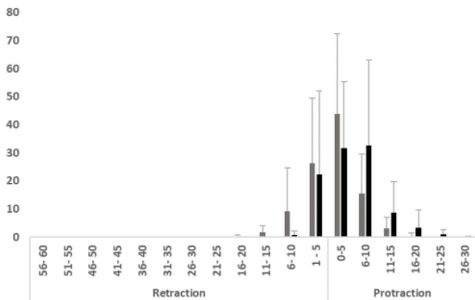

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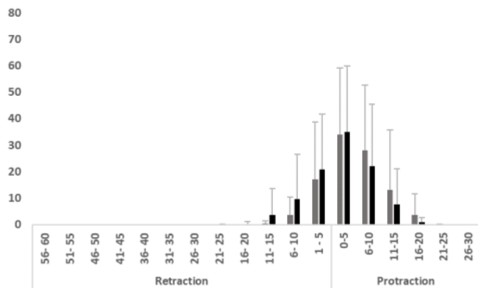
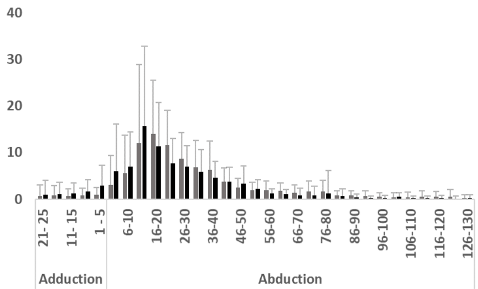


Shoulder

Kneeling



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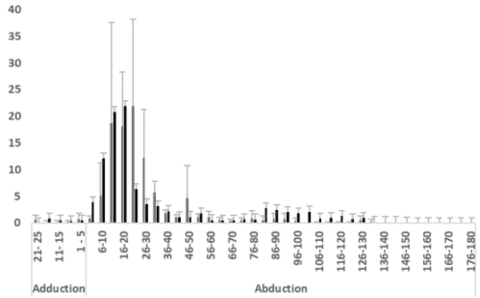

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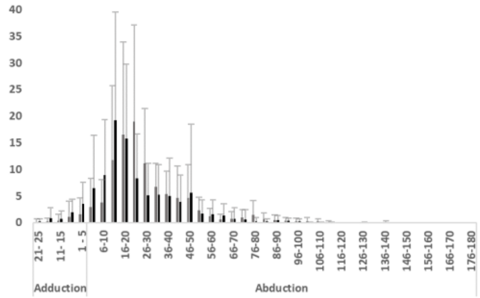

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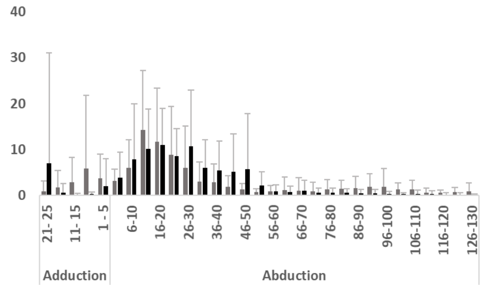
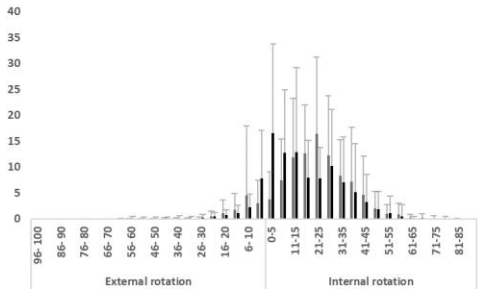


Shoulder

Kneeling



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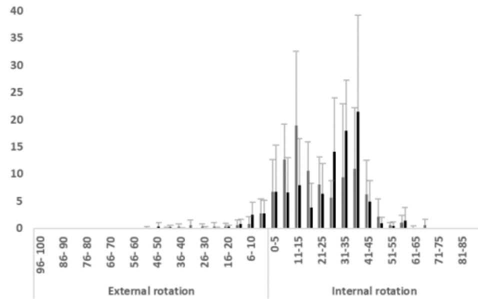

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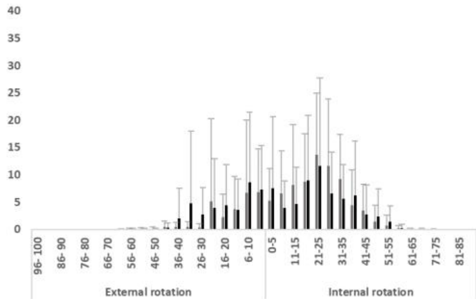

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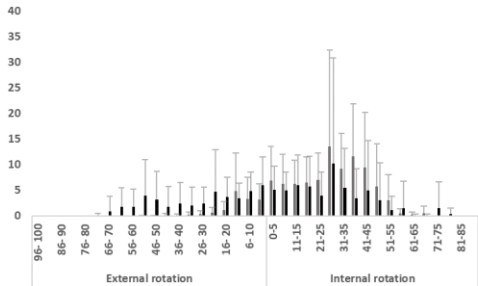
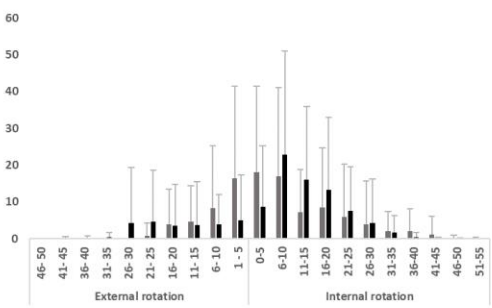


Hip

Kneeling



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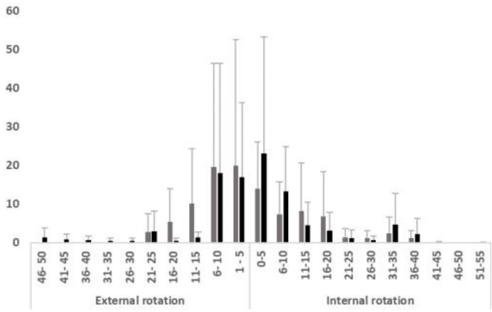

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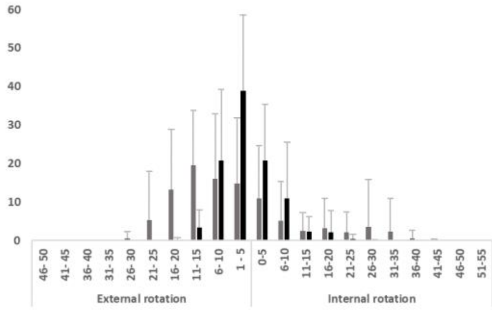
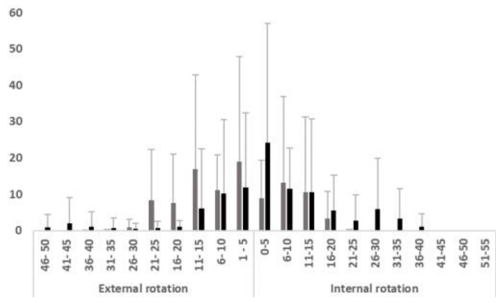


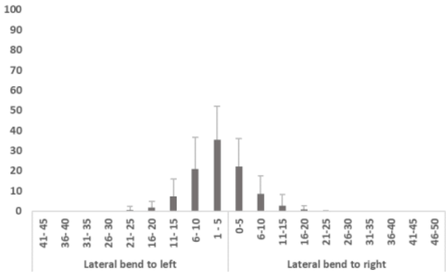
Sitting



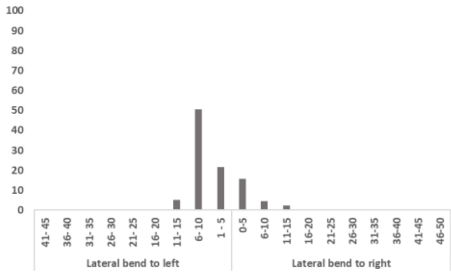
Stand

Neck

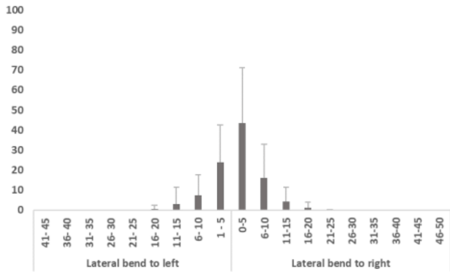
Kneeling



Half-kneeling



Standing



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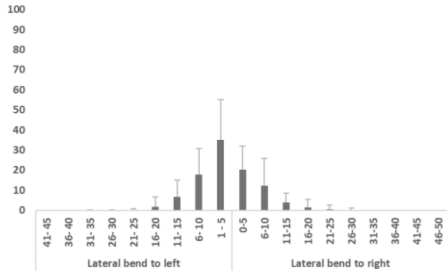
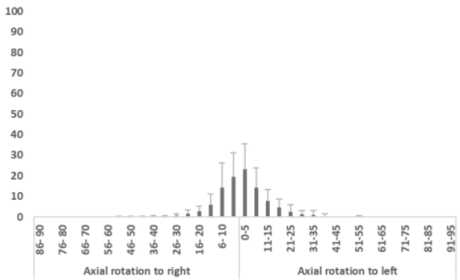


Neck

Kneeling



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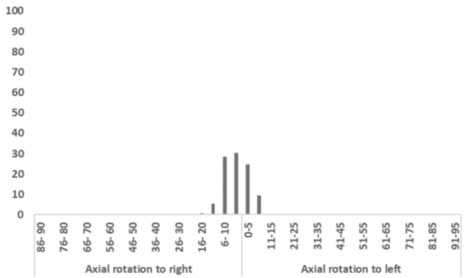

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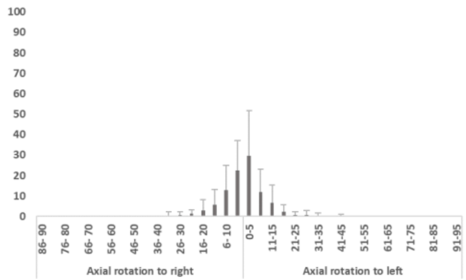

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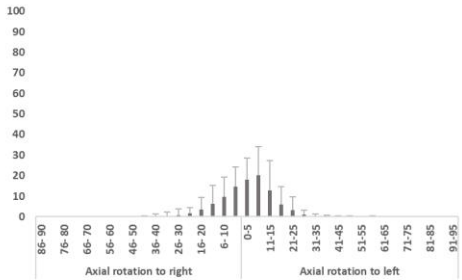
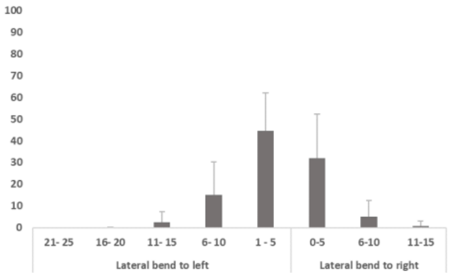
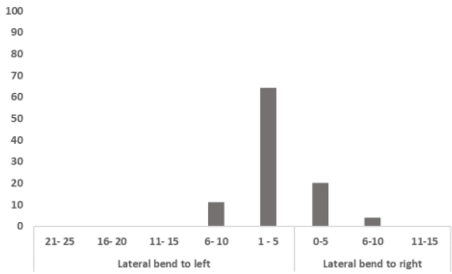


Cervicothoracic

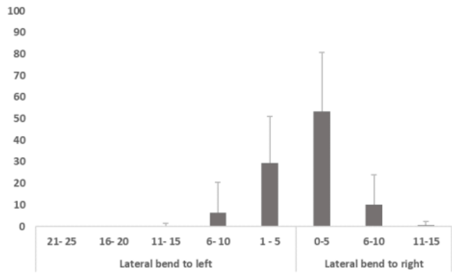
Kneeling



Half-kneeling



Standing



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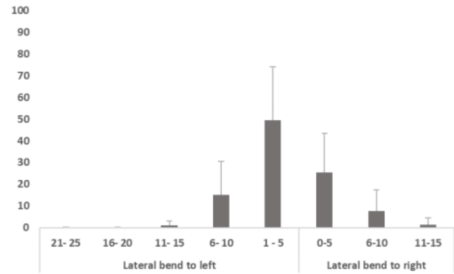
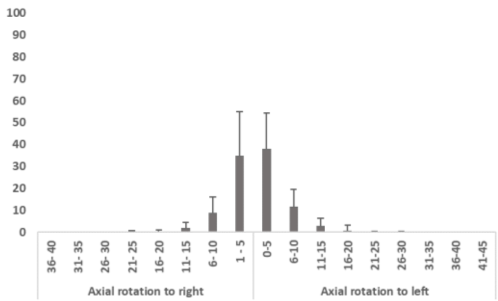


Cervicothoracic

Kneeling



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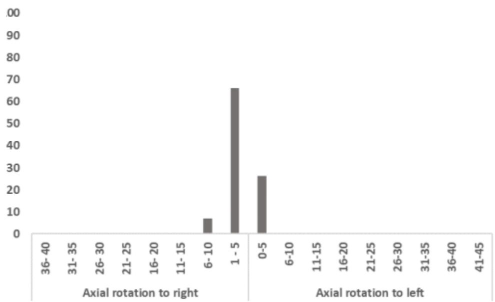

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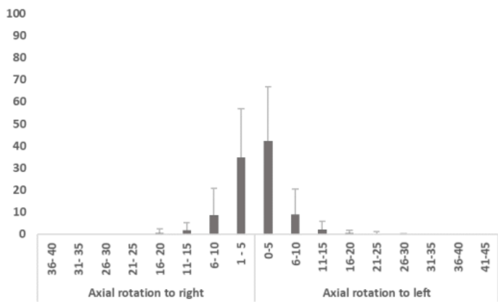

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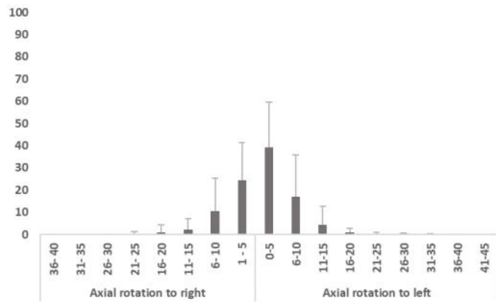
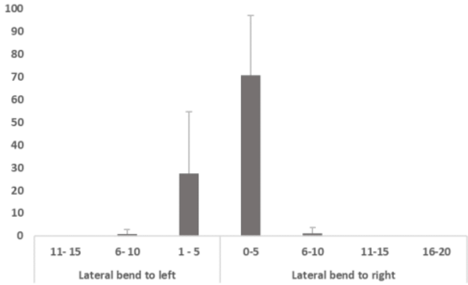


Thoracolumbar

Kneeling



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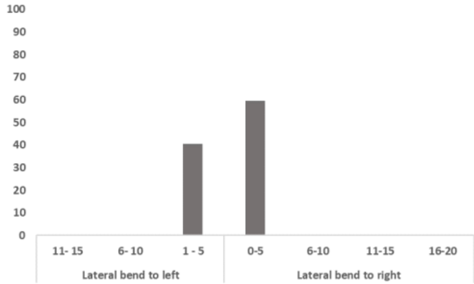

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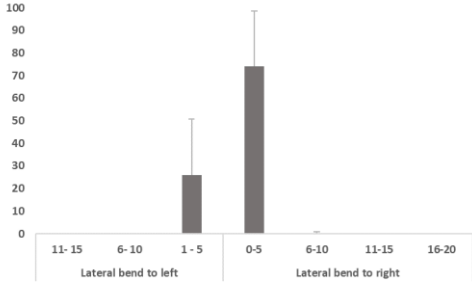

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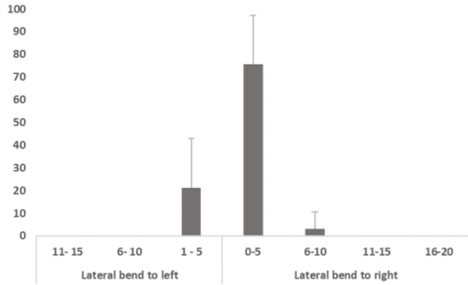
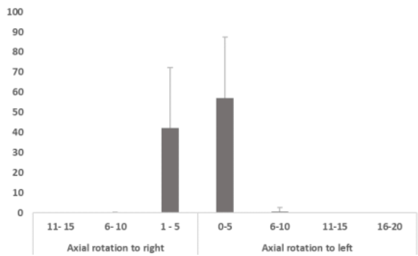


Thoracolumbar

Kneeling



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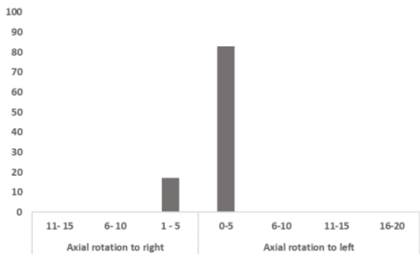

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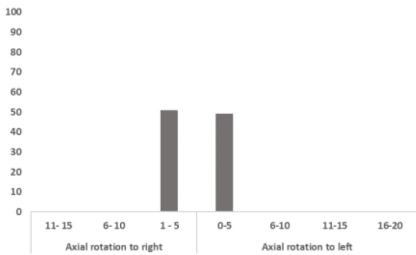

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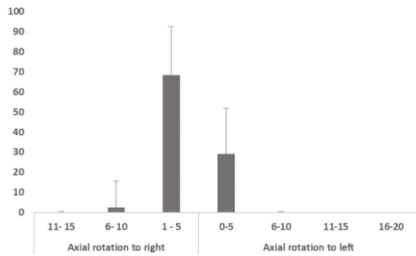
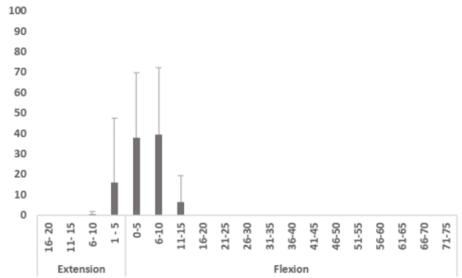


Thoracolumbar

Kneeling



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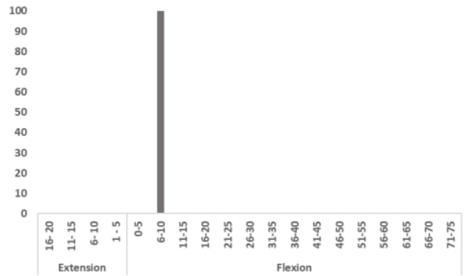

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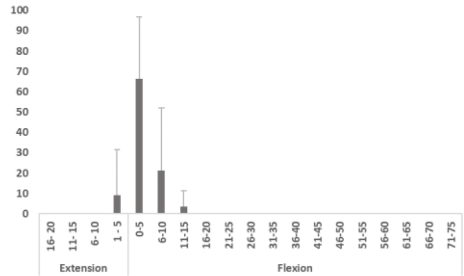

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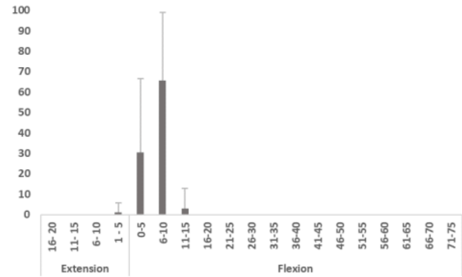
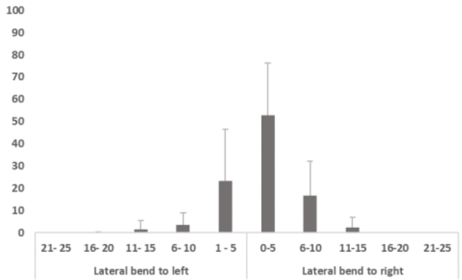
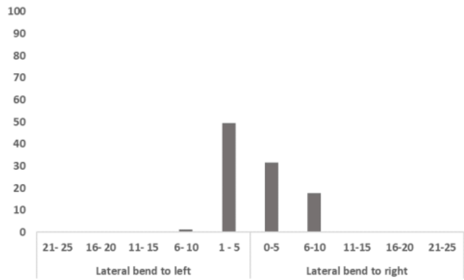


Lumbosacral

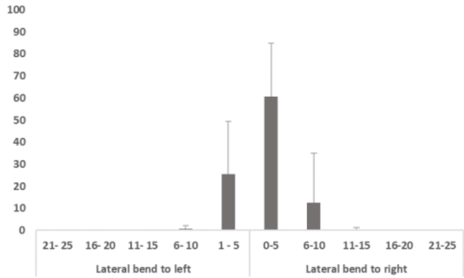
Kneeling



Half-kneeling



Standing



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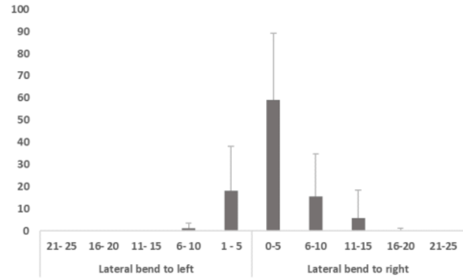
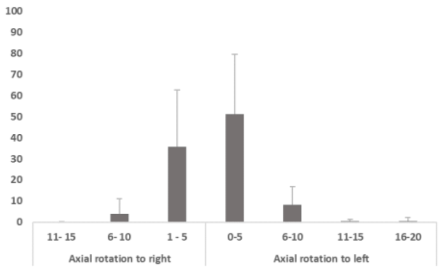
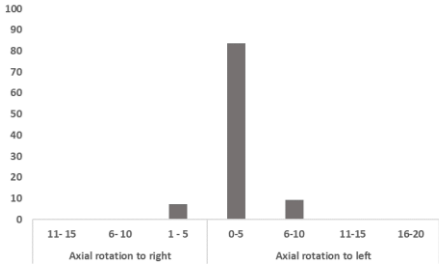


Lumbosacral

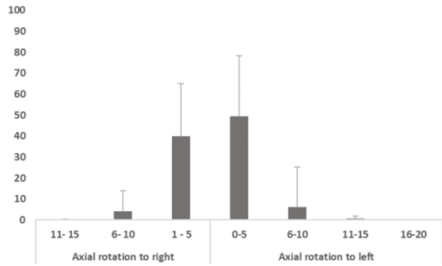
Kneeling



Half-kneeling



Standing



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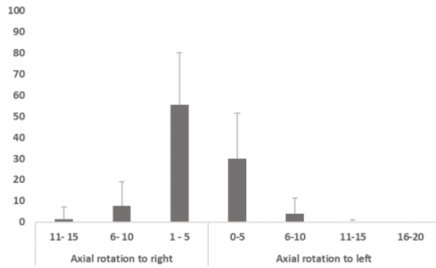
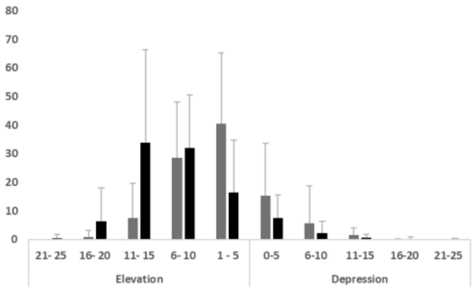


Shoulder Girdle

Kneeling



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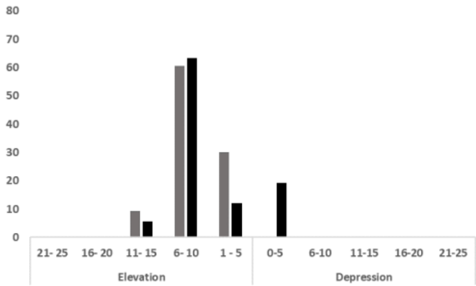

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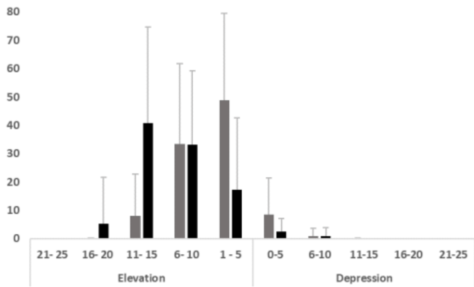
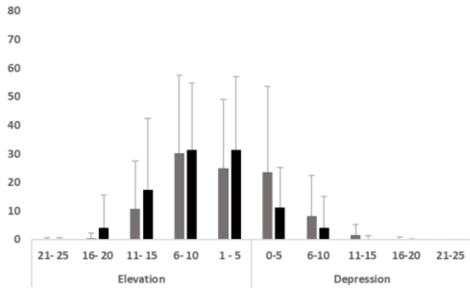
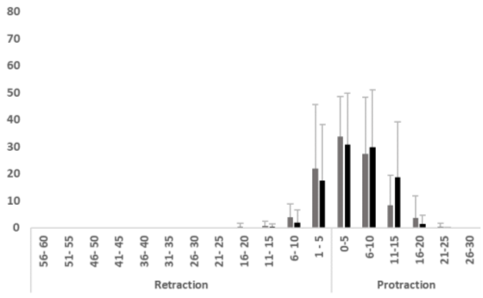


Sitting



Shoulder Girdle

Kneeling



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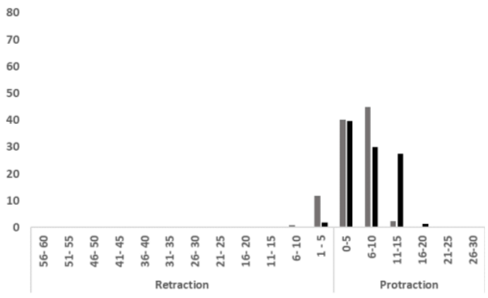
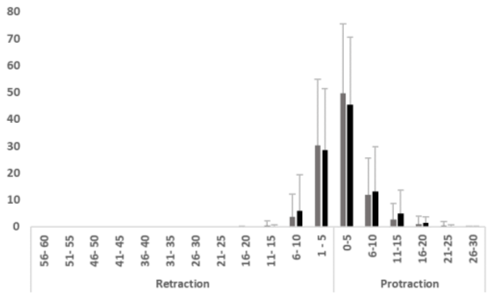


Standing



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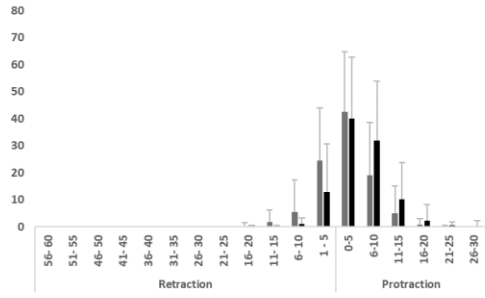
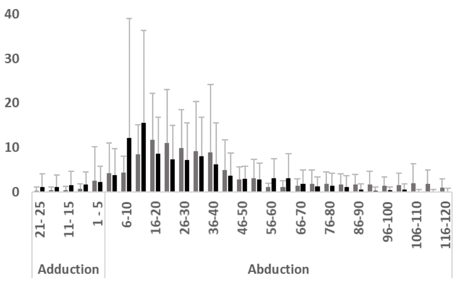


Shoulder

Kneeling



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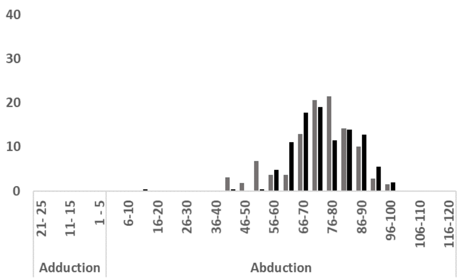
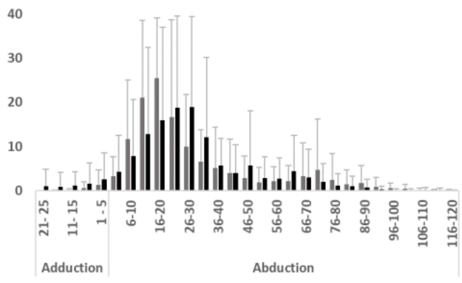


Standing



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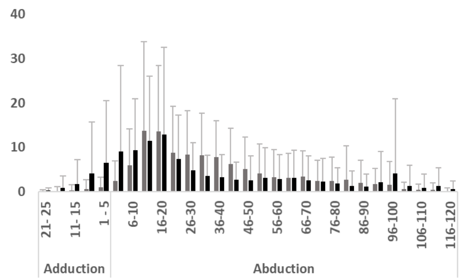
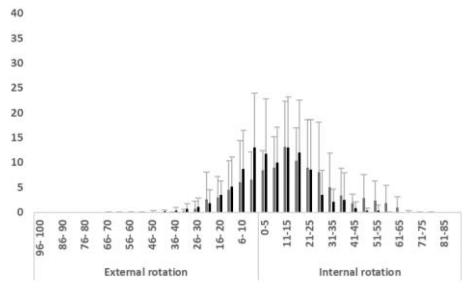


Shoulder

Kneeling



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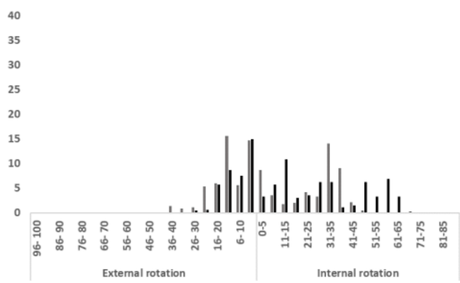
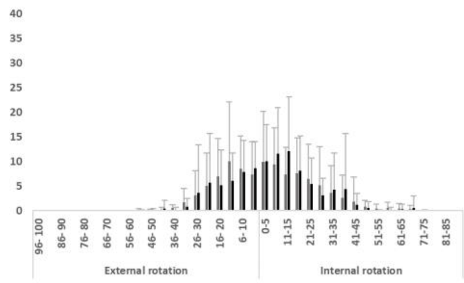
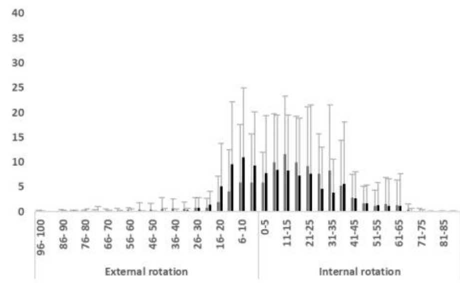


Standing

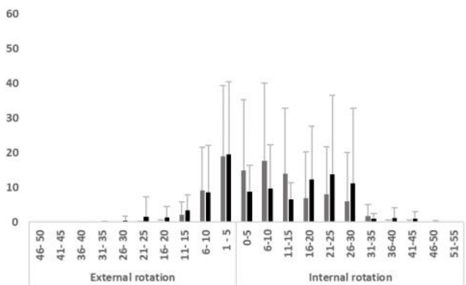


Sitting

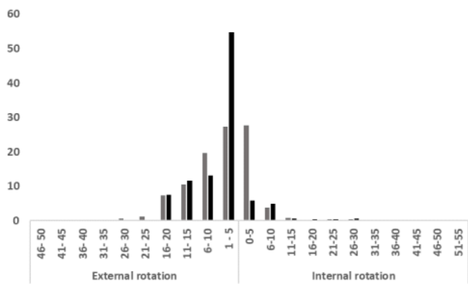


Hip

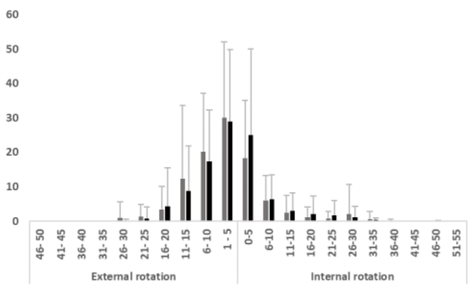
Kneeling



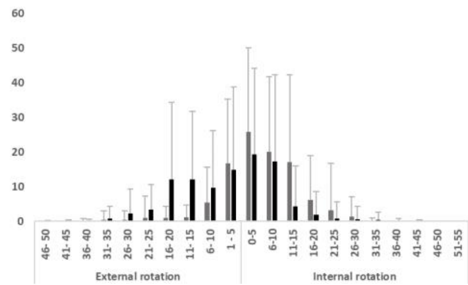
Half-kneeling



Standing



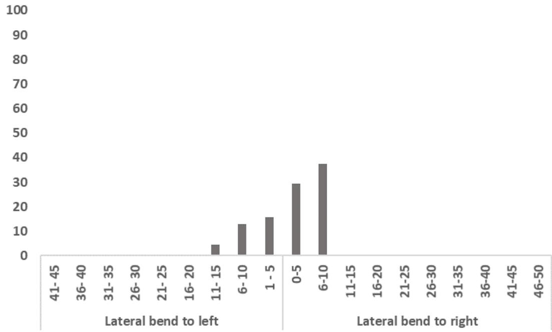
Sitting



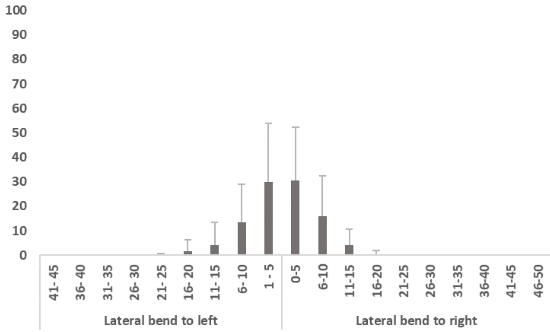
Walking

Neck

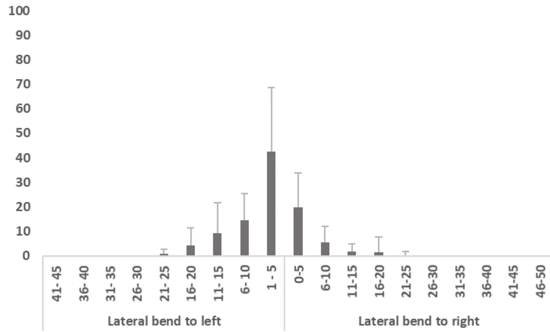
Half-kneeling



Standing

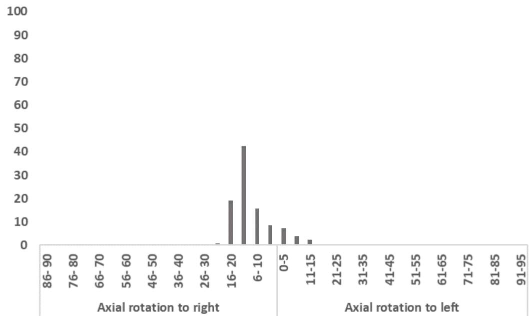


Sitting

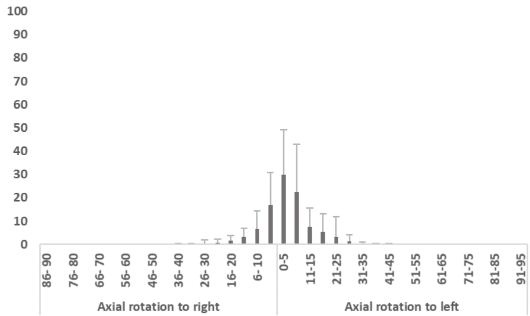


Neck

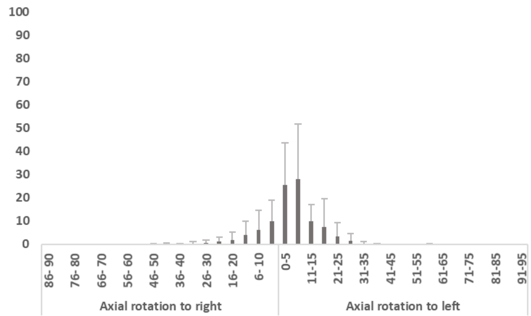
Half-kneeling



Standing

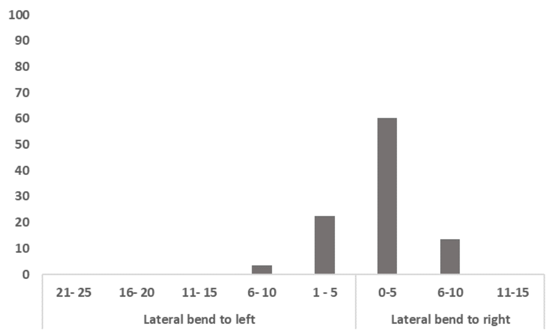


Sitting

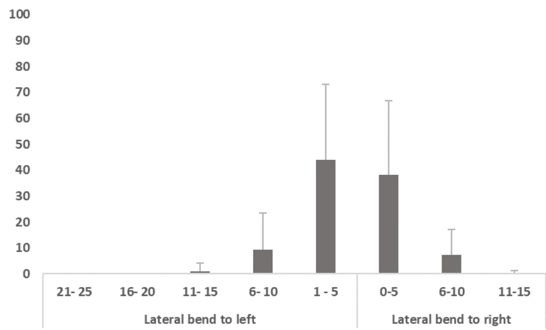


Cervicothoracic

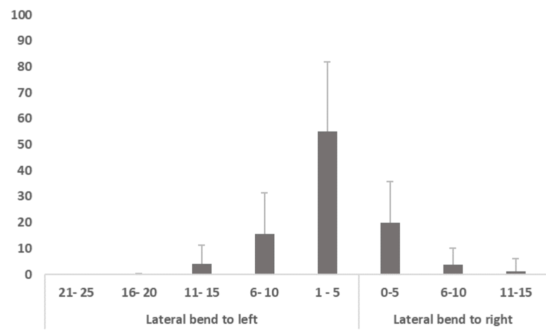
Half-kneeling



Standing

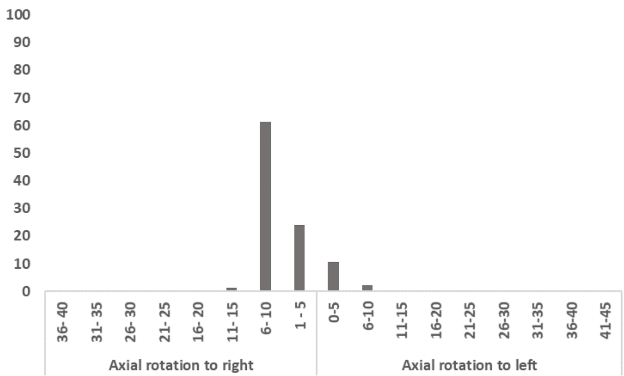


Sitting

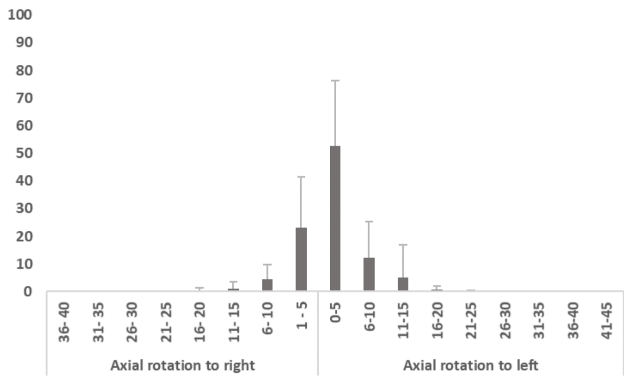


Cervicothoracic

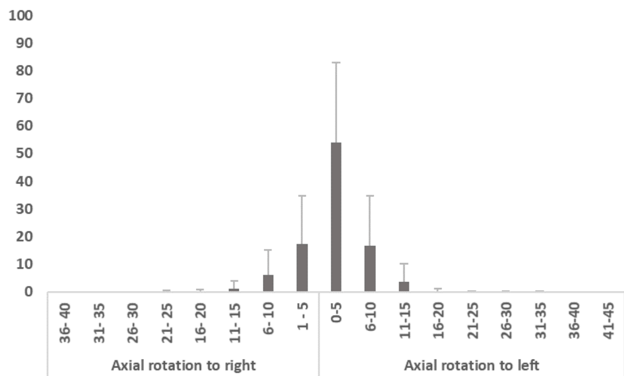
Half-kneeling



Standing

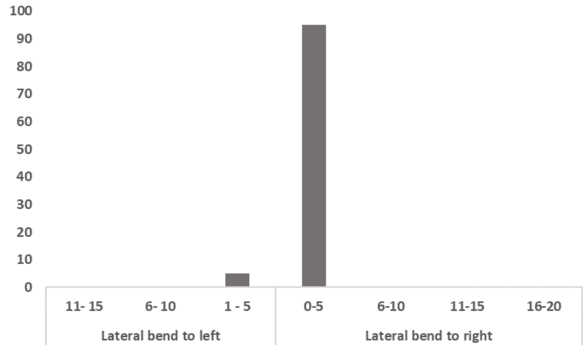


Sitting

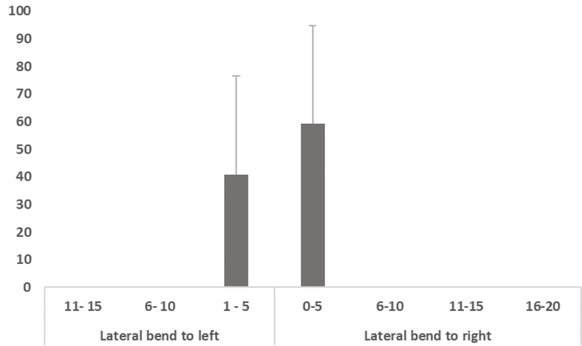


Thoracolumbar

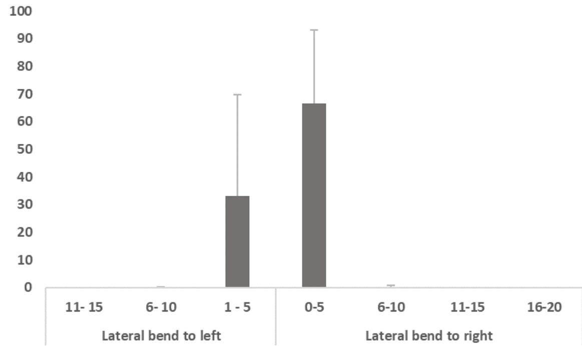
Half-kneeling



Standing

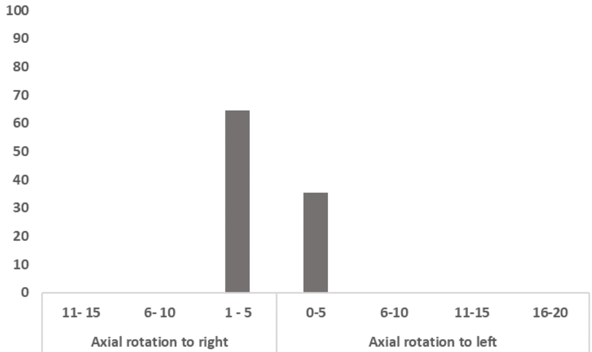


Sitting

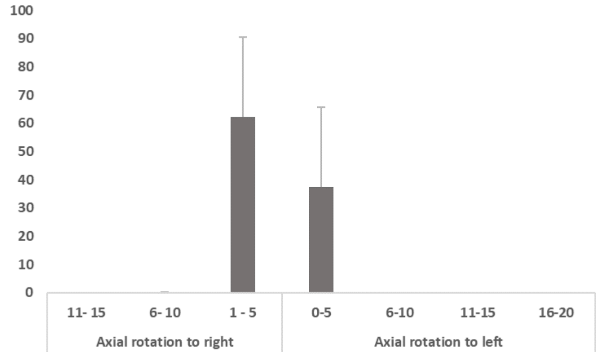


Thoracolumbar

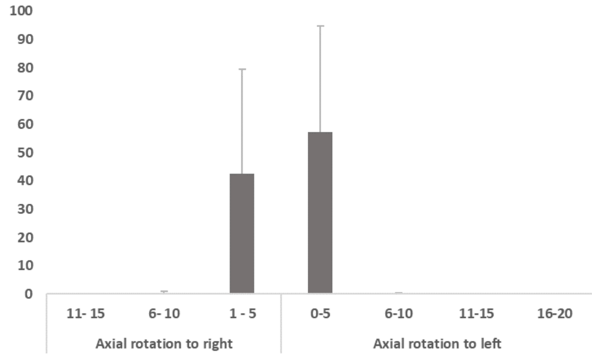
Half-kneeling



Standing

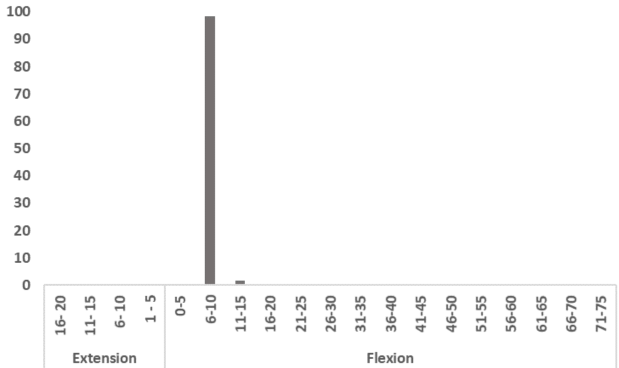


Sitting



Thoracolumbar

Half-kneeling



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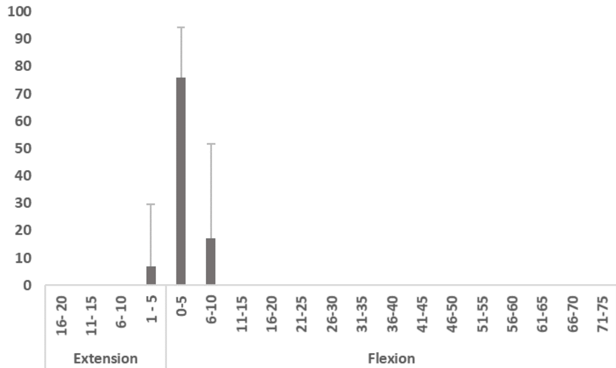
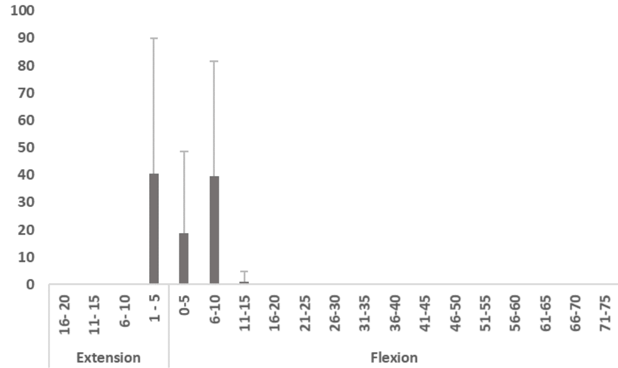
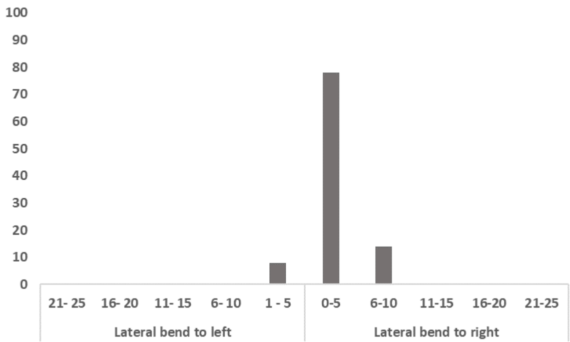


Sitting



Lumbosacral

Half-kneeling



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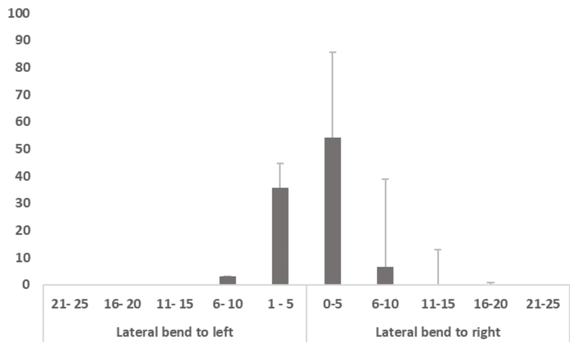

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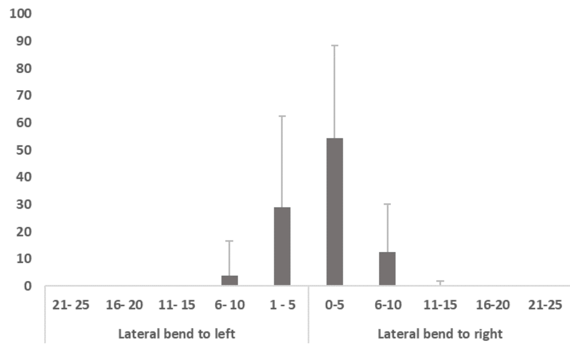
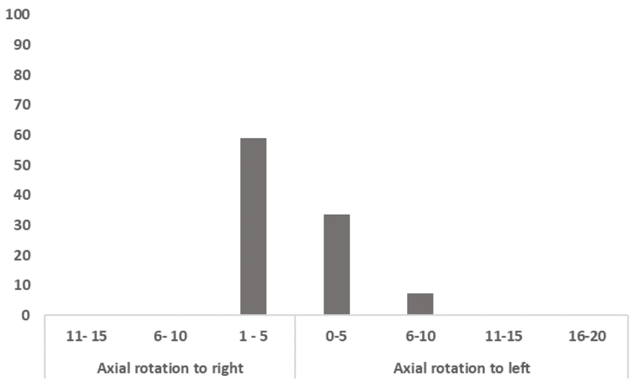


Lumbosacral

Half-kneeling



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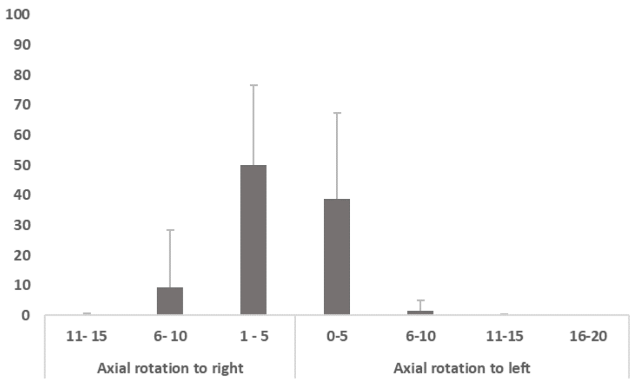
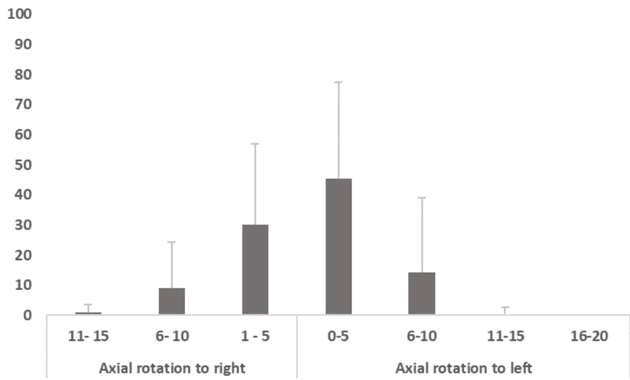
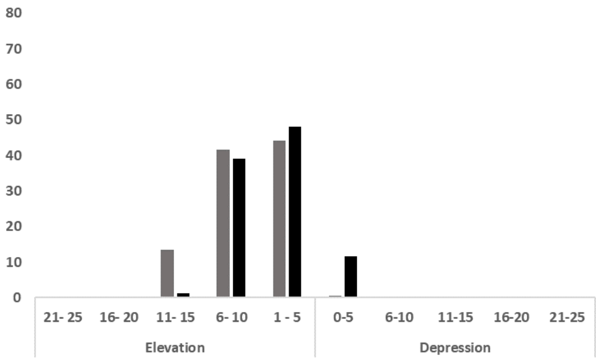


Sitting

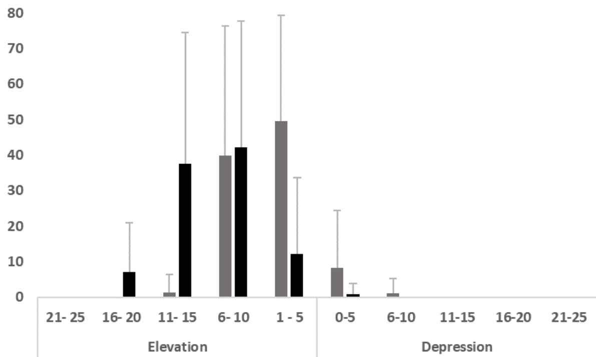


Shoulder Girdle

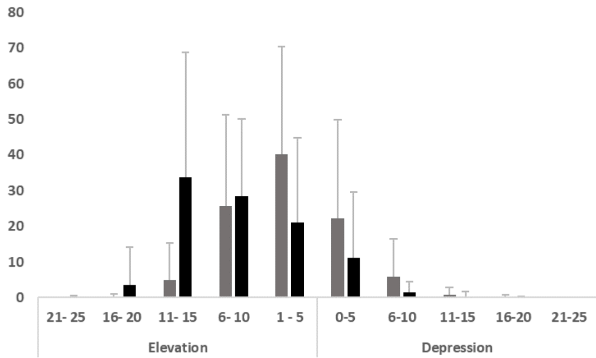
Half-kneeling



Standing

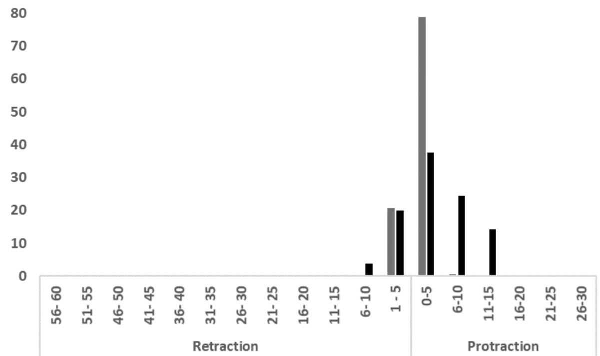


Sitting



Shoulder Girdle

Half-kneeling



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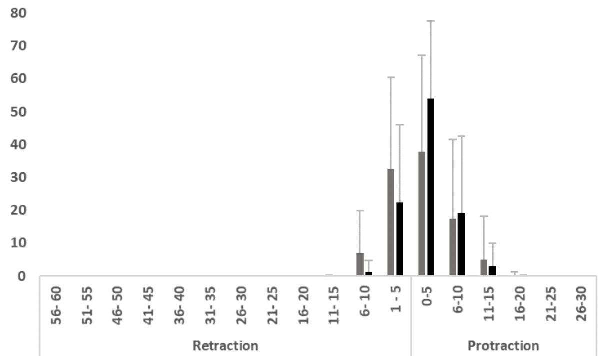

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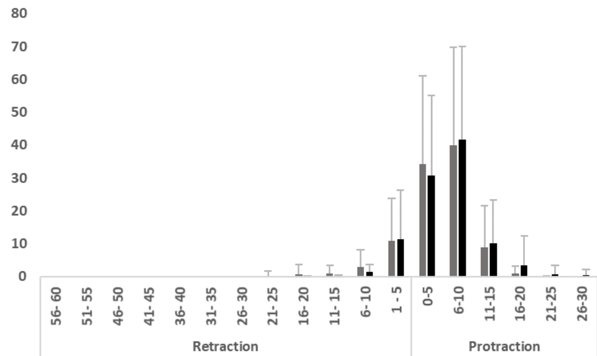
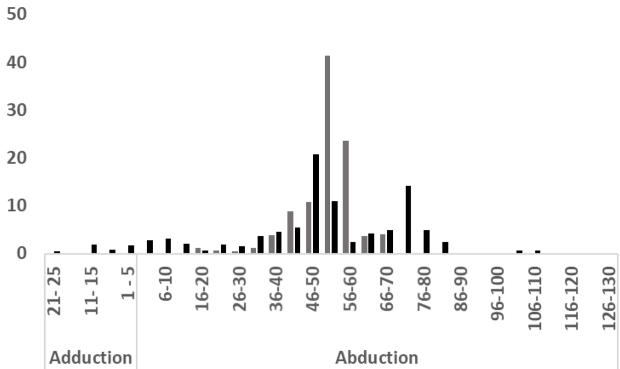


Shoulder

Half-kneeling



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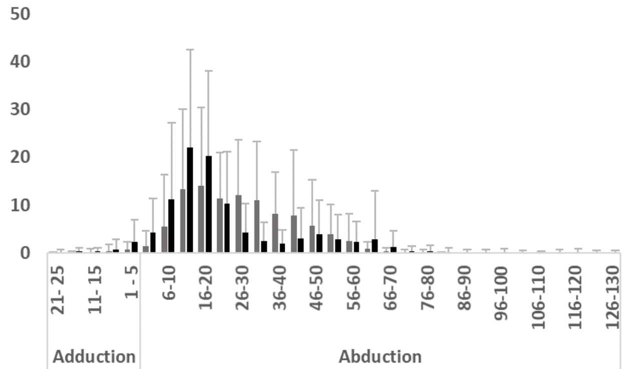

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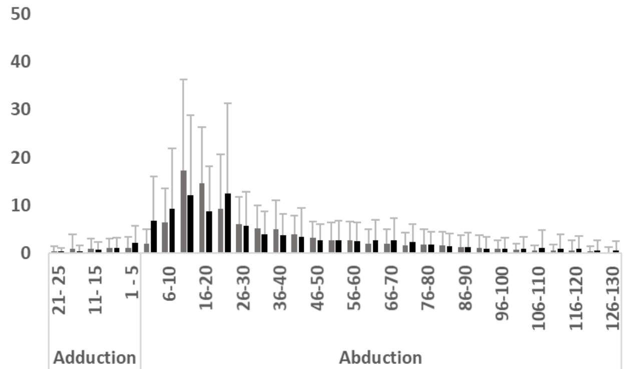
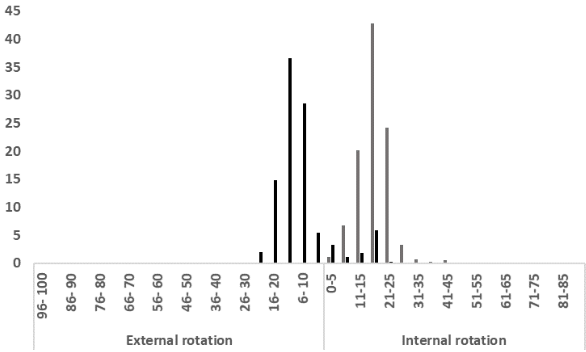


Shoulder

Half-kneeling



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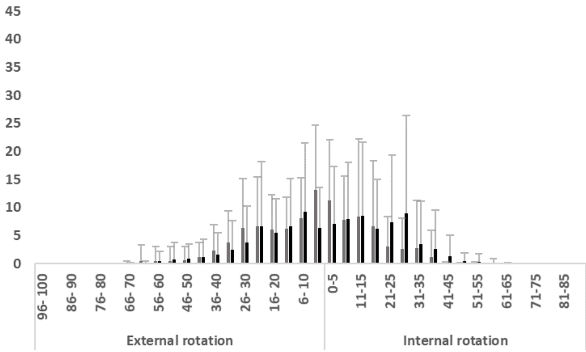

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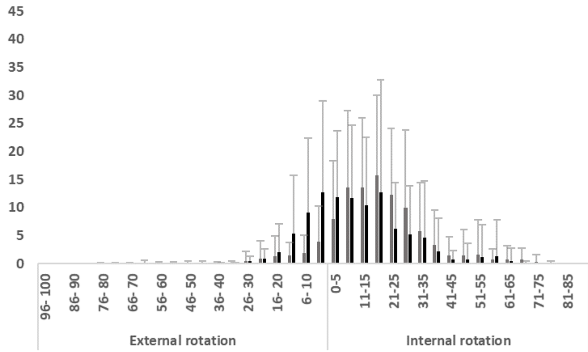
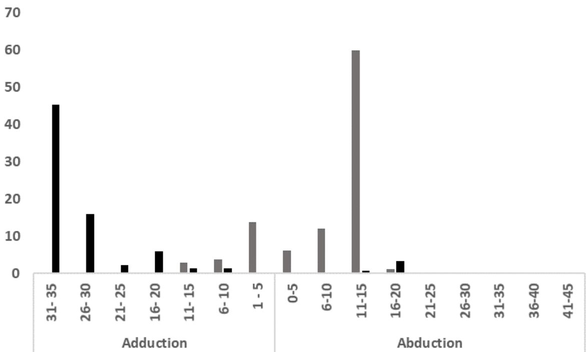
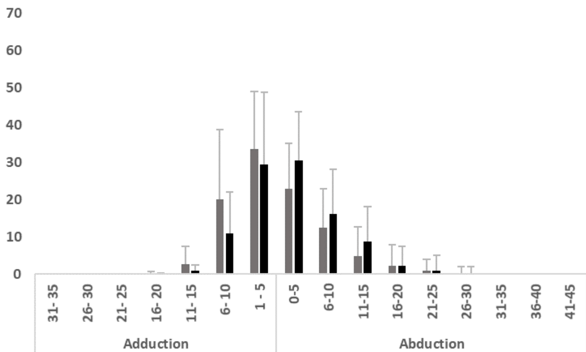


Hip

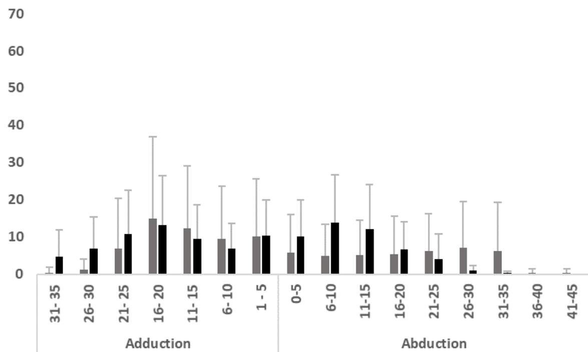
Half-kneeling



Standing

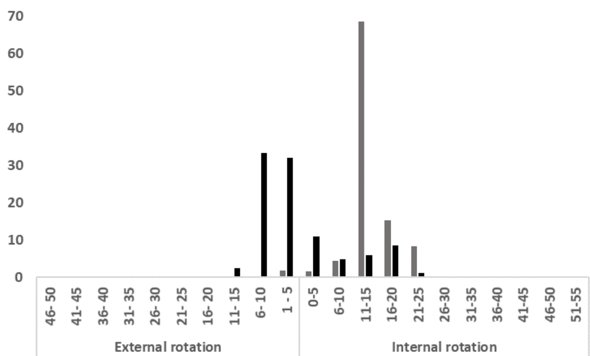


Sitting

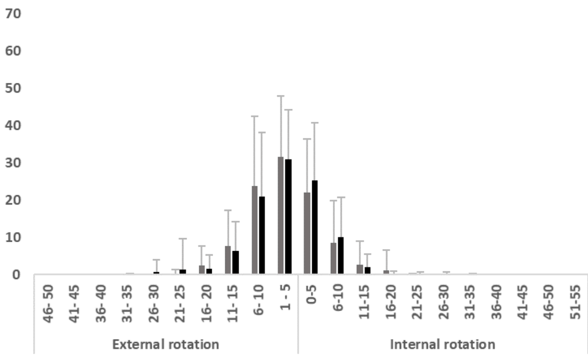


Hip

Half-kneeling



Standing



Sitting