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The use of physical characteristics to explain variation in ball-carrying capability in elite rugby union: a narrative review.

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The Use of Physical Characteristics to Explain Variation in Ball-Carrying Capability in Elite Rugby Union: A Narrative Review

Running Head: Physical Characteristics and Ball-Carrying Capability in Rugby Union

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Abstract

The effectiveness of offensive ball-carrying has been identified as a key determinant in elite rugby union try-scoring success and subsequent match outcome. Despite this, there is limited research evaluating the physical qualities believed to underpin ball-carrying capability amongst elite rugby union players. The aim of this review was to critically appraise the scientific literature that has investigated the use of physical characteristics to explain ball-carrying capability in elite rugby union. Measures of sprint performance, specifically acceleration, maximum sprinting speed, and sprint momentum have presented weak-to-strong correlations with the number of tries scored, line breaks, tackle breaks, defenders beaten, and dominant collisions recorded amongst international rugby union players. In addition, unilateral and bilateral vertical countermovement jump height, peak power output, and drop jump reactive strength index have each demonstrated meaningful associations with the number of tries scored, line breaks, tackle breaks, and dominant collisions. However, various measures of maximal lower-body strength have presented only trivial correlations with the game statistics associated with ball-carrying capability. These trivial correlations are likely a result of the inconsistent and inaccurate methods used to assess maximal lower-body strength, with methods ranging from a box-squat predicted one-repetition maximum to a maximal isometric mid-thigh pull. Further investigation is required to assess the contribution of maximal lower-body strength, agility, repeated sprint ability, and aerobic capacity to ball-carrying capability in elite rugby union. Such robust, objective data could be used to inform the specificity of physical preparation and maximise the transfer of these physical qualities to on-field performance.

Keywords

Speed; acceleration; momentum; strength; power; agility.

Introduction

Rugby union is characterised as a high-intensity, intermittent contact sport, requiring athletes to perform repeated running actions, collisions, and static efforts of differing work-to-rest periods (46). The profiling of the physical characteristics of elite rugby union players has highlighted a number of position-specific attributes (19). Typically, the forwards are the strongest, heaviest, and tallest players in order to be competitive within rucks, mauls, and lineouts (9). This is supported by research demonstrating the position-specific performance indicators for the forwards incorporated significant ball-carrying, tackling, and set-piece play (34,35,41,60). In contrast, the key performance indicators for the backs involved significantly more passing, kicking, evading the opposition, and try-scoring (10,34,35), therefore, necessitating the physical attributes of acceleration, maximum sprinting speed, and agility (14). These position-specific performance indicators are further evidenced by backs recording a greater number of line breaks, tackle breaks, defenders beaten, and tries scored than the forwards in elite rugby union match-play (53).

The number of tries scored has been identified as a main determinant of match outcome in elite rugby union (10), with winning teams recording more tries than losing teams in Rugby World Cup match-play (33). Recent evidence highlighted effectiveness of the offensive ball-carry, a motion where the player in possession of the ball challenges the opposition defensive line, as a key determinant of try-scoring success (51) and subsequent match outcome (7). For instance, Bennett et al., (2020) identified a number of performance indicators associated with ball-carrying capability as accurate predictors of match outcome in the group-phase and knockout phase of the 2015 Rugby World Cup (8). Previous notational analysis has quantified successful offensive ball-carries by the number of tries scored, line breaks, tackle breaks, offloads, defenders beaten, and metres advanced beyond the gain line per carry (Table 1) (14,49,53). Research indicates that the number of clean breaks and the average distance recorded per ball carry differentiated between successful and unsuccessful teams in both domestic (33) and international competition (43). Moreover, successful teams have been shown to deploy strategies that emphasise the involvement of players who record greater average distances per ball carry, as well as record a significantly greater number of clean breaks, when compared to their opponents (7).

INSERT TABLE 1 NEAR HERE.

Despite the clear relationship between offensive ball-carrying capability, try scoring likelihood, and subsequent match outcome, there has been limited research investigating the technical and physical characteristics common amongst effective ball-carriers. Previously, Sayers and Washington-King (2005) identified acceleration, maximum sprinting speed, sprint momentum, and the use of contact skills (e.g., fending strategies) as key determinants of positive phase outcome (51). Specifically, sprint times over 5-40 m have presented weak-to-strong correlations with the number of tries scored, line breaks, tackle breaks, defenders beaten, and metres advanced per carry amongst international rugby union (14,53) and rugby sevens players (49). In addition, Hart et al., (2022) concluded that improvements in lower-body relative strength, acceleration performance, and position-specific alterations in body mass are required to maximise the ball-carrying capability of sub-elite ruby union players due to the large associations observed between these physical measures and game statistics (26). These studies can provide objective data to inform the development of specific physical characteristics with the fundamental aim of optimising the transfer of these physical qualities to on-field ball-carrying performance. However, the majority of these studies have looked at key determinants of ball-carrying capability in isolation, rather than exploring the contribution of related physical characteristics to ball-carrying capability. Furthermore, comparison between these studies is difficult due to the inconsistency in the methods used to assess physical variables, such as maximal strength, peak power output, and sprint performance. For example, methods used to assess maximal lower-body strength vary from an isometric mid-thigh pull (IMTP) (14) to a box-squat estimated one-repetition maximum (1RM) (53). There are also large discrepancies in the accuracy and validity of the methods used to assess these physical characteristics. For instance, the application of a power clean estimated 1RM to assess peak power output (53) can be limited by the technical capabilities of the participant, rather than their potential muscular power. Despite these limitations, the identification of the physical characteristics that underpin offensive ball-carrying capability can have a number of significant implications for strength and conditioning practitioners, including the tailoring of position-specific physical preparation programmes to derive adaptations in the physical characteristics most associated with on-field ball-carrying performance, a key determinant in try-scoring success and subsequent match outcome (7). Therefore, the aim of this article was to critically analyse and provide a narrative review of the literature that has investigated the use of physical characteristics to explain ball-carrying capability in elite rugby union. This critical analysis will permit the main objectives of this review, namely, to identify specific physical characteristics/assessments that can be used as robust indicators of ball-carrying ability, as well as those that should not be used for this purpose. Based on the most compelling studies, and our hypotheses derived from their results, we will also propose new assessments for future research to investigate.

Methods

Literature Search Methodology

A structured literature search was conducted for empirical research studies and review articles using MEDLINE, SPORTDiscus, and PubMed databases from inception to September 2022 with a particular focus on identifying data by player subgroups of forwards and backs. Key terms were searched for within the article title, abstract, and keywords using conjunctions “OR” and “AND” with truncation “*.”. Combinations of the following Boolean phrases comprised the search terms: physical characteristics, physical qualities, fitness-test measures, anthropometric, height, body mass, lean body mass, strength, power, speed, acceleration, maximal velocity, agility, key performance indicators, KPIs, game statistics, ball carrying and rugby union. Reference lists were also utilised.

Inclusion and Exclusion Criteria

For the purpose of this article, athletes were classed as "elite" if they competed in the top tier of a professional competition in a tier one rugby union nation such as the Premiership (England), the Top 14 (France), the Pro 14 (Ireland, Italy, Scotland, South Africa, and Wales), and Super Rugby (Argentina, Australia, Japan, New Zealand, and South Africa), or if they competed in international competitions for a tier one nation, for example, 6 Nations (England, France, Ireland, Italy, Scotland, and Wales), the Rugby Championship (Argentina, Australia, New Zealand, and South Africa), or the Rugby World Cup. Studies were included in this review on the following criteria: (a) full text available in English and (b) peer-reviewed journal publications or doctoral dissertations. Studies were excluded if they were conference papers/posters/presentations.

Anthropometric Characteristics

With the establishment of professionalism, factors such as full-time training, enhanced access to sport science, and technical coaches' desire for more physical players, has led to improved athletic development and a substantial increase in player size (18). As an example, the body mass of Northern Hemisphere international rugby union players has increased by 24.3% (20.6 kg) between 1955 and 2015 (31). The anthropometric differences between forwards and backs have been well documented. Stoop et al., (2018) concluded that forwards were taller and heavier than backs across all Tier 1 nations (55). Success in rugby union has also been aligned to body mass with the highest performing teams in Rugby World Cups between 1987 and 2007 presenting the heaviest forwards and the heaviest average squad body mass (9). The greater mass of the forwards has been proposed to act as a protective mechanism from impact injuries as these positions are involved in 68% of all collisions during a match (55) and 60% more high acceleration/deceleration impacts than the backs (12), whilst also presenting a lower risk of injury (22). However, the composition of the additional body mass is vital to performance. Excessive body fat has a detrimental impact on performance by increasing metabolic demands, reducing the body's ability to dissipate heat, and subsequently reducing an individual's ability to perform repeated high-intensity actions (e.g., tackling and ball-carrying) (18,37,53). Moreover, higher levels of body fat have been associated with a reduced power-to-body mass ratio, reducing an individual's ability to position themselves in optimal attacking and defensive positions (62). In regard to the effect of excessive body fat on ball-carrying capability, Smart et al., (2014) demonstrated an inverse relationship between body fat percentage and activity rate amongst the forwards (53). Smart et al., (2014) defined activity rate as the count of any action that was performed by an individual player, divided by game time. Therefore, forwards with a greater body fat percentage demonstrated a reduced game involvement and recorded fewer repeated high-intensity actions (e.g., line-breaks, tackle-breaks, etc.). In contrast, the backs presented a weak positive correlation between body fat percentage and activity rate. However, this may be a result of the confounding position mix within the backs; as the anthropometrical requirements of the midfield backs (inside and outside centres) are more associated with the contact elements of rugby union, in comparison to the lighter and leaner half backs and back three (53). A clear limitation of this study is the lack of individual position analysis that would have provided further insight into the relationship between body composition and ball-carrying capability amongst the backs in particular.

A heavier body mass is considered fundamental for generating increased momentum in physical collisions (9). The difference in sprint momentum between the ball-carrier and the tackler has previously been proposed to play a much greater role in the prediction of tackle outcome than ball-carrier acceleration and velocity (28). Sprint momentum over 10 m has presented very strong correlations with the number of dominant collisions and offloads amongst international rugby union backs (14) and has been reported to be a greater indicator of ball-carrying capability than 10 m sprint time amongst international rugby sevens players (49). Despite this, Cunningham et al., (2018) identified no relationship between 10 m sprint momentum and ball-carrying capability amongst international rugby union forwards (14). However, 10 m sprint momentum may not be an applicable measure for the forward positions (26) as time-motion analysis has demonstrated that forwards typically perform a greater number of shorter distance sprints during a match in comparison to backs (3), with an average distance per sprint of <10 m (19). Therefore, 5 m sprint momentum may possess greater associations with ball-carrying capability amongst the forwards, a hypothesis that future research should investigate.

In addition, researchers may wish to utilise player tracking technology to identify the momentum of each player prior to contact with an opposition defender to isolate the relationship between the momentum of the ball-carrier and the achievement of positive phase outcomes (28).

Sprint momentum appears to be more trainable than sprint velocity; with maximum sprinting speed tending to peak for rugby union players in their mid-20s. In contrast, sprint momentum continues to improve amongst academy and elite senior rugby players in association with increased body mass (5,15). A novel aspect of one recent study is the inclusion of simple regression analysis to predict the level of change in a physical measure necessary to improve an associated game statistic (14). However, Cunningham et al., (2018) deemed the necessary improvements in 10 m sprint momentum required to improve the number of dominant collisions and offloads recorded amongst international rugby union backs to be beyond that which can be achieved from training (>20%) (14). Furthermore, sprint momentum is an underreported measure within the literature, with some studies failing to present the relationship between sprint momentum and ball-carrying capability despite reporting measurements of body mass and sprint times over 10 m, 20 m, and 30 m (53). The window for adaptation in the development of sprint momentum has been shown to be greater for players in their late teens and early 20s when compared with players in their mid-to-late 20s (5). As sprint momentum has been reported to be a strong indicator of ball-carrying capability amongst international rugby union players, particularly the backs (14), developing sprint momentum should be a key focus in the physical preparation of players within this age category (5,15). To increase sprint momentum, physical training will likely need to consist of exercises that will promote muscular hypertrophy and maintain maximum sprint velocity (5,15).

Strength and Power

Muscular strength has previously been defined as the ability to exert force on an external object or resistance (56). Given that rugby union demands high levels of muscular strength to effectively perform tackling, lifting, pushing, and pulling tasks, and to tolerate the collisions that occur during match-play (9). Despite the perceived importance of muscular strength, most studies have reported trivial correlations between various measures of lower-body maximal strength and the game statistics associated with ball-carrying capability (14,49,53). However, direct comparison between studies is problematic due to the inconsistency and inaccuracy of the testing protocols used to assess lower-body maximal strength. For example, Smart et al., (2014) utilised the box-squat exercise to predict a one-repetition maximum (1RM) from a 2-6RM test score using the formula derived by Lander (1985) (53). The inter-individual variation in the repetition maximum used to estimate box-squat 1RM compromises the accuracy and reliability of maximal lower-body strength assessment. Furthermore, the calculation of an estimated 1RM has been shown to be less accurate than a true 1RM measure (47) and the Lander (1985) formula has demonstrated a greater average error and lower relative accuracy when compared to the more commonly used Epley (1985) formula (63). In comparison, Cunningham et al., (2018) employed a maximum isometric mid-thigh pull (IMTP) assessment to determine absolute and relative peak force (14). The use of the maximum IMTP assessment has grown in popularity across all sports and is increasingly being used in rugby union due to its perceived ease of use, time efficiency, and the reduced requirements for technical instruction when compared to full range of motion compound lifts such as the barbell back squat or barbell deadlift (38). However, Cunningham et al., (2018) are the only investigators to employ the maximum IMTP assessment and failed to report the intraclass correlation coefficient (ICC), coefficient of variation (CV), and 90% confidence intervals (90% CI) leaving the test-retest reliability of their assessment unknown (38).

The trivial correlations observed between lower-body maximal strength and the game statistics associated with ball-carrying capability do not necessarily imply that lower-body muscular strength is unimportant for success in rugby union. Research investigating the characteristics common amongst effective ball carriers in Super Rugby (a professional men's rugby union club competition that has involved teams from Australia, New Zealand, and South Africa) identified 95% of tackle breaks were achieved with a combination of low body position and strong leg drive (51). Therefore, further research may seek to utilise a qualitative assessment of body position in addition to quantitative assessments of lower-body strength to identify the determinants of offensive ball-carrying capabilities, particularly with reference to contact situations. Fundamentally, muscular strength underpins rate of force development and power production by increasing maximal force potential (39). In theory, the enhanced force-time characteristics associated with high levels of muscular power should transfer to the ability to perform general sport skills (e.g., sprinting and jumping) (56). Previous studies have shown that athletes who are able to produce high levels of muscular power are more effective at the physical components of rugby union, such as dominating the breakdown or winning collisions (1,25). Therefore, more powerful athletes are likely to be effective in the areas of the game where physical domination of opponents increases the likelihood of maintaining possession, retrieving possession, and breaking the defensive line (2). The most common method for measuring or estimating lower-body muscular power in rugby union is through vertical jump height (9). Cunningham et al., (2018) reported a number of strong relationships between various countermovement jump (CMJ) and single-leg countermovement jump (SL CMJ) variables and the game statistics associated with ball-carrying capability amongst international rugby union players. For the forwards, CMJ height, absolute peak power output, and average SL CMJ peak power output presented strong correlations with the number of dominant collisions. Furthermore, CMJ height, relative peak power output, and average SL CMJ peak power output each presented a strong relationship with the number of line breaks. For the backs, CMJ peak power output and average SL CMJ peak power output correlated strongly with the number of dominant collisions (14). Despite these relationships, Cunningham et al., (2018) deemed the necessary improvements in muscular power required to enhance the associated game statistics to be beyond those that can be achieved from training (14). It is unclear why the authors of this study deemed 20% to be the arbitrary cut-off point for a practically achievable change in a physical quality, especially given the study reported an 18.4% increase in 20 cm drop jump height to be an achievable adaptation required to increase the count of being one of the first three players to a defensive ruck by one (14).

In contrast to the findings observed amongst international rugby union players, Ross et al., (2015) reported CMJ peak concentric power output presented no relationship with the number of tries scored and line breaks, and only a trivial correlation with the number of defenders beaten amongst international rugby sevens players (49). However, a linear position transducer affixed to a 1 kg weighted pole was used to calculate peak concentric power output from displacement-time data. The use of a linear position transducer has previously been shown to overestimate a number of kinematic variables used in the calculation of peak concentric power output, including countermovement jump height (61). Furthermore, the calculation of peak concentric power output from a linear position transducer has been shown to be inconsistent and unreliable when compared to measurements of peak force and time to peak force (24). Ross et al., (2015) also failed to report reproducibility data for the measurement of CMJ peak concentric power output, so the reliability of this measurement in this population is not known. . Similarly, Smart et al., (2014) reported only trivial correlations between power clean 1RM and the game statistics associated with ball-carrying amongst elite rugby union players (53). The power clean exercise is an Olympic weightlifting derivative that demands a high level of technical competency, and the use of higher loads has previously been shown to result in changes to kinematic variables attributable to alterations in technique (11). As such, some argue that Olympic weightlifting derivatives provide a less valid measure of peak power output when compared to vertical jump tests due to the greater technical proficiency required. Furthermore, Smart et al., (2014) reported power clean 1RM was predicted from a two to six repetition maximum lift with the use of the Lander (1985) formula, similar to the box-squat predicted 1RM (53). This study also failed to report reproducibility data for the power clean repetition maximum testing. Reproducibility data is essential to provide confidence in the findings of these studies when comparing physical characteristics and reliable game statistics. This review recommends further research seeks to use kinematic variables derived from force plate testing in the measurement of lower-body peak power output when examining the relationship between peak power output and ball-carrying capability.

Despite the trivial correlations observed between vertical CMJ peak concentric power output and the game statistics associated with ball-carrying capability, a moderate correlation was observed between horizontal jump distance and the number of defenders beaten amongst international rugby sevens players (49). This finding is attributable to the large associations between horizontal jump performance and an individual's ability to express large amounts of net horizontal ground reaction force, the key mechanical determinant of acceleration (40). Barr et al., (2014) previously demonstrated a significant relationship between horizontal jump distance and 10 m sprint velocity amongst international rugby union players (4). Despite this finding, Ross et al., (2015) is the only study to investigate the relationship between horizontal jump performance and the game statistics associated with ball-carrying capability, and the test-retest reliability of horizontal jump measurements was not reported. In order to be confident in the associations observed between horizontal jump performance and ball-carrying capability, further research is required that includes reproducibility data. In addition, Dobbs et al., (2015) highlighted that unilateral horizontal jump tests assess distinct lower-limb muscular power capabilities amongst highly trained rugby union players (16). Therefore, further research may seek to incorporate unilateral horizontal jump testing in their assessment of muscular power capabilities and the relationship with ball-carrying capability amongst elite rugby union players.

The countermovement jump assessment employed by Cunningham et al., (2018) provided a good measure of slower stretch shortening activities, shown to be primarily relied upon by the forward positions to break through contact and record positive phase outcomes (e.g., tackle breaks and dominant collisions) (14). However, the countermovement jump does not provide a strong measure of faster stretch shortening cycle (SSC) movements that are characterised by shorter contraction times and smaller angular displacement of the hip, knee, and ankle joints (6,21). Hamilton (2009) suggested a faster SSC measure, such as the drop jump reactive strength index (RSI), may provide a more relevant neuromuscular examination due to the increased eccentric and SSC demand (23). Cunningham et al., (2018) reported that 20 cm, 40 cm and SL 20 cm drop jump RSI presented strong correlations with the number of tries scored, line breaks, tackle breaks, and dominant collisions amongst international rugby union players (14). Producing a large RSI requires the ability to express large amounts of force in very short time frames; and drop jump RSI has previously been strongly related to maximum sprinting speed and agility amongst a mixed group of international rugby union players (13,65). Despite the strong correlations, Cunningham et al., (2018) reported the improvements in drop jump performance required to enhance ball-carrying capability were beyond those that could be achieved from training, similar to the improvements in sprint momentum and vertical jump performance (14). This study is also the first to analyse the relationship between drop jump performance and ball-carrying capability amongst elite rugby union players, and further research should incorporate drop jump RSI in the assessment of muscular power. In addition, future research may consider the assessment of peak power at submaximal loads (greater than body mass and less than 1RM) in both elite and sub-elite rugby union players, as currently unpublished peak power data from our group have demonstrated meaningful correlations with ball-carrying capability in a sub-elite rugby union population. Furthermore, we found the loaded barbell jump squat to be a reliable and valid measure of a rugby player's capacity to produce power at submaximal loads.

Speed

Sprint velocity is an essential characteristic for rugby union players, as it enables them to rapidly position themselves in attack and defence (9). Tierney et al., (2017) demonstrated high-speed running intensity (>5 m.s) and very high-speed running intensity (>7 m.s) were key determinants in successful attacking 22 m zone entries, as high-speed running intensity related to the forwards efforts in positioning themselves quickly and being available for the next phase of play (58). Research investigating the physical characteristics common amongst effective ball carriers has shown that acceleration, maximum sprinting speed, and sprint momentum are the main determinants of positive phase outcome (51). Specifically, average sprint velocity over 5 m, 10 m, 20 m, 30 m, and 40 m have presented strong correlations with the number of tries scored, line breaks, tackle breaks, defenders beaten, and dominant collisions amongst international rugby union (14,53) and rugby sevens players (49). These findings are attributable to the counterbalance reaction that is initiated when a ball-carrier enters the pre-contact phase at a velocity considerably greater than that of the tackler. If the tackler is unable to adjust their velocity to match that of the ball-carrier, the outcome of the tackle is likely to be unsuccessful resulting in a tackle break, dominant collision or a missed tackle (29). Furthermore, ball-carrier velocity has previously been described as the key technical determinant for successful line breaks (32) and individuals who received the ball at higher running velocities have been shown to record the greatest number of positive phase outcomes (51). Despite this, researchers propose the difference in momentum between the ball-carrier and the tackler plays a much greater role in the prediction of tackle outcome than the ball-carrier's velocity (28). The basic physical principles of collisions suggest the individual with the greater momentum is more likely to dominate the tackle contest. Hendricks et al., (2014) highlighted that forwards were generally heavier than backs and subsequently possessed a greater momentum and a tactical predetermination to carry the ball into contact (28). In comparison, the backs, particularly the back three positions, are more reliant on the application of maximum sprint velocity to evade defenders and achieve positive phase outcomes. Therefore, strength and conditioning practitioners should seek to enhance maximum sprint velocity amongst this position group, particularly as the backs frequently receive the ball in motion at high running velocities (54), reducing their reliance on rapid acceleration from a primary static position.

Agility

The ability to quickly accelerate, decelerate, and change direction is believed to be vital in rugby union (9). However, to the author's knowledge, there is no published data for tests of agility in elite rugby union athletes. This may be a result of the difficultly in the direct assessment of agility as common methods do not account for the perceptual and decision-making elements (66). Agility has recently been defined as "a rapid whole-body movement with a change of velocity or direction in response to a stimulus" (45). In comparison, a change of direction task is pre-planned (66) and assessed by protocols such as the Illinois agility test, L-Run, 505, and various other courses reported in the literature (9). In order to directly assess an athlete's agility, researchers must stimulate an individual's perception-action cycle. The perception-action cycle is the circular flow of information that takes place between the organism and its environment in the course of a sensory-guided sequence of behaviour towards a goal (36). Whether attacking or defending, agility is an open skill that requires the ability to perceive relevant information about an opponent's movements and react quickly and accurately. Therefore, in order to accurately assess an individual's agility, researchers must provide a stimulus for the athlete to respond to. Open-skill agility tests are typically more difficult to standardise as the testing environment is obviously unpredictable. Standardisation of protocol, such as how many direction changes there will be per test and fixing the distance to be moved when a directional change is indicated, will increase the test reliability (20,42,64,66). Further research should seek to standardise a rugby-specific agility test in order to investigate the relationship between agility and ball-carrying capability. Furthermore, to the authors' knowledge, there is no study that has investigated the relationship between a reliable and valid measure of change of direction speed and ball-carrying capability.

Aerobic and Anaerobic Characteristics

Rugby union has been characterised as a high intensity intermittent sport, requiring athletes to perform repeated bouts of high-speed running (>5 m.s) in short periods of time, as well as sustained and repeated high intensity actions, such as sprinting, tackling, and scrummaging (9). Typically, these repeated high-intensity actions are interspersed with periods of low intensity or static efforts (46). It has been established within literature that a well-developed aerobic capacity improves the repeatability and sustainability of repeated high-intensity actions (59). The aerobic system is essential for the replenishment of adenosine triphosphate (ATP) and the buffering of metabolites, such as lactic acid, following sustained periods of high intensity effort (44,50). Swaby et al., (2016) observed a strong relationship between maximal aerobic speed and the distance covered during a game amongst elite rugby union players (57). Maximal aerobic speed can be defined as the lowest running velocity at which maximal oxygen uptake occurs ($v\dot{V}O_2max$) and has been shown to be a valid measure of aerobic fitness amongst rugby union players (57). This finding suggests that superior physical performance has a strong relationship with aerobic capacity. However, aerobic capacity has not been shown to demonstrate a significant relationship with the limited measures of technical performance (i.e. total carries or total passes) examined amongst international rugby sevens players (27). Similarly, Cunningham et al., (2018) observed no significant correlations between Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IRT1) distance run and the game statistics associated with ball-carrying capability amongst international rugby union backs. In comparison, Yo-Yo IRT1 distance run only presented a strong correlation with the percentage of carries made that were over the gain-line amongst forwards (14). However, the game statistics associated with ball-carrying capability are predominantly characterised as performance-based match activities, and much stronger correlations were observed between Yo-Yo IRT1 distance run and effort-based match activities, such as the number of total carries, tackles, passes, or the count of times the player was in the first three support players to the ruck in attack and defence (14). Thus, although aerobic capacity is related to the ability to repeat high-intensity actions (through faster recovery between bouts) over a prolonged period (17), it may be more appropriate for future research to investigate a potential relationship between aerobic fitness (e.g., maximum aerobic speed) and the 'rate of fatigue' in ball-carrying capability across the course of a rugby union match. Whilst the latter variable has not yet been reported in the literature, it may be more informative to investigate such a relationship in terms of understanding how to maintain optimal ball-carrying capability throughout a match.

Due to the repeated sprinting nature of rugby union, anaerobic capacity has also been proposed as a key indicator of an individual's physical capacity for competition. Despite this, there are very few studies that have used repeated sprint tests to measure anaerobic performance amongst rugby union athletes. This lack of research may be due to the time consuming and resource dependent nature of repeated sprint testing, which is unfavourable amongst larger sample sizes (17). Smart et al., (2014) reported only a weak inverse correlation between repeated sprint fatigue and the number of tries scored amongst international rugby union backs (53). This finding is in accordance with Ross et al., (2015), who reported a moderate correlation between repeated sprint ability and the number of tries scored and line breaks amongst international rugby sevens players (49). Both studies also observed a weak-to-moderate correlation between repeated sprint ability and activity rate (49,53), defined by Smart et al., (2014) as the count of any action that was performed by the player divided by game time (53). The stronger correlations observed amongst international rugby sevens players may be a result of their greater reliance on repeated sprint ability when compared to rugby union backs (52). In addition, rugby sevens match-play is characterised by shorter periods of low intensity effort between longer sustained bouts of high-intensity activity (30,48). Despite this, these findings suggest repeated sprint ability may be an important contributing factor to an individual's ability to maintain ball-carrying capability during periods of repeated high-intensity activity, as well as over the course of a full rugby union match.

INSERT FIGURE 1 NEAR HERE.

INSERT TABLE 2 NEAR HERE.

Practical Applications

The aim of this narrative review was to critically appraise the scientific literature that has investigated the use of physical characteristics to explain ball-carrying capability in elite rugby union. Match analysis has established that the effectiveness of offensive ball-carrying, quantified by the number of tries scored, line breaks, tackle breaks, dominant collisions, offloads, defenders beaten, and metres advanced over the gain line (Table 1), is a main determinant of try scoring success and subsequent match outcome. The scientific literature investigating the relationship between physical characteristics and the game statistics associated with ball-carrying capability have identified acceleration, maximum sprinting speed, sprint momentum, repeat sprint ability, and muscular power output as key determinants of positive phase outcome. For the backs, measures of acceleration and maximum sprinting speed presented the most meaningful correlations with the game statistics associated with ball-carrying capability (Table 3) as a result of the counterbalance reaction that is initiated when a ball carrier enters the pre-contact phase at a velocity considerably greater than that of the tackler. For the forwards, slower stretch shortening activities, such as countermovement jump peak power output, and acceleration performance presented the most meaningful relationships with ball-carrying capability (Table 2). However, we recommend a cautious interpretation of some data reviewed in this article due to the limited information regarding certain parameters (e.g., agility) and the inconsistencies in the methods used to assess strength and power capabilities. Further investigation is required to assess the relationship between physical qualities and the game statistics related to ball-carrying capability and future research should seek to use simple regression analysis to predict the level of change in physical measures required to improve ball-carrying capability. In addition, future research may also seek to incorporate qualitative assessment of the body positions and fending strategies employed by the ball-carrier to identify the associations between these qualities and ball-carrying capability. These objective data could be used to inform the specificity of physical preparation and maximise the transfer of these physical qualities to on-field ball-carrying performance. Having provided a critical analysis of the literature pertaining to physical characteristics/assessments associated with ball-carrying capability in rugby union, the main objective of this review was to provide guidance on which characteristics could be used by practitioners as strong/weak indicators of ball-carrying capability, which we have summarised in Fig. 1. A second objective was to identify specific characteristics that require further investigation (also summarised in Fig. 1), thus providing direction for future studies in applied rugby union research.

Conflicts of Interest

The authors have no conflicts of interest to disclose.

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Table 1 – Operational definitions of game statistics reported in studies.

Game Statistic	Definition	Reference
Tries Scored	Number of tries scored by an individual.	(14,48,53)
Line Breaks	Number of times an individual in possession of the ball breaks the defensive line.	(14,48,53)
Tackle Breaks	Number of times an individual in possession of the ball breaks an unsuccessful tackle.	(14,53)
Defenders Beaten	Number of tackles evaded by an individual in possession of the ball.	(48,53)
Dominant Collisions	Number of collisions in attack where an individual makes ground following the collision.	(14)
Offloads	Number of times an individual completed a successful pass in the process of being tackled.	(14)
Carries Over Gain Line (%)	Percentage of carries made that were over the gain line.	(14,53)
Metres Advanced (m)	The total displacement travelled by an individual in possession of the ball. Half backs were excluded due to the large amount of backwards travelling when in possession of the ball.	(53)
Activity Rate ($m.min^{-1}$)	Count of any action performance by an individual and coded, divided by game time.	(53)

Table 2 – Physical characteristics, testing protocols, output measures and associated game statistics (*r*) amongst elite rugby union forwards reported in studies.

Characteristic	Test	Output Measure	Associated Game Statistic	Reference
Anthropometric Characteristics	Body Mass	Body Mass (kg)		(14,53)
	Sum of 8 Skinfolds	Body Fat Percentage (%)	Activity Rate (r = 0.17)	(53)
		Fat Free Mass (kg)		(53)
Strength	Box-Squat 2-6 RM	Estimated 1RM (kg)	Tackle Breaks (r = 0.09)	(53)
			Defenders Beaten (r = 0.05)	(53)
			Carries Over Gain Line (r =0.05)	(53)
	Bench Press 2-6 RM	Estimated 1RM (kg)		(53)
	Chin-Ups 2-6 RM	Estimated 1RM (kg)		(53)
	Isometric Mid-Thigh Pull	Peak Force (N)		(14)
		Relative Peak Force ($N.kg^{-1}$)		(14)
		Peak Rate of Force Development ($N.s^{-1}$)		(14)
Power	Countermovement Jump	Jump Height (cm)	Line Breaks (r = 0.53)	(14)
			Dominant Collisions (r = 0.70)	(14)
			Carries Over Gain Line (r = 0.58)	(14)
		Peak Power (W)	Dominant Collisions (r = 0.60)	(14)

		Relative Peak Power (W.kg^{-1})	Line Breaks (*r* = 0.55) Carries Over Gain Line (*r* = 0.58)	(14) (14)
	SL Countermovement Jump	Average Jump Height (cm)	Carries Over Gain Line (*r* = 0.59)	(14)
		Average Peak Power (W)	Line Breaks (*r* = 0.56) Dominant Collisions (*r* = 0.57)	(14) (14)
	Power Clean 2-6 RM	Estimated 1RM (kg)	Tackle Breaks (*r* = -0.12) Defenders Beaten (*r* = -0.20) Carries Over Gain Line (*r* = 0.02)	(53) (53) (53)
	20 cm Drop Jump	Jump Height (cm)	Tackle Breaks (*r* = 0.53) Carries Over Gain Line (*r* = 0.73)	(14) (14)
		Peak Power (W)		(14)
		Reactive Strength Index (au)	Line Breaks (*r* = 0.56) Dominant Collisions (*r* = 0.59) Offloads (*r* = 0.59)	(14) (14) (14)
	SL 20 cm Drop Jump	Average Jump Height (cm)		(14)
		Average Peak Power (W)		(14)
		Average Reactive Strength Index (au)		(14)
	40 cm Drop Jump	Jump Height (cm)	Tries Scored (*r* = 0.63)	(14)
		Peak Power (W)		(14)

		Reactive Strength Index (au)		(14)
Speed	10 m Sprint	Velocity (m·s^{-1})	Tries Scored (*r* = 0.14) Line Breaks (*r* = 0.26) Tackle Breaks (*r* = 0.72) Tackle Breaks (*r* = 0.17) Defenders Beaten (*r* = 0.33) Carries Over Gain Line (*r* = 0.65) Metres Advanced (*r* = 0.32)	(53) (53) (14) (53) (14) (14) (53)
		Momentum (kg·m·s^{-1})		(14)
	20 m Sprint	Velocity (m·s^{-1})	Tries Scored (*r* = 0.17) Defenders Beaten (*r* = 0.39) Metres Advanced (*r* = 0.32)	(53) (53) (53)
Aerobic Characteristics	Yo-Yo Intermittent Recovery Test Level 1	Distance Run (m)	Carries Over Gain Line (*r* = 0.61)	(14)
Anaerobic Characteristics	Rugby-Specific Repeated Speed Test	Average Sprint Velocity (m·s^{-1})	Tries Scored (*r* = 0.24) Activity Rate (*r* = 0.38)	(53) (53)
		Fatigue Decrement (%)	Tries Scored (*r* = -0.02) Activity Rate (*r* = -0.05)	(53) (53)

Table 3 - Physical characteristics, testing protocols, outcome measures and associated game statistics (*r*) amongst elite rugby union backs and rugby sevens players reported in studies.

Characteristic	Test	Output Measure	Associated Game Statistic	Reference
Anthropometric Characteristics	Body Mass	Body Mass (kg)	Dominant Collisions (r = 0.92)	(14)
	Sum of 8 Skinfolds	Body Fat Percentage (%)	Activity Rate (r = 0.10)	(53)
		Fat Free Mass (kg)		(53)
Strength	Box-Squat 2-6 RM	Estimated 1RM (kg)	Tackle Breaks (r = -0.02) Defenders Beaten (r = -0.03) Carries Over Gain Line (r = 0.08)	(53) (53) (53)
	Bench Press 2-6 RM	Estimated 1RM (kg)	Defenders Beaten (r = 0.16)	(48) (53)
	Chin-Ups 2-6 RM	Estimated 1RM (kg)		(48,53)
	Isometric Mid-Thigh Pull	Peak Force (N)	Offloads (r = 0.62)	(14)
		Relative Peak Force ($N.kg^{-1}$)	Carries Over Gain Line (r = 0.53)	(14)
		Peak Rate of Force Development ($N.s^{-1}$)		(14)
Power	Countermovement Jump	Jump Height (cm)		(14)
		Peak Power (W)	Defenders Beaten (r = 0.11) Dominant Collisions (r = 0.75)	(48) (14)

			Offloads (*r* = 0.69)	(14)
		Relative Peak Power ($W.kg^{-1}$)		(14)
	Countermovement Jump (50 kg)	Peak Power (W)	Defenders Beaten (*r* = 0.06)	(48)
	SL Countermovement Jump	Average Jump Height (cm)		(14)
		Average Peak Power (W)	Dominant Collisions (*r* = 0.79) Offloads (*r* = 0.73)	(14) (14)
	Horizontal Jump	Jump Distance (cm)	Defenders Beaten (*r* = 0.47)	(48)
	Power Clean 2-6 RM	Estimated 1RM (kg)	Tackle Breaks (*r* = 0.01) Defenders Beaten (*r* = -0.03) Carries Over Gain Line (*r* = 0.08)	(53) (53) (53)
	20 cm Drop Jump	Jump Height (cm)		(14)
		Peak Power (W)		(14)
		Reactive Strength Index (au)	Tries Scored (*r* = 0.62)	(14)
	SL 20 cm Drop Jump	Average Jump Height (cm)		(14)
		Average Peak Power (W)		(14)
		Average Reactive Strength Index (au)	Tries Scored (*r* = 0.61) Line Breaks (*r* = 0.62)	(14) (14)
	40 cm Drop Jump	Jump Height (cm)		(14)
		Peak Power (W)		(14)

		Reactive Strength Index (au)	Tries Scored (*r* = 0.64)	(14)
			Line Breaks (*r* = 0.62)	(14)
Speed	5 m Sprint	Velocity (m·s^{-1})	Tries Scored (*r* = 0.17)	(48)
			Line Breaks (*r* = 0.35)	(48)
			Defenders Beaten (*r* = 0.27)	(48)
	10 m Sprint	Velocity (m·s^{-1})	Tries Scored (*r* = 0.12)	(53)
			Tries Scored (*r* = 0.27)	(48)
			Line Breaks (*r* = 0.25)	(53)
			Line Breaks (*r* = 0.47)	(48)
			Defenders Beaten (*r* = 0.20)	(53)
			Defenders Beaten (*r* = 0.41)	(48)
			Tackle Breaks (*r* = 0.15)	(53)
			Carries Over Gain Line (*r* = -0.03)	(53)
			Metres Advanced (*r* = 0.13)	(53)
		Momentum (kg.m.s^{-1})	Tries Scored (*r* = 0.37)	(48)
			Line Breaks (*r* = 0.32)	(48)
			Defenders Beaten (*r* = 0.30)	(48)
			Dominant Collisions (*r* = 0.86)	(14)
			Offloads (*r* = 0.78)	(14)

	30 m Sprint	Velocity ($m \cdot s^{-1}$)	Tries Scored (r = 0.16) Defenders Beaten (r = 0.25) Metres Advanced (r = 0.13)	(53) (53) (53)
	40 m Sprint	Velocity ($m \cdot s^{-1}$)	Tries Scored (r = 0.25) Line Breaks (r = 0.51) Defenders Beaten (r = 0.50)	(48) (48) (48)
Aerobic Characteristics	Yo-Yo Intermittent Recovery Test Level 1	Distance Run (m)		(14)
	Multi-Stage Fitness Test	Distance Run (m)	Activity Rate (r = 0.36)	(48)
Anaerobic Characteristics	Rugby-Specific Repeated Speed Test	Average Sprint Velocity ($m \cdot s^{-1}$)	Tries Scored (r = 0.09) Activity Rate (r = 0.03)	(53) (53)
		Fatigue Decrement (%)	Tries Scored (r = 0.21) Activity Rate (r = -0.17)	(53) (53)
	10 x 40 m Repeat Sprint Ability Test	Average Sprint Velocity ($m \cdot s^{-1}$)	Tries Scored (r = 0.31) Activity Rate (r = 0.39)	(48) (48)

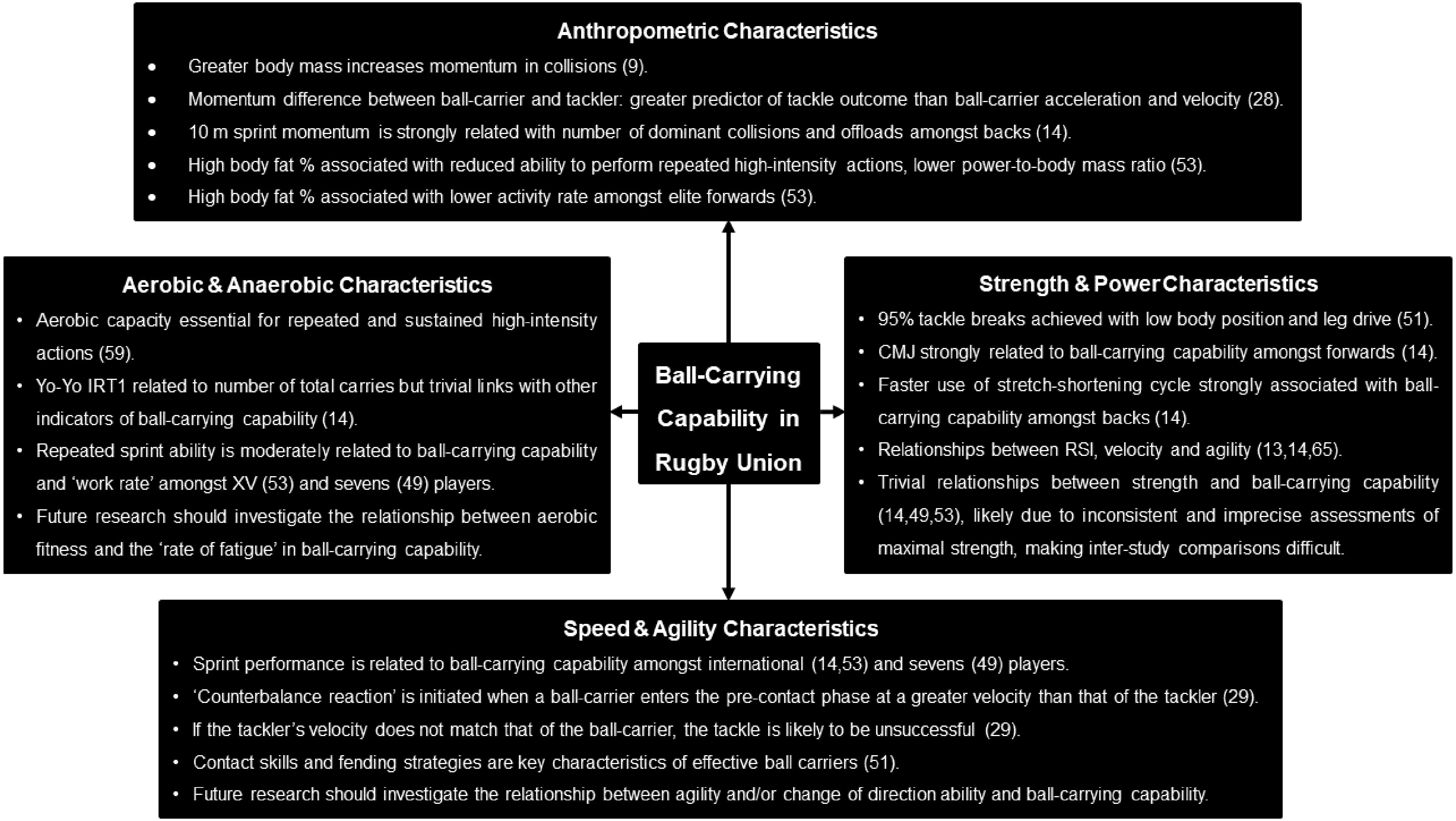

Figure 1. A summary of the main findings of the literature review, providing guidance for coaches on which physical characteristics should be prioritised to optimise ball-carrying capability in rugby union players, and guidance for researchers on which physical characteristics require further investigation.