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The Application of 3D Motion Analysis in Surgical Evaluation and Training: A pilot study.

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Background:
The existence of reference model tasks to be performed by experienced Surgeons means that it is feasible to evaluate the surgical competences of junior NHS surgeons from the very earliest years of their training. Parameters such as hand movement economy and precision, time efficiency and consistency can all be measured, assessed, stored and compared to the expected level of performance. A high precision optical motion capture system is a promising tool in Surgical Skills Teaching & Training as it can record and analyse movements of forearm, hands, digits and surgical tools in great detail. This project addresses a need to establish a reliable, repeatable and objective method for the evaluation of the progress and the quality of training of the surgical trainees during their surgical curriculum.

Aim:
To evaluate whole body, forearm, hand and surgical tool movements during stitching (continuous, subcuticular, interrupted, figure of 8) and excising skin lesion in experienced surgeons and final year medical students.

Objectives:
1) To determine the time required to complete each surgical task.
2) To analyse the whole body centre of mass, neck, elbow, forearm and hand kinematics
3) To determine the distance travelled by the surgical tool (forceps, scissors and knife).
4) To determine the reliability, repeatability and compare differences of the aforementioned objective measures within and between surgeons and students.

Method:
A cross-sectional 3D motion analysis pilot study was performed on five volunteer surgeons from NHS Grampian and five medical students from Aberdeen University Medical School.

Retro-reflective markers were affixed to each participant's skin on specific palpated anatomical landmarks (Fig. 1) and on a silicon suturing pad and surgical tools. Participants carried out 4 stitches (continuous, subcuticular, interrupted, figure of 8), and a skin lesion excision. The surgical procedures were repeated three times. The Vicon optical motion capture system recorded the markers at 120 Hz. Ranges of motion (ROM), distances covered and times required for task completion were calculated. Mann-Whitney independent samples tests were conducted to identify potential significant differences between levels of experience, at p=0.05.

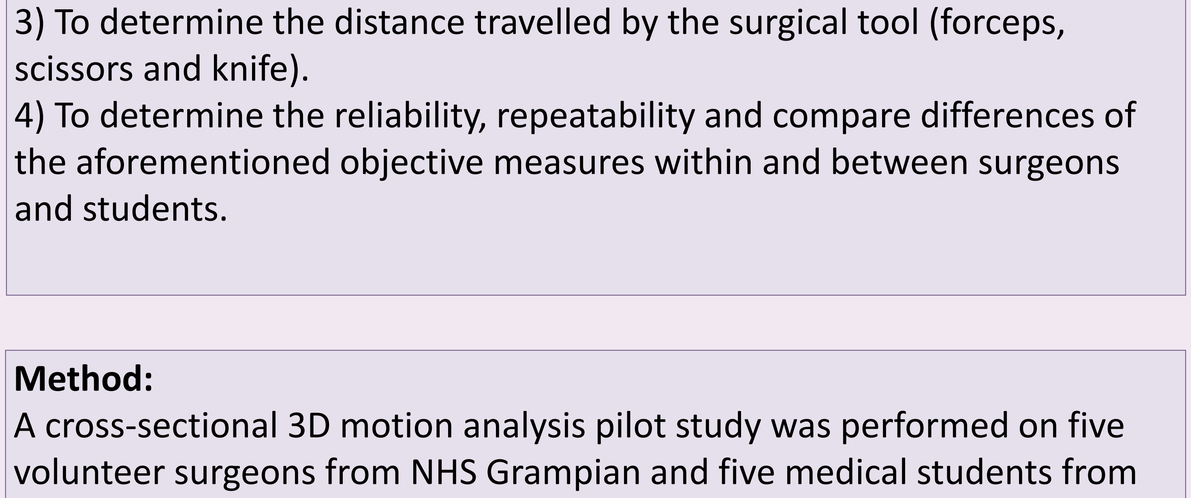

Fig.1: (A) Photograph of the surgeon's forearm and hand with retro-reflective markers; (B) Animated stick figure of these segments; (C) A graph of data collected: the flexion extension angle between the forearm and hand segments during the stitching procedure.

Results:

Experienced surgeons required significantly less time to complete each task. Their whole body centre of mass as well as their neck ROM were significantly smaller. The surgical tool (forceps, scissors and knife) also travelled less distance when used by surgeons ($p<0.05$). On the other hand, elbow, forearm and hand kinematics did not show significant differences between surgeons and students ($p>0.05$). Repeatability was higher in surgeons (ICC>0.70) compared to students (ICC>0.55). These are shown in Table 1.

Table 1: Ranges of motion (ROM), distances covered and times required for task completion Bold numbers represent significant differences between groups.

	Stitching						
	Surgeons			Students			p
	Mean	St. Dev	ICC	Mean	St. Dev	ICC	
Neck flex/ext ROM (deg)	6.32	0.82	0.79	9.93	0.89	0.67	**0.003**
Elbow flex/ext ROM (deg)	13.84	3.43	0.78	16.84	3.87	0.72	0.070
Hand flex/ext ROM (deg)	60.41	17.10	0.70	62.37	19.15	0.65	0.092
Hand side flex/ext ROM (deg)	58.23	15.34	0.71	61.11	16.33	0.64	0.081
Hand rotation ROM (deg)	53.94	12.40	0.72	53.85	14.17	0.63	0.116
Tool distance travelled (m)	0.12	0.04	0.85	2.12	0.29	0.08	**0.001**
CoM distance travelled (m)	0.26	0.05	0.81	0.87	0.10	0.75	**0.002**
Completion time (s)	36.24	6.41	0.89	64.80	12.50	0.56	**0.001**

	Lesion Excision						
	Surgeons			Students			p
	Mean	St. Dev	ICC	Mean	St. Dev	ICC	
Neck flex/ext ROM (deg)	6.12	0.87	0.75	10.17	0.93	0.67	**0.020**
Elbow flex/ext ROM (deg)	21.31	3.86	0.73	22.54	4.58	0.62	0.070
Hand flex/ext ROM (deg)	81.86	16.27	0.71	85.83	21.73	0.66	0.120
Hand side flex/ext ROM (deg)	44.51	16.49	0.70	66.94	18.48	0.62	0.091
Hand rotation ROM (deg)	52.84	13.70	0.73	58.12	14.02	0.59	0.120
Tool distance travelled (m)	0.11	0.02	0.87	2.18	0.37	0.07	**0.001**
CoM distance travelled (m)	0.25	0.04	0.91	0.82	0.09	0.72	**0.001**
Completion time (s)	21.30	5.85	0.92	71.20	13.49	0.55	**0.001**

Discussion and Implications:
The results supported the hypothesis that smaller movements and shorter time to complete the procedure were required by experienced surgeons compared to students, which is related to lower energy expenditure and increased efficiency.

The existence of reference model tasks to be performed by experienced Surgeons means that it is feasible to evaluate the surgical competences of junior NHS surgeons from the very earliest years of their training.

Parameters such as hand movement economy and precision, time efficiency and consistency can all be measured, assessed, stored and compared to the expected level of performance. A high precision optical motion capture system is a promising tool in Surgical Skills Teaching & Training as it can record and analyse movements of forearm, hands, digits and surgical tools in great detail.

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