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Variations in knee flexion measurements for overhead squat as measured with marker-based and markerless motion capture systems

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Introduction: Measuring movement performance is of value in the rehabilitation and management of movement in both clinical and athletic settings. Computerised motion analysis allows clinicians to more precisely quantify movement parameters. Traditionally, motion capture systems are expensive, technically demanding and require a specialised laboratory setting with highly trained individuals. Recent developments in the gaming industry have resulted in low cost systems such as the KINECT™ which can be customised and developed to meet motion capture requirements in a more accessible way. However, the accuracy of such markerless systems has been questioned extensively in research [1–6]. Notably, the accuracy of markerless technology is task-dependent: Knee flexion is an important motion that is required for a wide range of movements from basic locomotion (stride pattern and gait analysis) to complex motor skill execution (e.g. squat). Thus, investigation of knee flexion accuracy during a closed kinetic chain motion is required.

Research questions: How accurately can knee flexion be tracked by markerless motion capture techniques compared to marker based approach both using skeletal data?

Methods: Data was obtained from seven healthy athletic male participant (age, 22–26 years). Comparison was completed between VICON and KINECT. A 6 camera system was positioned in a circular fashion around the athlete so that all body segments were visible enabling 3D reconstruction. KINECT version 2 sensor

Table 1
Knee flexion at peak of overhead squat for VICON and KINECT.

Participant	Trial	Left Knee Kinect (°)	Left Knee Vicon (°)	Absolute difference left (°)	Right Knee Kinect (°)	Right Knee Vicon (°)	Absolute difference right (°)
1	1	106.7	111	4.3	106.6	105	1.6
1	3	99.7	107.2	7.5	101.3	104.2	2.9
2	1	100.1	108	7.9	99	109	10
2	2	102.2	107	4.8	100.6	106.8	6.2
2	3	83.7	89.1	5.4	79.9	86.3	6.4
3	1	83.2	78.1	5.1	82.3	87.7	5.4
3	2	87.2	79.3	7.9	84.5	89.5	5
3	3	81.8	70.7	11.1	81.3	82	0.7
4	1	90.3	99.8	9.5	87.5	103	15.5
4	2	85.8	96.4	10.6	85.6	98.3	12.7
4	3	86.7	95.5	8.8	86.7	97.7	11
5	1	90.4	98	7.6	92.3	102	9.7
5	2	92.7	101	8.3	95.8	104	8.2
5	3	90.2	99.8	9.6	93.5	103	9.5
6	1	81.4	79	2.4	82.5	75.6	6.9
6	2	75.1	77.5	2.4	75.8	72	3.8
6	3	77.7	80	2.3	80.3	76	4.3
7	1	83.7	88.5	4.8	82.8	90.2	7.4
7	2	96.6	103	6.4	96.2	105	8.8
7	3	81.9	90	8.1	80.7	89.6	8.9

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(KINECT for Windows and Xbox One, Microsoft corporation, Redmond, WA, USA) and Software Developer Kit (SDK) was used to track motion without the application of markers. The raw data was exported to Matlab/Visual 3D for processing. The VICON and KINECT data were coregistered using the location of the VICON markers. The knee flexion angle was measured as the two dimensional angle between the upper and lower leg (as defined by the hip, knee, and ankle joint coordinates) as seen in the height and depth plane. An angle of 0° was measured for straight legs during standing.

Results: The absolute difference between VICON and KINECT averaged across 7 participants performing three trials each ($N = 20$, participant 1 performed only 2 trials) was measured to be $7.2 \pm 3.7^\circ$ (right) and $6.7 \pm 2.7^\circ$ (left). The single trial results for peak flexion are listed in Table 1.

Discussion: The results indicate that the difference between VICON and KINECT is larger than 5° – the error margin required for clinical relevance. It is worth considering the large errors $>10^\circ$ in multiple single trials. The error appeared to have been also strongly angle dependent with overestimated knee flexion for normal squats and underestimated knee flexion for deeper squats. The findings suggest that low-cost markerless motion capture has potential to provide an objective method for assessing lower limb squat mechanics and trunk control in an applied sports setting. Furthermore, the outcome of the study warrants the need for future research to examine more fully the potential implications of the use of low-cost markerless motion capture in the evaluation of athletic movement screens for injury prevention. Further development is needed potentially using the depth information rather than the inferred skeletal data to achieve closer agreement with existing marker based systems.

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