Inter-examiner and inter-day reliability of dynamic tibiofemoral movements measurement using motion capture during functional tasks

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Summary
This study assessed the inter-examiner and inter-day reliability of measuring dynamic anterior tibia translation (ATTd) and internal tibia rotation (ITRd) during functional tasks using 3D motion capture with reflective markers. Intraclass correlation coefficient values indicated good-to-excellent reliability during walking (ICC=0.66-0.82) and excellent reliability during the landing of jumping tasks (ICC=0.75-0.90) for both ATTd and ITRd. Standard error of measurement values were below 21% of the mean range of motion during the respective tasks.

Introduction
The primary function of the anterior cruciate ligament (ACL) is to prevent dynamic tibiofemoral movements (i.e. dynamic anterior tibia translation [ATTd] and internal tibia rotation [ITRd]). It is crucial to assess these movements, as a lack of control can increase strain on the ACL and elevates (re)injury risk. Using 3D optoelectronic motion capture, these movements can be measured during demanding activities without limiting patients' range of motion. This study aimed to assess the inter-examiner and inter-day reliability of measuring dynamic ATTd and ITRd during functional tasks using motion capture.

Methods
Nineteen healthy participants performed walking, the side hop, single-leg hop for distance, and triple hop for distance. ATTd and ITRd were measured with 42 reflective markers on the lower extremities. Using the optimal common shape technique, markers on each segment (femur and tibia) were virtually replaced to act as a rigid body, reducing soft tissue artifacts. Based on a star-arc calibration movement, the center of rotation of the hip was calculated using the symmetrical center of rotation estimation. Based on a knee flexion-extension calibration movement, the axis of rotation in the knee was calculated using the symmetrical axis of rotation approach. This axis was placed in the rigid body of both the femur and tibia segment, resulting in two functional axes of rotation. By combining these methods, referred to as the OSSCA [1], a coordinate system for each segment is established, allowing for the calculation of ATTd and ITRd. For inter-examiner reliability, all tasks were repeated two times on the same day after marker placement performed by two different examiners. For inter-day reliability, tasks were repeated on two separate days.

Results and Discussion
Intraclass correlation coefficient (ICC) values indicated good reliability for ATTd and good-to-excellent reliability for ITRd during the stance phase of walking (Table 1). The peak ground reaction force (GRF) phase (phase where GRF exceeds the upper 33%) of the jumping tasks showed excellent reliability for both ATTd and ITRd (Table 1), with higher inter-examiner reliability compared to inter-day reliability. Standard error of measurement (SEM) values were below 14% of the mean range of motion during the respective tasks, except for ATTd during the side hop and ITRd during walking and the triple hop for distance. Lowest SEM values occurred around 0.05s following initial contact of the jumping tasks.

Conclusion
Measurement of dynamic ATTd and ITRd using 3D optoelectronic motion capture during the peak GRF phase of jumping tasks is reliable and can be utilized in research to assess ACL injury risk factors and outcomes of various surgical and rehabilitation methods after ACL injury.

References
[1] Taylor WR et al. (2010). *Gait Posture*, **32**: 231-6

Table 1. Mean ICC and SEM for the stance phase during walking, and during the peak GRF phase of the side hop, single leg hop for distance, and triple hop for distance.

	Inter-examiner reliability		Inter-day reliability	
	ICC	SEM	ICC	SEM
Dynamic Anterior Tibia Translation (ATTd)				
Walking	.72 (.39-.88)	3.1 (12%)	.69 (.37-.87)	3.2 (13%)
Side Hop	.90 (.75-.96)	2.0 (16%)	.83 (.62-.93)	2.6 (21%)
Single Leg Hop for Distance	.83 (.61-.93)	2.1 (10%)	.75 (.46-.90)	2.2 (11%)
Triple Hop for Distance	.90 (.75-.96)	1.7 (8%)	.81 (.57-.92)	2.2 (10%)
Dynamic Internal Tibia Rotation (ITRd)				
Walking	.82 (.54-.93)	2.0 (13%)	.66 (.31-.85)	2.8 (19%)
Side Hop	.88 (.72-.95)	1.8 (11%)	.77 (.50-.91)	2.0 (14%)
Single Leg Hop for Distance	.86 (.68-.94)	1.8 (14%)	.82 (.59-.93)	1.7 (13%)
Triple Hop for Distance	.84 (.63-.93)	2.1 (16%)	.75 (.45-.89)	2.2 (17%)

Note. ICC and SEM are reported as means of the pointwise ICC (with 95% confidence intervals) and SEM across the duration of the task.
ICC was categorized as poor (< 0.4), fair (0.4-0.6), good (0.6 - 0.74) or excellent (> 0.74).
SEM is shown in millimeters for ATTd and in degrees for ITRd, and as percentage of the mean range of motion during the respective task.