RELIABILITY OF A NOVEL KNEE SIMULATOR AND ITS CONCURRENT VALIDITY AGAINST A VALIDATED DYNAMIC KNEE SIMULATOR

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Introduction

In recent decades, a multitude of new *ex-vivo* knee simulators, frequently based on the Oxford Knee Rig (OKR) design and often limited to squatting motion, have been developed [1,2]. Such simulators are crucial to provide novel insights in knee biomechanics and evaluating the impact of surgical procedures and rehabilitation strategies [1,2]. Typically, new simulators are conceptually designed to allow more physiologic simulations by replicating more intricate and precisely controlled motions, and thus exhibit potential differences in comparison to their predecessors [1,2]. However, despite the advancements in current designs and control strategies, there remains a lack of quantitative data in literature that comprehensively evaluates the biomechanical behavior of the same knee across different simulators. Recently, we have developed a novel physiological knee simulator that allows the control of translations in three axes at the ankle as well as independent improved control of quadriceps and bilateral hamstring muscle groups to perform more complex motions beyond squatting. Therefore, the aim of this study is to assess the reliability of the novel knee simulator (NKS) and, for the first time, determine its concurrent validity with a previously validated OKR-based knee simulator (VKS) by repeating squatting motion in both simulators within a single cohort of cadaveric knees.

Methods

Seven fresh-frozen legs (82±8yrs) were subjected to squatting motions (30°-105°) on the NKS following previously described specimen preparation [2]. The quadriceps and bilateral hamstrings tendons were actively controlled using feedforward proportional-integral-derivative, while a constant vertical ankle force of 110 N was set as target, during the squatting motions. A cemented TKA (GMK Sphere, Medacta International, Switzerland) was then implanted in each knee. Subsequently, all postoperative knees were tested on the NKS and previously validated VKS [2], the latter only allowing squatting motion and with actively controlled quadriceps tendons and 50N force spring on each hamstring, using same flexion range, ankle load and time. All motion data were collected using a six-camera motion capture system (VERO-1.3X, Vicon, UK) with each knee tested in quintuplicate in both simulators. A pointwise intraclass correlation (ICC, 95% CI poor<0.4 and 0.74<excellent) and standard error of measurement (SEM) as a function of knee flexion angle were used to analyze the intra-simulator reliability of the resulting tibiofemoral kinematics, ankle and quadriceps loads within NKS as well as the inter-simulator reliability of tibiofemoral kinematics across the simulators [3].

Results

The mean intra-simulator reliability was excellent for valgus (ICC>0.99, SEM<0.09°) and tibial internal rotation (ICC>0.99, SEM<0.3°) during squatting (Fig.1). Moreover, the ankle (ICC>0.65, SEM<1.1N) and quadriceps (ICC>0.78, SEM<61.7N) showed good to excellent reliability. Additionally, the inter-simulator reliability was excellent for valgus (ICC>0.98, SEM<0.34°) and tibial internal rotation (ICC>0.82, SEM<1.5°) throughout the squatting motion.

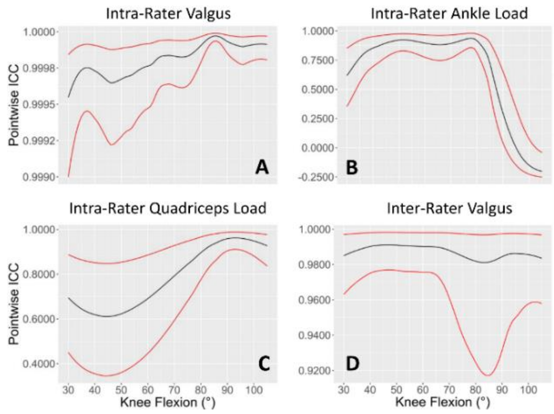

Figure 1: Pointwise intraclass correlation (ICC) of valgus (A), ankle load (B) and quadriceps load (C) for intra- simulator reliability and ICC of valgus for inter-rater reliability during squatting. Black and red curves show mean and 95% confidence intervals, respectively.

Discussion

The novel knee simulator showed excellent kinematics and good force reliability, indicating the effectiveness of the implemented control strategy. Nevertheless, it is crucial to thoroughly assess the lower and upper CI of ICC and SEM to avoid misinterpretation. Besides, our findings exhibited that different OKR-based simulators have comparable kinematics during squatting despite potential hardware and software differences, suggesting they are primarily driven by the knee specimen itself.

References

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