Within-Session Reliability and Minimal Detectable Change of Peak Knee Angles and Moments Between Gait and Squats, using Markerless Motion Capture

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Summary

Within-session reliability and minimal detectable changes (MDC_{95}) have been explored for gait but are limited for occupational postures. Rejecting our hypothesis for most outcomes, squats had higher within-session reliability and lower MDC_{95} compared to gait.

Introduction

Within-session reliability and minimal detectable changes (MDC_{95}) have been reported for gait [1-3], but there is a significant knowledge gap for occupational postures. Gait studies have identified an acceptable MDC_{95} of 5° for lower extremity joint angles [3]. Our aim was to quantify and compare the reliability and MDC_{95} of peak knee angles and moments between high flexion squats and gait in the field (early learning centres). We hypothesized there would be reduced within-session reliability and greater MDC_{95} for squatting compared to gait due to increased intra-individual variations not manifested in the cyclic pattern of gait.

Methods

In their workplace, 13 female early childhood educators performed 3 squat and 3 gait trials before and after their work shift. Segment motion and ground reaction forces were recorded using 3 platform embedded force plates (AMTI, Watertown, USA) synchronized with 8 markerless motion capture cameras (Qualisys, Göteborg, Sweden). 3D segment poses (Theia3D, Theia Markerless, Inc., Kingston, Canada) and peak knee adduction angles (KAA), knee flexion angles (KFA), knee adduction moments (KAM), and knee flexion moments (KFM) (Visual 3D, HAS-Motion, Kingston, Canada) were extracted from a minimum of 2 trials. Standard error of measurement (SEM) and MDC were computed as: $SEM = SD_{diff}/\sqrt{2}$; $MDC_{95} = 1.96 \times \sqrt{2} \times SEM$ [2]. Within-session reliability (intraclass correlation coefficient) was defined as $ICC_{2,1} = \frac{MS_{Row} - MS_{Error}}{MS_{Row} + (k-1)MS_{Error} + \frac{k}{n}(MS_{Column} - MS_{Error})}$

*MS = mean square, k = number of measurements, n = number of subjects, row = between-groups, column = within-groups, error = residual

[4]. Two-tailed paired sample t-tests ($\alpha = 0.05$) were performed to test for significant differences in knee outcomes between sessions.

Results

Reliability for gait was moderate to good except the KFM_{After} (was poor) (Table 1). Opposing our hypothesis, squats demonstrated greater reliability than gait ranging from good to excellent except the KAAs (moderate before and poor after) (Table 1). For squatting, MDC_{95} were larger for angles but smaller for moments, compared to gait (Table 1). All angle MDC_{95} were less than the accepted threshold of 5°, except for squat KFAs (Table 1). No between-session differences were found in any outcomes ($p > 0.05$) (Fig. 1).

Table 1: ICCs and MDCs for Peak Knee Angles and Moments of Before and After Squat Sessions

		Before		After	
		Gait	Squat	Gait	Squat
ICC (2,1)*	KAA	0.73	0.64	0.79	0.48
	KFA	0.85	0.97	0.87	0.94
	KAM	0.80	0.86	0.68	0.89
	KFM	0.64	0.99	0.47	0.98
MDC_{95}	KAA	2.8°	4.0°	3.3°	4.0°
	KFA	4.5°	7.3°	2.5°	9.9
	KAM	14.6 Nm	5.9 Nm	22.9 Nm	2.7 Nm
	KFM	24.0 Nm	8.2 Nm	36.3 Nm	11.4 Nm

*Poor = <0.5, moderate = 0.5-0.74, good = 0.75-0.9, excellent = >0.9

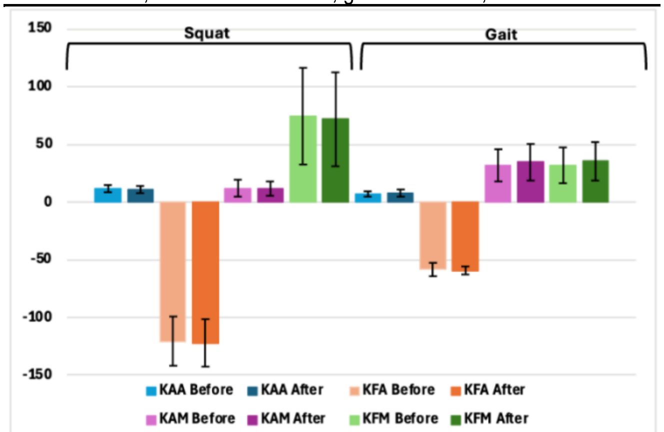

Figure 1: Squat and gait peak knee angles (°) and moments (Nm)

Discussion and Conclusions

Despite the cyclic nature of gait, squatting had higher reliability, indicating consistent and repeatable measurements with less intra-individual variability. The complexity of phase transitions, variability in speed, stride length, heel strike patterns, as well as experimental uncertainty may account for lower gait reliability [3]. Sensitivity to detect MDC_{95} of <5° was exhibited, except for squat KFAs. Thus, a greater change in knee flexion is required to be interpreted as meaningful for squatting. Future studies should explore other occupational postures to assess reliability and develop normative variability and error measurements for a diverse range of applications.

Acknowledgments

The authors gratefully acknowledge the support from the early childhood educators and staff, as well as our funding sources: the Canadian Foundation for Innovation and NSERC Canada.

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