ISB 2013 BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

DOES THE RELIABILITY OF KNEE JOINT KINEMATICS AND KINETICS OF DROP JUMPING AFFECT ITS RELEVANCE AS A CLINICAL ASSESSMENT?

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SUMMARY

When estimating knee joint angles and moments in vertical two-legged drop jumps, data from contemporary models with functional knee joint axes showed moderate to good reliability, with low extrinsic variability compared to intrinsic variability. These findings should be considered for diagnostic interpretations of screening tests, for example with reference to knee valgus angles or moments.

INTRODUCTION

Lower limb injuries are very common during dynamic sports activities with ~70% of injuries affecting the lower extremities [1]. With preventative screening, clinicians monitor how athletes cope or fail to cope with the external moments acting on the lower limbs. Therefore, screening tests have been developed using motion analysis and force plates to determine movement patterns and joint loading. Two-legged drop vertical jumps are arguably the most popular screening test with clinicians as they resemble an impact situation and are relatively easy to monitor [2]. In a diagnostic context, easy-to-obtain outcome variables are often tested against those variables that have been shown to have predictive qualities for injuries, such as knee valgus angles or peak valgus moments. However, the reliability of the latter has never been fully addressed, particularly in the context of recently developed modelling approaches [3].

Schwartz et al. [4] reported different sources of error in gait data. Intrinsic errors arise naturally, and represent either trial to trial or subject to subject variability. These intrinsic errors cannot be reduced but are important to keep in mind when interpreting data. On the other hand, extrinsic errors arise from intra- and inter-therapist variability. For example anatomical landmark identification is dependent on the accuracy of the therapist and can lead to increased extrinsic error.

The aim of the present study was to assess the reliability of discrete and continuous knee joint kinematic and kinetic variables obtained from the Liverpool John Moores University biomechanical model (LJMU-model) during drop vertical jumping (DVJ). Knowledge of the reliability and variability of such variables will better inform clinical interpretations of drop jumping.

METHODS

Eight participants consented to participate in this study (four males, four females; mean age: 25.8 ± 4.4 yrs; mass: 64.8 ± 7.2 kg; height: 1.7 ± 0.1 m). A repeated-measures design was used. Each subject attended six testing sessions; four on day one and two on day two. Two therapists conducted three sessions each; two each on day one, and one each on day two. This allowed each participant to be tested by each therapist within and between days (see figure 1). There was a one hour rest period between sessions on the same day.

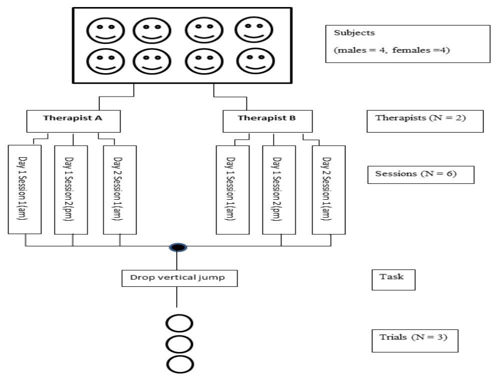

Figure 1. An outline of the study design.

During DVJ, subjects were instructed to drop off a 0.3 m box, with their feet positioned 0.3 m apart, and immediately perform a maximum vertical jump. Each participant had 46 spherical reflective markers positioned according to the LJMU-model, a 6-degrees-of-freedom eight segment model including feet, upper and lower legs, pelvis and trunk [3]. Functional hip joint centres and functional knee joint axes were calculated [5] to minimise errors due to anatomical landmark placement. Geometric volumes were used to represent segments based on cadaver segmental data. DVJ tasks were completed on two 0.9x0.6 m force plates which sampled the forces of both legs separately at 1500 Hz. 3D kinematic data were simultaneously recorded using a 10 camera optoelectronic system sampling at 250 Hz. Joint angles were calculated for the lower limbs and (external) joint moments were calculated using inverse dynamics.

The reliability of peak values and waveforms was analysed by calculating the inter-trial (σ^{trial}), inter-session (σ^{sess}) and inter-therapist (σ^{ther}) errors, as proposed by Schwartz et al. [4]. For peak values, the therapist versus trial error ratios were also calculated ($\sigma^{ther/trial}$).

RESULTS & DISCUSSION

Visual observations of the entire waveforms of the inter-trial, inter-session and inter-therapist errors of all knee angles showed somewhat consistent waveform patterns over time, suggesting a similar amount of intrinsic and extrinsic variability throughout the landing phase (Figure 2). In contrast, the knee joint moment variability waveforms showed more variation over time. Most of the variability peaks coincided with the time of peak loading, probably due to variability of the ground reaction force peak at impact.

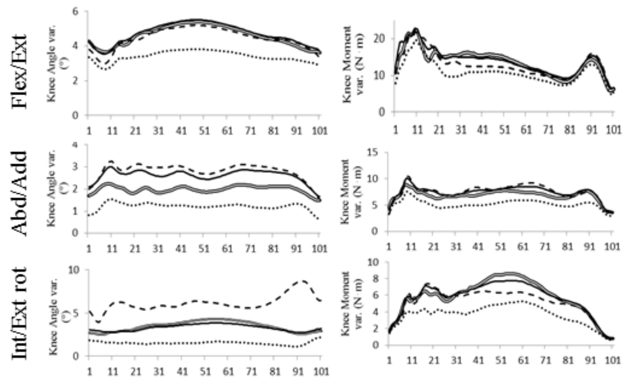

Figure 2. Waveform variability of joint angles (left) and joint moments (right) expressed in terms of σ^{trial} (dotted), $\sigma^{sess\ therapist\ a}$ (dashed), $\sigma^{sess\ therapist\ b}$ (double), σ^{ther} (bold) during first landing phase of the drop vertical jump.

The σ^{trial} of the peak knee joint angles and moments were smaller than 3.8° and 9.1 N.m respectively (Table 1). The σ^{sess} of the peak values ranged from 1.9° - 5.3° for all angles and from 5.9 N.m - 12.8 N.m for all moments. The σ^{ther} of the peak values ranged from 2.7° - 5.5° for all angles and from 6.2 N.m – 12.5 N.m for all moments. These values may be considered to represent moderate to good reliability. In accordance with Schwartz et al. [4], the inter-session variability (σ^{sess}) of all peak kinematic and kinetic parameters was higher than the σ^{trial} suggesting a larger variability between sessions than between trials. Small inaccuracies of marker placement are expected to have caused this higher σ^{sess}. There was no clear difference between $\sigma^{sess\ therapist\ a}$ and $\sigma^{sess\ therapist\ b}$ highlighting the same accuracy and experience of both therapists.

The inter-therapist errors (σ^{ther}) for all kinematic parameters were slightly larger than a previous study analysing gait data [4]. However, this did not have a significant impact on the $\sigma^{ther}/\sigma^{trial}$ ratio of most kinematic and kinetic parameters as most peak values had a $\sigma^{ther}/\sigma^{trial}$ ratio lower than 2. These low $\sigma^{ther}/\sigma^{trial}$ ratios suggest that only a small proportion of the total variability arose from extrinsic methodological sources, supporting the value of therapist independent methods such as functional joint centre and axes calculations.

When interpreting our overall findings in the light of other studies investigating group or intervention effects on kinematic and/or kinetic parameters in DVJ tasks, significant effects based on statistical comparisons using means and standard deviations can now be better interpreted. Where the potential impact of intrinsic and extrinsic errors was previously not known, this now becomes possible. For example, Myer et al. [6] assessed the effect of neuromuscular training in “high-risk” athletes and they showed a significant decrease of 5.3 N.m (13%) in external knee abduction (also called valgus) moment (Pre-test: 39.9 ± 15.8 N.m to Post-test: 34.6 ± 9.6 N.m). Our findings indicated an σ^{sess} of the peak knee abduction moment of 7.1 N.m. This suggests that the changes in peak external knee abduction moment could well be due to between session variability. The advancement towards diagnostic decision-making for such intervention should be made cautiously until the reliability of their methods is demonstrated.

CONCLUSIONS

The present findings have indicated that contemporary modelling approaches as in the LJMU-model are suitable for assessing knee joint angles and moments in DVJ, with moderate intrinsic and low extrinsic measurement error. Our data can inform clinicians on the diagnostic utility of research findings from the LJMU-model for drop jumping.

REFERENCES

1. Agel J, et al. *Am. J. Sports Med.* **33**: 524-30, 2005.
2. Hewett TE, et al., *Am. J. Sports Med.* **33**: 492-501, 2005.
3. Vanrenterghem J, et al., *Gait Posture* **31**: 517-521, 2010.
4. Schwartz MH, et al., *Gait Posture* **20**: 196-203, 2004.
5. Robinson MA, et al., *J. Biomech*. **26**: 1941-6, 2012.
6. Myer GD, et al., *J. Electromyo. Kinesiol*. **15**: 181-9, 2005.

Table 1. Inter-trial (σ^{trial}), inter-session (σ^{sess}) and inter-therapist (σ^{ther}) errors, and therapist versus trial error ratios ($\sigma^{ther/trial}$) for peak knee joint angles (°) and joint moments (N.m) during the first landing phase of the drop vertical jump.

Variable		σ^{trial}	$\sigma^{sess\ therapist\ a}$	$\sigma^{sess\ therapist\ b}$	σ^{ther}	$\sigma^{ther/trial}$
Knee joint angle	Flex/Ext	3.8	5.2	5.3	5.5	1.5
	Abd/Add	1.1	2.9	1.9	2.7	2.5
	Ext/Int rot	1.5	2.4	3.2	2.9	1.9
Knee joint moment	Flex/Ext	9.1	10.5	12.8	12.5	1.4
	Abd/Add	4.8	7.8	6.3	7.3	1.5
	Ext/Int rot	3.6	5.9	6.2	6.2	1.7