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EFFECT OF EXPRESSING LOWER EXTREMITY JOINT MOMENTS IN DIFFERENT REFERENCE FRAMES – IMPLICATIONS FOR INTERPRETATION OF RESULTS

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SUMMARY

Analyses of joint moments are essential in the study of human movement. They may be expressed in different reference frames, which affects the interpretation of these measures. Knee joint moments in drop jumps and sidestep cutting from 120 elite athletes were expressed in the laboratory frame, in the tibia local coordinate systems and projected and decomposed to the Joint Coordinate System. There was a significant effect on the ranking of athletes based on maximum values on expressing joint moments in different coordinate systems. Standards should be developed to improve comparison of results between different studies.

INTRODUCTION

Analyses of joint moments are essential in the study of human movement. They are interpreted in the context of muscle force generation and ligament loading, and provide insight into gait, running and sporting mechanics.

Joint moments can be expressed in different reference frames, e.g. the laboratory frame or the coordinate systems of the local segments adjacent to the joint [1]. Different methods are in use, and the choice of reference frame affects the interpretation of results [2, 3]. With joint moments not expressed relative to the joint rotation axes, there may not be correspondence between the joint angles and the joint moments, i.e. a net flexion moment may not result in a pure flexion.

Differences between different expressions of joint moments have previously been investigated in gait [1, 4-6], and the choice of knee axes affects kinetics of sidestep cutting [3]. The aim of this investigation is to describe the effect of expressing knee joint moments in drop jumps and sidestep cutting in four different reference frames: laboratory frame (global), local coordinate system of the tibia (tibia), projected to the joint coordinate system (JCS) axes (JCS1) and decomposed to the JCS axes (JCS2) [7]. The effect is described by the correlation between methods of the ranking of subjects based on maximum joint moments.

METHODS

Elite female handball players (N = 120) performed sidestep cutting and drop jumps from 30 cm, while eight cameras (Qualisys) recorded the movement of 35 markers attached over anatomical landmarks. Two force platforms (AMTI LG6-4-1) recorded ground reaction forces. The recording and analysis procedures are described previously [8]. Both marker and force data were filtered with Woltring's smoothing spline with a 15 Hz cut-off to avoid impact artefacts [8]. Calculations were performed in custom Matlab (Mathworks) programs, with joint moments calculated with recursive inverse dynamics.

Knee joint moments were expressed in the tibia frame by multiplying the rotation matrix from the global to the local system with the global joint moments (tibia). They were expressed in a standard JCS by projecting (JCS1) or decomposing (JCS2) the global moment to the JCS axes [9].

The right leg from one trial of sidestep cutting and jumping from each subject were selected for analysis. Spearman's rho was used to describe the correlation of ranking based on maximum values between methods.

RESULTS AND DISCUSSION

Plots of knee abduction and internal rotation joint moments for a typical athlete are provided for jumping (Figure 1) and sidestep cutting (Figure 2). For abduction, JCS 1 and JCS2 are mathematically equivalent, as are tibia and JCS1 for internal rotation.

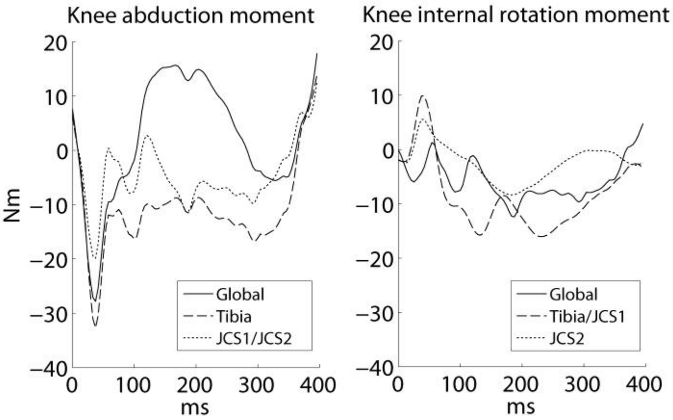

Figure 1: Knee joint moments during a jump expressed in the different reference frames. Typical trial.

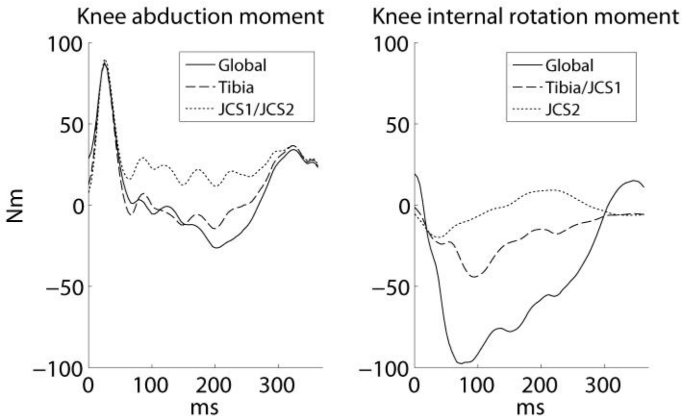

Figure 2: Knee joint moments during a sidestep cut expressed in the different reference frames. Typical trial.

There was a significant effect on ranking of subjects of expressing knee joint moments in different reference frames (Table 1). The ranking was most consistent across conditions for flexion moments in drop jumps and for flexion and abduction moments in sidestep cutting. Abduction and internal rotation in drop jumps and internal rotation moment in sidestep cutting show only a poor to moderate correlation when comparing conditions. In sidestep cutting the abduction moment occurred early in the stance phase, where a low knee flexion angle may have reduced the difference between methods. However, as can be seen from the plot of a typical trial, there was greater differences between methods later in the stance phase.

Expressing joint moments in the JCS facilitates interpretation of results and is the natural choice in multi-planar motion [1]. This ensures correspondence between joint kinematics and kinetics. If joint moments are expressed in other reference frames, the interpretation of joint moments as torques about joint axes is not valid. As the rank correlation can be moderate or poor between the different expressions for relevant joint moments, misguided conclusions may result from joint moments expressed in frames other than the kinematic joint axes. However, there is only moderate correlation of internal rotation moments projected or decomposed to JCS axes, thus the choice of method to express joint moments in the JCS also affects results.

CONCLUSIONS

The choice of reference frame to express knee joint moments significantly affects results. This is especially true for abduction and internal rotation moments, where there may be only a poor or moderate correlation of the ranking of subjects between different methods. A standard of joint moment reporting could facilitate comparison of studies and improve the quality of motion analysis studies.

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Table 1: Rank correlation between maximum knee joint moments in jumps and sidestep cuttingexpressed in different reference frames. *: mathematically equivalent

		Global vs tibia	Global vs JCS1	Global vs JCS2	Distal vs JCS1	Distal vs JCS2	JCS1 vs JCS2
Drop jump	Knee flexion	1.00	1.00	1.00	1.00	1.00	1.00
	Knee abduction	0.35	0.59	0.59	0.55	0.55	1.00*
	Knee internal rotation	0.36	0.36	0.58	1.00*	0.61	0.61
Sidestep cutting	Knee flexion	0.91	0.92	0.92	0.98	0.99	0.98
	Knee abduction	0.92	0.90	0.90	0.97	0.97	1.00*
	Knee internal rotation	0.59	0.59	0.57	1.00*	0.69	0.69