Energy dissipation due to lower limb soft tissue motion during drop landings from four different heights in female athletes

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Summary

Soft tissue motion contributes to energy dissipation during impacts. Energy losses due to soft tissue motion were calculated using marker arrays on the lower limb in female athletes during drop landings from four heights. Energy loss was calculated from modelling soft tissue movement as a damped simple harmonic oscillator. Energy dissipation due to soft tissue motion increased with drop height and was typically higher during passive landings.

Introduction

Soft tissue deformation is an established mechanism of energy dissipation during impacts that can account for up to 70% of the energy lost [1]. Zelik and Kuo [2] used indirect methods to indicate passive energy losses within the system during locomotion. Studies to date have had nearly all male subjects. The aim of the study was to calculate energy lost due to soft tissue motion during drop landings from 4 different heights with two landing techniques in female athletes, using arrays of markers on the lower limbs and modelling the motion as a damped harmonic oscillator.

Methods

Twelve female athletes (age, 20.9 ± 1.68 years; height, 1.76 ± 0.06 m; mass, 77.0 ± 10.6 kg), gave informed consent and had the soft tissue motion of the shank and thigh quantified in 3D via 8x9 arrays of 6.4 mm reflective markers (details in [3]). Markers, including 40 on bony landmarks, were tracked, reconstructed and gap filled with a 17-camera motion analysis system sampling at 750 Hz (Vicon Vantage, Oxford Metrics PLC., Oxford, UK) and Nexus software (Oxford Metrics PLC, Oxford, UK). Subjects performed “Active” and “Passive” landings from 15, 30, 45, and 60 cm onto a force plate (1500 Hz; AMTI OR6, MA., USA). Active: forefoot landing on the test leg whilst controlling the landing with both legs. Passive: instructed to land heel-first with minimal muscle activation of the test leg with weight being borne on the other leg as needed for a safe landing.

Soft tissue centre of mass (COM) locations for each segment were calculated via a Delaunay triangulation representation of the soft tissue [3]. Rigid body COM was determined from inverse kinematics based on joint markers and anthropometric values [4]. Rotation of the soft tissue relative to the fixed segment was established from the relative orientation of the soft tissue local coordinate system (LCS), defined using the eigenvectors of its inertia tensor. Both the soft tissue COM positions and rotation angles of the LCS were filtered at 60 Hz using a 4th order low-pass Butterworth filter. The energy dissipated due to translational and rotational soft tissue motion was calculated by fitting damped simple harmonic oscillator (SHO) solutions,

Results and Discussion

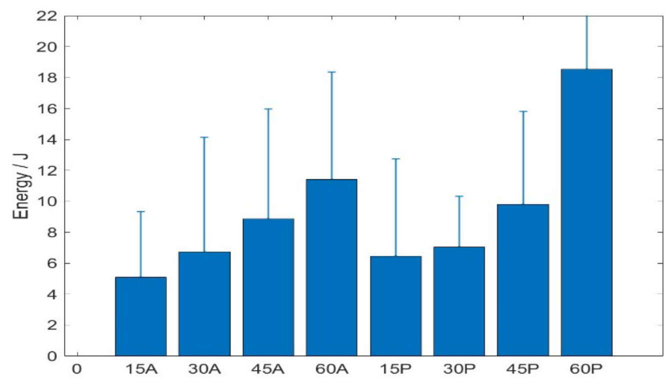

Figure 1. Group mean energy loss for the thigh from 4 heights (cm) and two landing conditions (A= Active, P= Passive).

Overall group mean results showed that energy losses associated with the damped soft tissue motion were typically greater during Passive landing than Active landing and greater at higher drop heights (Figure 1). As drop height increased peak vertical ground reaction force (vGRF) also increased but vGRF was higher in the Active condition for each landing height. 30A and 45P were the closest in terms of vGRF (difference of 0.2 BW; total BW range across all conditions was 2.3 to 5 BW) and consequently the closest impact intensity between any conditions but with very different energy losses (30A, 8.9 J and 35P, 14.5 J) emphasising the effect of landing type on energy loss.

Standard deviations are high, probably due to a combination of differences in subject mass and possibly ease or comfort of performing the landing tasks for different subjects. Normalisation to athlete body mass, or segment mass may improve this.

Conclusions

Measurement of marker arrays can determine substantial changes in soft tissue motion relative to a rigid segment during landings in a manner that is consistent with expected mechanical outcomes. It demonstrates that energy dissipation due to soft tissue motion increased with drop height and was typically higher during passive landings.

References

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