Energy dissipation due to thigh and shank soft tissue motion during drop landings performed from two heights and using two different landing techniques

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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 shank and thigh during drop landings from two different heights, using two different landing techniques. Energy dissipation due to soft tissue motion increased with landing height and was typically higher during passive landings (Table 1).

INTRODUCTION

Soft tissue deformation is a well-established mechanism of energy dissipation during impacts that can account for up to 70% of the energy lost [1]. Studies [such as 2,3] have inferred soft tissue energy losses indirectly via centre of mass work of the whole body minus joint work, however, attempts to calculate the dissipated energy directly have been limited and used different calculation methods that have, in some cases, produced some extreme values [4]. The aim of the study was to calculate energy lost due to soft tissue motion during two types of drop landings, by modelling its motion as a simple harmonic oscillator and comparing two methods for calculating energy loss.

METHODS

Seven recreationally active males (age: 32 ± 7 years, height: 1.79 ± 0.07 m, mass: 80 ± 8 kg) provided informed consent and had the soft tissue motion of the shank and thigh quantified in 3D using 7x8 and 7x9 arrays of 6.4 mm reflective markers respectively, at a sampling rate of 750 Hz, (details are described in [5]). The participants performed "Active" and "Passive" landings from 30 cm and 45 cm. Active condition: subjects landed on the forefoot of the test leg whilst controlling the landing with both legs. Passive condition: the non-test leg landed marginally first whilst the subjects were instructed to land heel-first with minimal muscle activation of the test leg.

Soft tissue centre of mass (COM) locations for each segment were calculated via a Delaunay triangulation representation of the soft tissue [5]. Rigid body COM was determined from joint centres and anthropometric tables [6] and the relative COM distances calculated. 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 COM position and rotation angles of the LCS where filtered at 60 Hz and 100 Hz respectively using a 4th order low-pass Butterworth filter.

The energy dissipated due to translational and rotational soft tissue motion was calculated for both sets of filtered data, by: a) fitting damped simple harmonic oscillator (SHO) solutions, and b) calculating the total maximum kinetic energy of the soft tissue.

RESULTS AND DISCUSSION

The SHO energy values were largely independent of the cut-off frequency (<1% between the 60 Hz and 100 Hz). In contrast, the KE-based energy values differed by 15.6%. Both methods produced comparable results; however, the dependence of the KE energy values on the cut-off frequency suggests that the SHO-based solution is more robust.

SHO and KE energy values calculated at the 60 Hz cut-off frequency were proportional to drop height for both landing techniques (Table 1). The dissipated energy during Passive landings was larger compared to the respective Active-landing values likely due to reduced energy dissipation via muscle contraction. It is noted however, that the trend was not ubiquitous possibly due to the small number of participants and individual differences in the modulation of landing muscle work to alleviate discomfort.

Table 1 Energy losses, in Joules, per segment due to soft tissue motion, calculated at two different landing heights using the SHO and KE methods at a 60 Hz cut-off frequency

	Thigh (J)			
	Active 30	**Passive 30**	**Active 45**	**Passive 45**
SHO	3.14 ± 2.95	3.0 ± 2.8	5.75 ± 9.2	6.32 ± 9.41
KE	1.78 ± 1.67	1.21 ± 0.55	2.5 ± 2.37	3.47 ± 5.47
	Shank (J)			
SHO	0.61 ± 0.22	1.48 ± 1.71	1.29 ± 0.95	1.98 ± 1.65
KE	0.53 ± 0.32	0.77 ± 0.75	1.07 ± 0.95	1.61 ± 0.39

CONCLUSIONS

Both methods of energy loss calculation appear to have successfully captured the effect of force magnitude and voluntary muscle activation on the amount of energy dissipated via soft tissue motion during lower limb impacts [2,3]. This suggests that the dissipated energy can be effectively modeled through SHO and KE-based solutions, with the former being more robust to the cut-off frequency value used.

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