INFLUENCE OF EXTERNALLY DAMPING ON IMPACT-INDUCED SOFT TISSUE VIBRATIONS AND MUSCLE RESPONSES IN LANDINGS

Weijie Fu, Yu Liu, Xi Wang

Key Laboratory of Exercise and Health Sciences of Ministry of Education, Shanghai University of Sport, Shanghai, China

The aim of this study was to investigate the changes in activation of the musculoskeletal system in response to soft-tissue vibrations with different compression conditions (externally applied) in a drop-jump landing task. Twelve trained male participants were instructed to perform drop-jump landings from 3 heights in compression shorts (CS) and regular shorts without compression (CC). Externally induced soft-tissue vibration damping, i.e. reduced peak acceleration and increased damping coefficient, was associated with a significant decrease in muscular activity of the rectus femoris and the biceps femoris muscles during drop-jump landing from different heights. Therefore, a greater increase in the damping is associated with a greater decrease in muscle activity.

KEY WORDS: soft tissue vibrations, externally damping, muscle activity, landing

INTRODUCTION: During two-footed landings from a vertical jump, the peak magnitudes of impact forces range from 3.5 to 6 times BW (Gross & Nelson, 1988). These impact forces cause large transient shocks that act upon the lower body and excite local vibrations that are either absorbed or transmitted through the soft tissues. Such vibration characteristics (i.e., amplitude and frequency) are tissue dependent (Boyer & Nigg, 2007; Wakeling, Nigg, & Rozitis, 2002), and the related muscles react by contracting when the soft tissues are exposed to vibrations (Nigg & Wakeling, 2001; Roelants et al., 2006).
Theoretically, the impact force is an input signal into the human locomotor system, whereas the soft tissues are the oscillating masses (Wakeling & Nigg, 2001). When the frequency of the impact force and the natural frequency of a specific soft-tissue compartment are similar, the soft tissue will vibrate with maximal amplitude (Boyer & Nigg, 2007). This common frequency is the resonance frequency specific to each soft-tissue compartment. To avoid large soft-tissue vibrations that can cause micro-damage to the tissue, muscles in the lower extremity will be activated (Coza, Nigg, & Dunn, 2011).
Generally, the muscle action required for damping soft-tissue vibrations during a drop landing and jump task cannot be well distinguished from those needed for vertical ascension. Alternatively, soft-tissue vibrations should be partly dampened while maintaining all other conditions (contact velocity, contact surface, etc.) constant (Coza, Dunn, Anderson, & Nigg, 2012). Compression apparel can dampen soft-tissue vibrations during various sports-related tasks (Mills, Scurr, & Wood, 2011). However, no neurophysiological methodology (e.g., surface EMG) has been involved in previous research, which further hinders our understanding of the potential mechanisms underlying the compression effects and the relationship between muscular activity and soft-tissue vibrations.
Based on the above observation, the aim of the study was to investigate how the activation of musculoskeletal system changed in response to the soft tissue vibrations with different external compression conditions in a drop jump landing task.

METHODS: Twelve trained male volunteers (age: 23.7 ± 2.7 years, height: 178.3 ± 2.5 cm, mass: 70.1 ± 4.6 kg), who were used to regular high-intensity training, participated in this study. The inclusion criteria for the participants were 1) free of any injuries at the time of the experiment and 2) suffered no injuries within six months prior to the experiment. We adopted two shorts conditions that differed in compression attributes. Participants were instructed to perform drop-jump landings from 30, 45, and 60 cm heights in compression shorts (CS) and regular shorts without compression (control condition, CC).
Vibrations of the quadriceps femoris and hamstring muscles through the accelerometers attached to the rectus femoris (RF) and biceps femoris (BF) were simultaneously collected using two biaxial accelerometers (Biovision Corp., Wehrheim, Germany). The medial–lateral

direction of the muscles was neglected. Biovision system (Biovision Corp., Wehrheim, Germany) was used to record the surface EMG signals from the RF and BF in the dominant leg which was defined as the preferred leg that the participant used to kick a ball (Fu, Liu, Zhang, Xiong, & Wei, 2012). Bipolar surface electrodes were placed along the longitudinal axes of the RF at approximately 50% of the distance between the anterior superior iliac spine and the superior border of the patella.

The main variables used in this study characterized the vibration signals, including peak soft-tissue acceleration (a_{peak}) and damping coefficient (*c*). The latter parameter was determined by least-squares minimization method (Levenberg–Marquardt) of the following equation: $s = ae^{-ct}\sin(2\pi f_v t + \varphi)$ (Wakeling & Nigg, 2001). EMG data were analyzed with DASYLab software (8.0, DATALOG GmbH, Mönchengladbach, Germany). Raw signals were band-pass filtered at 10 Hz to 400 Hz and then full-wave rectified. EMG amplitudes were normalized as a percentage of the highest value recorded during 18 trials of drop jumps. Root mean square of the muscle activity (EMG_{RMS}) was calculated during pre- and post-activation phases of landing.

Two-way ANOVAs were used to determine the compression effects and the drop heights on soft-tissue acceleration, damping coefficient, and muscle activity. Tukey's post-hoc tests were used to determine individual significant differences (17.0, SPSS Inc., Chicago, IL, U.S.A.). Significance level was set at α = 0.05.

RESULTS AND DISCUSSION:

Soft-tissue vibrations: A significant decrease in a_{peak} was observed in CS condition. For the quadriceps femoris, the a_{peak} in CS was significantly lower than that of CC during landings from 45 and 60 cm drop heights ($p < 0.05$). Similarly, hamstring muscles showed a significantly lower a_{peak} in CS than that of CC in 30 cm drop landings ($p < 0.05$); trend toward decreased a_{peak} in CS was also shown in landings at 60 cm height ($p < 0.01$). (Table 1)

Table 1
Comparison of peak soft tissue acceleration (a_{peak}) of quadriceps and hamstrings between compression shorts (CS) and control condition (CC) groups during landings at three different heights

Muscle groups	Shorts conditions	Landing heights		
		30cm	45cm	60cm
Quadriceps femoris	CS	6.85 ± *3.1*	10.25 ± *4.9*	11.18 ± *4.1*
	CC	7.82 ± *3.2*	13.16 ± *4.4*	14.31 ± *4.2*
	Diff.%	−12.5%	−23.1%	−22.0%
	p-value	0.272	0.038*	0.039*
Hamstrings	CS	3.18 ± *1.2*	4.07 ± *1.5*	5.01 ± *1.1*
	CC	4.42 ± *1.9*	4.85 ± *1.0*	5.92 ± *2.4*
	Diff.%	−28.2%	−15.8%	−16.5%
	p-value	0.027*	0.144	0.093†

Note: Diff.% shows percentage difference between CS and CC divided by the data of CC.
* Significantly different between shorts in the same landing height with $p < 0.05$.
† Significantly different between shorts in the same landing height with $p < 0.1$.

Wearing CS can increase the *c* of soft-tissue vibrations during landings from different drop heights (Figure 1).Specifically, the c of both the quadriceps femoris and hamstring muscles in CS was significantly higher than that in CC during landings at 60 cm height ($p < 0.05$). The c of the thigh muscles also increased with landing heights increasing from 30 cm to 60 cm (*p < 0.05*).

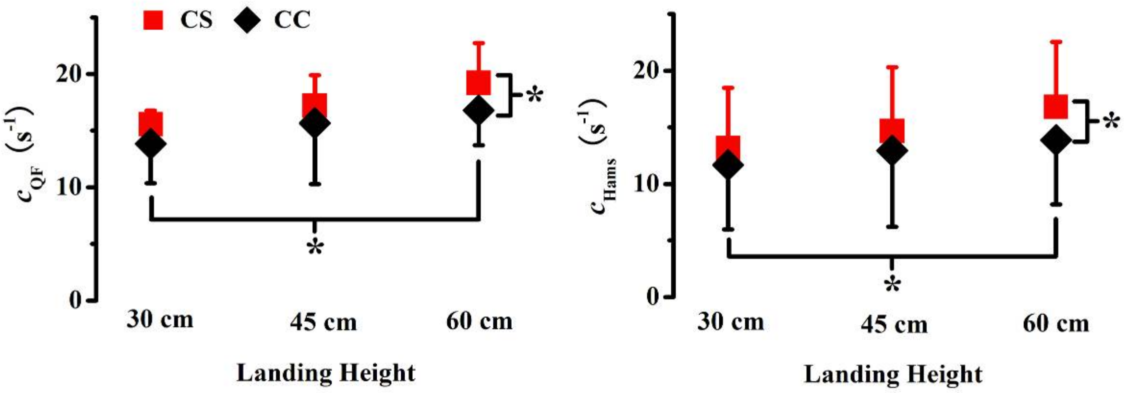

Figure 1: Influence of compression shorts (CS) on damping coefficient (c) of quadriceps (QF) and hamstrings (Hams) vibrations during landings at three different heights.

Muscular activity: The results showed a decrease in EMGRMS when wearing CS during landing (Figure 2).Post-hoc comparisons showed that the EMG_{RMS} of the RF with CS was significantly lower than that of the CC in both pre- and post-activation phases of DJ at all heights ($p < 0.05$). For the BF, a significant decrease in EMG_{RMS} was observed in CS compared with that in CC during post-activation phase of landing at 30 cm ($p < 0.05$).

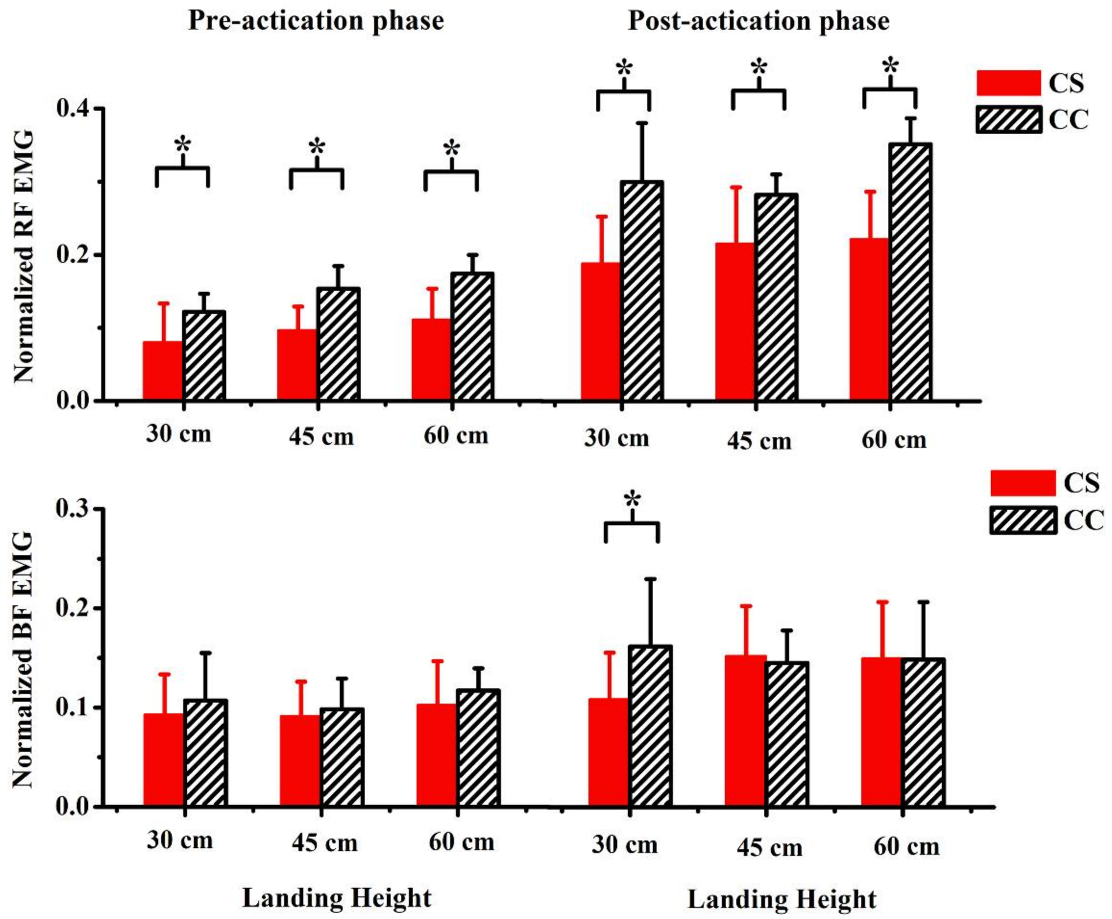

Figure 2: Influence of compression shorts (CS) on normalized EMG of rectus femoris (RF) and biceps femoris (BF) during pre- and post-activation phases of landings at three different heights.

DISCUSSION: To our knowledge, few studies have examined the relationship between partial damping of soft-tissue vibrations and reduction in muscle activity during jump landing. The current findings imply both the understanding of mechanisms modulating the active damping of vibrations and the energetics of soft-tissue vibrations. Although some data can explain the relation between soft-tissue vibrations and muscle activity during controlled experiments (Roelants, Verschueren, Delecluse, Levin, & Stijnen, 2006), little is known about this relation during complex activities, such as jump landing. The decrease in soft-tissue vibrations associated with decline in muscle activity during landings confirms that active damping of soft-tissue vibrations is also manifested during complex tasks involving such vibrations. Muscle activity can also be related to energy consumption, although no direct and unique relation exists (Praagman, Veeger, Chadwick, Colier, & van der Helm, 2003). Therefore, changes in muscle activity caused by or related to active damping presumably influence energy utilization positively. Consequently, the observed relation between partial soft-tissue vibration damping and muscle activity may represent a correlation between partial damping and muscle energy consumption.

CONCLUSION: Externally induced soft-tissue vibration damping was associated with a decrease in muscular activity of the rectus femoris and the biceps femoris muscles during drop-jump landing from different heights. A greater increase in the damping is associated with a greater decrease in muscle activity. Although no causal relationship between changes in damping and changes in muscle activity can be inferred, these findings contribute to further understanding and manipulation of parameters specific to landing and other activities involving soft-tissue vibrations.

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Acknowledgement

The authors would like to acknowledge supports for the study from the National Natural Science Foundation of China (11302131, 11372194), the Doctoral Fund of Ministry of Education of China (20123156120003), the Innovation Program of Shanghai Municipal Education Commission (14YZ125), and the Science and Technology Commission of Shanghai (14DZ1103500).