SOFT TISSUE COMPARTMENT RESPONSE TO AN UNEXPECTED SURFACE CHANGE.

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INTRODUCTION

During locomotion, the body adapts to changes in surface or shoe sole properties by changing the GRF, kinematics, joint stiffness and/or muscle activity [1,2,3]. It has been speculated that one reason for these changes may be to limit vibrations of the soft tissue [4]. The amplification of the skeletal acceleration (input) for soft tissue vibrations depends on the magnitude, length and shape of the input signal. Resonance will occur when the input frequency equals the natural frequency of a given soft tissue compartment (Fig 1.). It has been shown that accelerations of soft tissue compartments remain constant and that EMG pre-activation changes with changing loading rate, G_z [5] when the input frequency is close to the natural frequency of a soft tissue compartment. Maintaining a constant acceleration level is possible if (a) damping in the soft tissue compartment is increased to reduce the accelerations [4] or (b) lower extremity kinematics are altered to change the skeletal acceleration transient rate. However, for an unexpected change of the input signal the muscle pre-activation should remain constant while the acceleration level should change. Thus, the purpose of this study was to compare the soft tissue vibrations for an expected and an unexpected excitation signal near its resonance vibration frequency. It is expected that this study will increase the understanding of the function of muscle pre-activation and the potential adaptations to changes in surface stiffness during running. The hypotheses tested were:

H(1): Frequencies: f_{nat}(expected) ≈ f_{nat}(unexpected),
H(2): accelerations: a(expected) < a(unexpected/hard),
H(3): EMG(preHS): EMG(expected) ≈ EMG(unexpected)

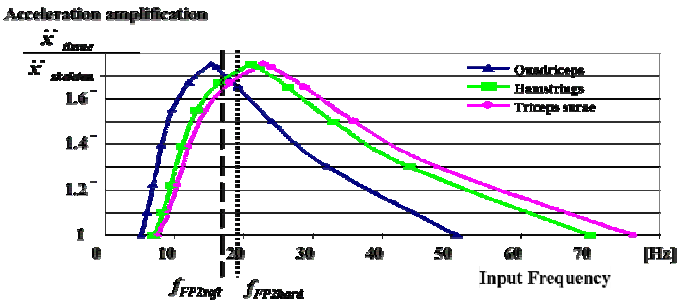

Figure 1: Theoretical response spectrum for the quadriceps, hamstrings and triceps surae soft tissue compartments, assuming a system with a simple mass and linear spring. Input is a versed sine pulse with magnitude and duration τ; thus f_{in}=1/(2*τ).

METHODS:

Fourteen male subjects ran at 4.8 +/- 0.2 m/s on a 24 m long runway instrumented with 3 consecutive force platforms (Kistler, Type Z4852/C) while soft tissue accelerations and muscle activity [5] were measured. Overlying the runway were two different flooring surfaces to change the input signal. To hide the location of the surface change a thin carpet was placed on top of the flooring. The surfaces were arranged in two different ways (Fig. 2). The experimental conditions were presented in a randomized block sequence, ABBAAB. Data was collected for the following steps of running: (Control condition) $FP1_{soft}$, $FP2_{soft}$, $FP3_{hard}$; (Test condition) $FP1_{soft}$, $FP2_{hard}$ (unexpected), $FP3_{hard}$ (expected).

Peak acceleration and the frequency power spectra were determined for each accelerometer signal. The EMG intensity was summed for a 50 ms window prior to heel-strike to determine the pre-activation EMG intensity. F_z, and G_z, were determined from the GRF data. The time of peak leg acceleration was estimated from the F_z and G_z maximums. Each subject was examined independently to determine the relationship between EMG, input signal and soft tissue accelerations. Paired t-tests and repeated measures ANOVA ($p<0.05$) were used to determine group differences between the expected and unexpected conditions.

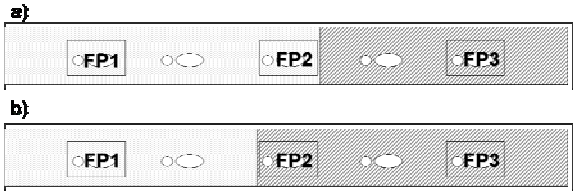

Figure 2: Experimental set-up. a) Control condition b) Test condition.
Surface 1: soft Surface 2: hard

RESULTS AND DISCUSSION:

(1) The natural frequencies of the soft tissue compartments were the same for the expected and the unexpected situation, indicating that the vibration characteristics have not been changed because the change was not expected.
(2) The soft tissue accelerations were typically higher for the unexpected than for the expected condition. They were highest when the input frequency was close to the natural frequency of a soft tissue compartment.
(3) The EMG intensities were the same for the expected and the unexpected situation since the subjects could not prepare.
(4) EMG and GRF showed no systematic changes for the third step, which suggests that the expectations and/or the applied strategies were different for the different subjects.
Specifically illustrated for subject P: The natural frequencies were estimated at 15.23 Hz, 20.95 Hz, and 22.85 Hz for the quadriceps, hamstrings and triceps surae, respectively. There was no change in the EMG pre-activation intensity between the unexpected (step $FP2_{hard}$) and the expected surface condition (step $FP2_{soft}$). There was an increase in the magnitude of the peak acceleration of 3%, 10% and 7% for the quadriceps, hamstrings and triceps surae. The input frequencies were estimate as 17.7 Hz for the soft expected and 19.0 Hz for the hard unexpected surface. As expected based on the theoretical response spectrum (Fig 1.) for a shift in the input frequency from 17.7 to 19 Hz the greatest increase in acceleration occurred in the hamstrings.

CONCLUSIONS

Increased soft tissue vibrations did occur when a runner experienced an unexpected impact with a frequency close to the natural frequency of a soft tissue compartment.

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