DIFFERENCES OF MUSCULOTENDINOUS STIFFNESS PRE AND POST-FATIGUE OF THE TRICEPS SURAE

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SUMMARY
The effect of fatigue in the MTU stiffness of the triceps surae was evaluated in 33 male subjects. Fatigue was induced by performing the standing heel-rise test until exhaustion. The stiffness of the triceps surae muscle-tendon unit (MTU) was assessed in vivo using a damped oscillation technique before and after fatigue was induced. The post-test (17541 N/m) measurement showed significant (P < 0.01) lower MTU stiffness than the pre-test (19406 N/m) due fatigue effects. These suggest that MTU stiffness decrease with fatigue which may contribute to increase the risk of ankle injuries.

INTRODUCTION
Clinical and sports biomechanists are frequently involved in the study of stiffness as it relates to both injury and performance. Muscle fatigue often occurs in sports and during daily tasks contributing to reduction of performance and to the risk of injury [1-3]. Furthermore, some studies indicated that a relationship between fatigue and stiffness may exist [4-7]. Therefore the purpose of this study was to investigate the muscle-tendon unit stiffness of the triceps surae pre and post fatigue.

METHODS
To assess muscle-tendon unit stiffness vertical ground reaction forces were measured with a Kistler force plate (Kistler 9281B; Kistler Instruments, Amherst, NY, USA) and the software BioWare 4.0 type 2812A (Kistler Instruments, Amherst, NY, USA). This force plate (sampling rate-1000 Hz) was used in conjunction with the equipment illustrated in Figure 1.

The maximal voluntary isometric contraction (MVIC) and free oscillation data was calculated from vertical ground reaction forces, in this order respectively. A damped oscillation technique was used to acquire free oscillation data and evaluate MTU stiffness of triceps surae “in vivo”. Free oscillation data was obtained using external pure gravitational mass equivalent to 30% of MVIC [8-12]. This load is representative of the level of muscle activation observed during gait activities which are associated with the ability to perform daily tasks independently [13]. With regard to the details of the methods for stiffness assessment more information can be found in the literature [11, 14, 15].

RESULTS AND DISCUSSION
Table 1 shows the descriptive statistics of age and anthropometric parameters.
Table 1: Subject characteristics

<table>
<thead>
<tr>
<th>Variables</th>
<th>Male Subjects (n = 33)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>20.7 ± 1.7</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.74 ± 0.06</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>66.6 ± 6.7</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>21.9 ± 1.6</td>
</tr>
</tbody>
</table>

Values are mean ± standard deviation

After checking normality with the Shapiro-Wilk test the paired sample t-tests for dependent variables were used to determine differences of MTU stiffness between the pre and post-test measurement (Table 2). Statistical significant differences were found between test groups.

Table 2: MTU stiffness between test groups

<table>
<thead>
<tr>
<th>Variable (N.m⁻¹)</th>
<th>Pre-test (n=33)</th>
<th>Post-test (n=33)</th>
<th>t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTU stiffness</td>
<td>19406 ± 3674</td>
<td>17541 ± 3748</td>
<td>.003*</td>
</tr>
</tbody>
</table>

Values are mean ± standard deviation
* Significant change from the Pre-test to the Post-test p<0.01

The purpose of this study was to investigate the muscle-tendon unit stiffness of the triceps surae pre and post fatigue. As can be seen in Table 2, significantly lower values of stiffness were found after fatigue of the triceps surae, induced during the heel-rise test. Previous studies have shown that fatigue [1-3, 6] and stiffness [4, 14, 18] relates to performance and the risk of injuries. Dutto and Smith [5] investigated stiffness characteristics of the leg change during a treadmill run to voluntary exhaustion. This study revealed significant decreases in both vertical and leg stiffness over the run. Considering that ankle stiffness play an important role in leg stiffness [19], this may explain the values obtained in the present study. Furthermore, Kuitunen et al [20] examined the acute and long-term fatigue effects of exhausting stretch-shortening cycle (SSC) exercise on the stiffness of ankle and knee joints. A significant decrease in ankle and knee joint stiffness was induced by the exercise. The authors attributed this reduction to the effects of both central (neural) and peripheral (metabolic) fatigue, while the prolonged impairment was associated to peripheral fatigue (muscle damage). The results of the present study appear to substantiate the previous studies mentioned since a significant decrease of the triceps surae MTU stiffness was found between pre and post fatigue tests. This reduction of MTU stiffness [4, 14] due to fatigue may contribute to increase the risk of injury.

CONCLUSIONS

The study of stiffness has been frequently developed as it relates to both injury and performance. Due to the effect of fatigue, the post-test measures showed significant lower MTU stiffness than the pre-test. These results suggest that (1) MTU stiffness decrease with fatigue and (2) this reduction may increase the risk of ankle injuries.

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REFERENCES