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EFFECT OF FATIGUE ON HAMSTRING REFLEX RESPONSES AND KNEE STABILITY IN MEN AND WOMEN

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SUMMARY

We investigated gender differences in hamstring reflex responses and posterior-anterior tibial translation (TT) before and after fatiguing exercise. We assessed the isolated movement of the tibia relative to the femur in the sagittal plane as a consequence of mechanically induced TT in standing subjects. The muscle activity of the hamstrings was evaluated. After fatigue, reflex onset latencies were enhanced in women. A reduction of reflex responses associated with an increased TT was observed in females. Men showed no differences in these parameters. The results of the present study revealed that the fatigue protocol altered the latency and magnitude of reflex responses of the hamstrings as well as TT in women. These changes were not found in men. Based on our results, it is conceivable that the fatigue-induced decrease in neuromuscular function with a corresponding increase in TT probably contributes to the higher incidence of ACL injuries in women.

INTRODUCTION

Anterior cruciate ligament (ACL) rupture ranks among the most common injuries in sports. The incidence of ACL injuries is considerably higher in females than in males and the underlying mechanisms are still under debate [1].
Furthermore, it has been suggested that muscle fatigue can be a risk factor for ACL injuries [2]. Epidemiological data suggest that injury rates tend to be higher at the end of matches [3], suggesting fatigue could be related to injury. Therefore, fatigue may play an important role in the pathomechanics of knee joint injuries.
The purpose of the present study was to analyze gender differences in hamstring reflex responses and TT before and after a fatigue protocol. We assessed the isolated movement of the tibia relative to the femur in the sagittal plane as a consequence of mechanically induced TT in standing subjects. The muscle activity of the lateral and medial hamstrings was evaluated. It was hypothesized that, due to fatigue, reflex components of the muscles are impaired and TT is altered.

METHODS

Fifty healthy subjects (25 males / 25 females) with no history of neurological disorders or injuries participated. During the experiment, participants were examined with regard to reflex responses and TT before and after a fatiguing jumping task. The measurements were performed using a knee arthrometer (Figure 1).

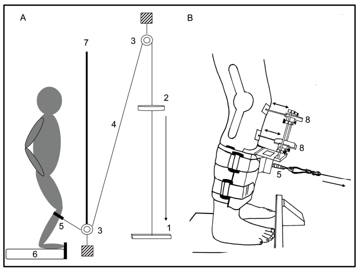

Figure 1: Schematic drawing of the experimental setup. A: Experimental setup, B: Measurement system | 1: stopper, 2: falling weight, 3: pulley, 4: steel rope, 5: force transducer, 6: force plate, 7: visual cover, 8: linear potentiometer. Arrows indicate the direction of the force. Posterior-anterior tibial translation was assessed by two linear potentiometers (8) placed on the patella and the tibial tuberosity. A force transducer (5) was used to measure the force transmitted to the shank.

Participants were examined in bipedal stance with the knees in 30° flexion (0° = full extension). A standardized force was applied to the proximal shank of the dominant leg using a pulley system in order to induce TT. A device was attached to the tibia to secure two linear potentiometers (Type CLR13-50, Megatron, Germany) placed on the patella and the tibial tuberosity (Figure 1). The knee arthrometer enabled us to measure the translational movement of the tibia relative to the femur in the sagittal plane. The TT was elicited 15 times in order to familiarize with the measurement. Thereafter, further 15 perturbations were applied before and immediately after the fatigue protocol. EMG signals were recorded from biceps femoris (BF) and semitendinosus / semimembranosus (ST) of the dominant leg. Maximum TT was determined based on the TT curves. The EMG signals of each subject were averaged. Reflex activity was calculated over different time intervals relative to the onset of TT, i.e. 20-40, 40-60 and 60-95 ms, using the root mean square of the EMG signal (RMS-EMG). Fatigue was induced by repetitive jumping performed between ~90° and 0° knee flexion (0° = full extension). The fatigue protocol consisted of consecutive maximal countermovement jumps, each one separated by 4 s. The jumps were performed until the subjects reached a fatigued state defined as the inability to reach 50% of their maximal jump height for 3 consecutive jumps or until the subjects reached an intolerable state of dyspnea or exhaustion. Data were checked for normal distribution. Differences between the values were tested for significance by repeated measures ANOVA.

RESULTS AND DISCUSSION

During the fatiguing exercise, men performed 159.8 ± 90.9 and women 150.6 ± 62.4 jumps. TT increased significantly after the fatigue protocol in females ($P = 0.002$) (Figure 2). Reflex onset latencies of BF and ST were significantly delayed in women at post. BF muscle activity decreased after fatigue in women in the time intervals 20-40 ms ($P = 0.035$) and 40-60 ms ($P = 0.013$). Reflex activity of ST was significantly reduced after fatigue between 20-40 ms in women ($P = 0.029$) (Figure 3). TT did not change following the fatigue protocol in males (Figure 2). No statistical differences in the reflex responses of BF and ST between 20-40 ms, 40-60 ms and 60-95 ms were observed in men.

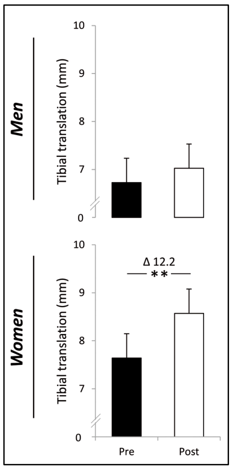

Figure 2: Effect of fatigue on tibial translation. Data are displayed as means ± standard error of the mean. * denotes a significant difference to pre-measurement, $^{**}P \leq 0.01$.

It has been assumed that increased joint laxity may contribute to increased ACL injury risk [4]. Kvist et al. [5] have compared males and females after fatiguing exercise and found an increase in TT for men. Nevertheless, these studies measured anterior knee laxity while subjects were relaxed. In contrast, in the current study TT was measured in a functional weight-bearing situation. In a situation such as this, axial loading and forces due to muscle contraction could reduce rotation and translation compared to the passive condition [6]. The present study found an increase in TT in women but not in men after the fatiguing exercise.

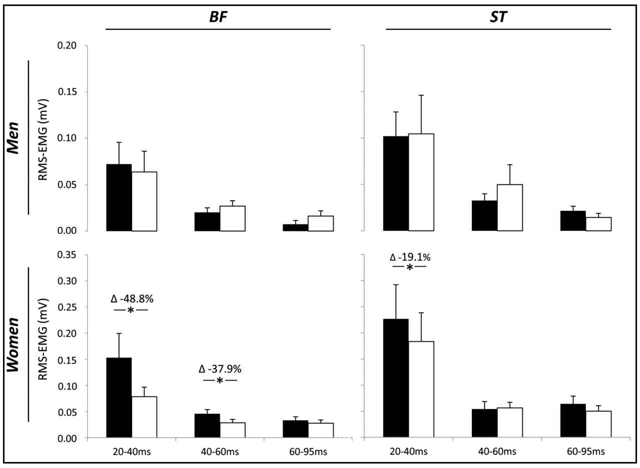

Figure 3: Effect of fatigue on reflex responses. BF: biceps femoris, ST: semitendinosus/semimembranosus. Data are displayed as means ± standard error of the mean. * denotes a significant difference to pre-measurement, $^{*}P \leq 0.05$.

The fast activation of muscles by means of reflexes may play a substantial role in the stabilization of the knee joint [7]. In the current study, delayed reflex onset latencies for BF and ST were found in women after the fatigue protocol. The onset latencies for BF and ST in men were not statistically different after fatigue. Furthermore, the reflex response of the females was significantly reduced in BF for the time intervals 20-40 and 40-60 ms. The same was true for ST from 20-40 ms. The results of the present study correspond with the results of Melnyk and Gollhofer [8] who have found significantly decreased iEMG values for the short latency response and medium latency response of the hamstring stretch reflex after an isokinetic concentric-eccentric fatigue protocol. However, gender-specific differences were not investigated. Moore et al. [9] have investigated vastus lateralis reflex activity induced by a standardized tendon tap with a spring-loaded reflex hammer before and after fatiguing isokinetic contractions. The authors reported a significant increase in reflex amplitude in men and a tendency to a reduction in women. They concluded that males and females might respond differently to fatigue. A reason for this could be that men and women activate their muscles differently according to the requirements of the movement task. For example, Rozzi et al. [10] have observed that women show greater muscle activity of the lateral hamstring muscle when landing from a jump and possess increased knee joint laxity as well as longer time to detect knee joint motion compared with men. The authors concluded that the greater EMG peak amplitude and area in women might be an attempt of the nervous system to compensate for the greater joint laxity and proprioceptive deficit. Furthermore, the authors argued that an interruption of this compensatory mechanism, for example due to fatigue, might increase joint laxity that may cause ligament injury. The greater muscle activity of the hamstrings when landing from a jump in females may be an explanation for the differing results in the present study between men and women regarding reflex responses and TT. It is conceivable that the fatigue protocol used in this study, which consisted of repetitive jumps performed until exhaustion, induced more fatigue in the hamstring muscles of women and therefore impaired hamstring reflex responses.

CONCLUSIONS

Based on our results it is conceivable that the fatigue-induced decrease in neuromuscular function with a corresponding increase in TT probably contributes to the higher incidence of ACL injuries in women.

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