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INFLUENCE OF FATIGUE ON THE AMPLITUDE AND LATENCY OF THE PERONEUS LONGUS AND TIBIALIS ANTERIOR MUSCLES ON SUDDEN ANKLE INVERSION

Alex Sandra Oliveira de Cerqueira[1,2], Juliana de Souza[2], Bruno Mezêncio[2], Jaqueline Esterque[2], Alberto Carlos Amadio[2], Júlio Cerca Serrão[2]
[1]Physical Therapy Department of Universidade de Taubaté (UNITAU), [2]School of Physical Education and Sport of Universidade de São Paulo (USP)
email: lesoares@usp.br

SUMMARY
The reduction in feedback from the neuromuscular system due to fatigue is among the factors that can interfere in joint stability. The present study aims to analyze the influence of fatigue on muscle reflex response during a sudden ankle inversion. Eighteen futsal athletes were divided into unstable ankle group (UG, n=9) and stable ankle group (SG, n=9) and submitted to a series of exercises to induce fatigue. Before and after the experiment, the EMG signal of the tibialis anterior and the peroneus longus muscles was analyzed during an unexpected sudden ankle inversion of 30^o imposed by an ankle inversion platform. In the UG, there was a reduction in the EMG signal of the tibialis anterior and the peroneus longus after fatigue, and there was premature activation of the peroneus longus. The SG was less affected and showed only reduced amplitude in the tibialis anterior. The reduction in the magnitude of the activity of the peroneus longus may be associated with recurrent sprains, episodes of giving way, and intensified joint instability.

Keywords: Fatigue, EMG, ankle sprain

INTRODUCTION
The high rate of ankle sprains in the final moments of a sports match suggests that fatigue is a predisposing factor for injury [1]. The study of the influence of fatigue on muscle reflex response through functional protocols that include intensive exercise to exhaustion can offer relevant information related to changes that occur during real training and competition [2]. Therefore, with the aim of understanding the effects of fatigue on ankle joint stability, the present study proposes to analyze the influence of fatigue on muscle reflex response after a sudden ankle inversion.

METHODS
The study was approved by the Research Ethics Committee of the School of Physical Education and Sport of Universidade de São Paulo (protocol n.: 133.682). Eighteen athletes of the futsal team of this university took part in the study and were divided into two groups according to the condition of the ankle to be tested: unstable group [UG, n=9 (22.6±2.2 years, 59.4±6.3 kg, 1.66±0.05 m)] and stable group [SG, n=9 (23.4±1.9 years; 66.4±9.3 kg; 1.60±0.05 m]. To be included in the study, the athlete had to be female, 18 to 30 years of age, and a futsal player for at least 3 years. The exclusion criteria were: fracture and/or surgery in the lower limbs in the past 6 months and acute sprain/pain at the time of the experiment. Athletes with a history of inversion sprain resulting in pain, edema, and abnormal gait followed by recurrent sprains, giving-way episodes, and perceived ankle instability for at least 1 year and who had a score ≤27 in the Cumberland Ankle Instability Tool (CAIT) [3] were classified as UG and the remaining athletes as SG. The CAIT score in the UG (20.2±4.4) was lower than in the SG [28.3±1.4 ($p<0.001$)]. To simulate the sudden ankle inversion, we used a platform composed of two moving rectangular boards mounted on a base and supported at the end by two axles for inversion movement (range of 30º). The raw EMG signal was recorded (EMG 1000 - Lynx) using differential amplification (amplified 50x at 16-bit resolution and band-pass filtered between 20 and 450 Hz, CMRR >100dB, sample frequency 2 kHz). Bipolar, active surface electrodes (Ag/AgCl, 20mm inter-electrode distance, amplified 20x) were placed on the peroneus longus and the tibialis anterior according SENIAM rules after the skin was shaved and cleansed with alcohol.

The experiment began with a familiarization with the sprain simulation, followed by recording of the EMG signal during 10 random falls, 5 trials with the left foot, and 5 with the right, before the fatigue induction protocol. The participants then performed the protocol 5 times to become familiar with the sequence, circuit, and movements. After a rest period, fatigue induction began. The fatigue protocol was divided into three stages: a) sprint with change in direction, b) vertical jump, and c) lateral shuffling. In stage a, the athletes had to sprint forward, sprint back and sprint forward again (5m), turn 45º to the right and sprint for 3.2m, after turn again and run backwards for 4m, then turn for the last time to right and run sideways 3.2 m to the starting point (Figure 1a). Next, they immediately started a new series, this time making left turns. Two full runs were completed in stage a. After that, the athletes proceeded to stage b, which consisted of 10 vertical jumps with both feet over a 10-cm obstacle at the sound of a metronome every 2 seconds (Figure 1b). Finally, in stage c, the athletes did lateral shuffling for 4m 3 times consecutively (Figure 1c). After completing the entire protocol, the participants rated their perceived exertion (Borg Scale) and repeated the protocol. The term fatigue is defined as the inability to produce or maintain a certain level of muscle strength or power during exercise [4]. Thus, when the time taken to perform stage a (sprint) was greater than 50% of the initial time (fatigue threshold), timed during the first run, the induction was suspended. When they reached the threshold, the participants immediately stepped on the platform for EMG recording in the simulations.

For data processing (Matlab2009b), the raw EMG was low-pass filtered (4th order Butterworth 30 Hz), and the data amplitude normalized in relation to its mean. We studied the latency and the amplitude of the signal. Latency was defined as the moment in which the signal was >3 SD + mean from baseline (400 to 200ms pre-fall). The amplitude was studied using analysis of the Root Mean Square (RMS) 50ms pre-fall, RMS 50ms post, and RMS 150ms post. Non-parametric statistics were used as normal distribution and equal variance verified by the Kolmogorov-Smirnov test and homoscedasticity by the Levene test did not hold. We compared the pre and post results of each group using the Mann-Whitney test and, if necessary, Tukey's post-hoc test (SigmaStat 3.5, significance level $p<0.05$). The descriptive analysis is shown as [median (1^{st} quartile/3^{rd} quartile)].

RESULTS

In both groups, the number of completed runs [UG, 16 (12.8/23); SG, 23 (20.8/25) p=0.7], performance times [UG, 27s (26/28); SG, 27s (26/28) p=0.9], and perceived exertion on the first run [UG, 15 (11/15); SG, 13 (11/13) p=0.20] were similar. Both groups showed a rapid increase in perceived exertion. After only 30% of the test, the mode was at 20 and remained there until the end of the protocol. After fatigue in the SG, the tibialis anterior had reduced RMS_pre_50ms (p=0.047) and RMS_post_150ms (p=0.043). In the UG, the tibialis anterior showed reduced RMS_pre_50ms (p=0.043), RMS_fall_50ms (p=0.022), and RMS_post_150ms (p=0.027) and the peroneus longus showed reduced RMS_fall_50ms (p=<0.001), RMS_post_150 (p=<0.001), and latency (p=0.036).

DISCUSSION

The condition of the ankle influenced the manifestations caused by fatigue. The reduction in signal amplitude indicated by the lower RMS values after induction can be considered a response to fatigue. However, taking into account that stability is restored by the peroneus longus, the result found only in the unstable ankles suggests that the reduction in amplitude of peroneus longus muscle were due to the chronic ankle instability. This can be considered a factor that predisposes athletes with chronic ankle instability to injury.

CONCLUSIONS

Fatigue reduced the amplitude of the tibialis anterior and the peroneus longus during a sudden ankle inversion in athletes with chronic instability. To compensate, the peroneus longus activated prematurely. In the athletes with stable ankles, only the tibialis anterior showed similar behavior.

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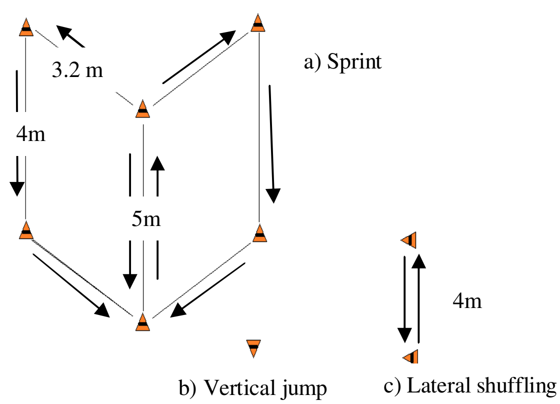

Figure 1 - Illustration of the protocol used to induce fatigue a) sprints, b) vertical jump and c) lateral shuffling.

Table 1: Descriptive analysis [median (1st quartile/3rd quartile)] and comparisons among the selected variables of the tibialis anterior and peroneus longus before and after fatigue in the stable group (SG) and the unstable group (UG). **(p<0.05)**

		Tibialis anterior				**Peroneus longus**			
		SG		**UG**		**SG**		**UG**	
		Before	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
Latency	**Median**	-24	-59	-28	-29	-91	-92	**-53**	**-128**
	$1^{st}/3^{rd}$ Quartile	-87/-17	-83/-29	(-61/-23)	(-84/-17)	-123/-20	-126/-19	**-133/-22**	**-149/-74**
RMS_pre_50ms	**Median**	**6.1**	**4**	**6**	**3.5**	7.1	9.8	6.5	5.8
	$1^{st}/3^{rd}$ Quartile	**4.1-6.9**	**3/5.4**	**(3-7.2)**	**(2.7-5.5)**	4.9/13.7	6.5/16.4	5.2/9.3	4.4/7.8
RMS_fall_50ms	**Median**	31.1	15.4	**18.8**	**11**	24.4	26.2	**27.4**	**11.1**
	$1^{st}/3^{rd}$ Quartile	11.4/40.8	7.8/26	**(9.2-37.8)**	**(4.1-19.6)**	15.2/35.7	12.8/33.3	**10/35.4**	**5.2/14.4**
RMS_post_150ms	**Median**	**69.1**	**45.6**	**96.4**	**63.4**	93.8	54.2	**117.6**	**46.7**
	$1^{st}/3^{rd}$ Quartile	**35.9-147.9**	**27.8-78.3**	**(61.9-139.8)**	**(40.4-88.6)**	41.5/133.9	34.8/105.4	**52/136.7**	**40.5/60.4**