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original article

Electromyographic reaction time in older female fallers and non-fallers after postural perturbation

Tempo de reação eletromiográfica em idosas caidoras e não-caidoras após desequilíbrio postural

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Abstract – The electromyographic reaction time (ERT) reflects the magnitude and speed with which muscles are activated to perform movements, to prevent injuries, or to position a joint. This parameter can be used to analyze postural control performance after an external perturbation and can be correlated with the possibility of falls in older adults. The objective of this study was to determine the ERT of the internal oblique, rectus femoris, vastus lateralis, tibialis anterior, multifidus, gluteus maximus, biceps femoris, and lateral gastrocnemius muscles to balance threats in older adults with and without a history of falls. Twenty-nine physically active and noninstitutionalized women aged 60 years or older were divided into two groups: fallers (n=13; 72.4 ± 8.0 years) and non-fallers (n=16; 67.8 ± 6.8 years). The ERT of the muscles tested did not differ significantly between groups following forward or backward perturbations. The results suggest that the activation of the muscles tested in response to forward or backward perturbations is not a determinant factor of falls

Key words: Aging; Electromyography; Postural balance.

Resumo – *O tempo de reação eletromiográfica (TRE) reflete a magnitude e a velocidade com que os músculos são ativados para realizar movimentos, evitar lesões ou posicionar uma articulação e pode ser avaliado após uma perturbação externa para análise do desempenho do controle postural e relacioná-lo com a possibilidade de quedas em idosos. O objetivo do estudo foi verificar o TRE dos músculos oblíquo interno (OI), reto femoral (RF), vasto lateral (VL), tibial anterior (TA), multífido (MU), glúteo máximo (GM), bíceps femoral (BF) e gastrocnêmio lateral (GL) em situações de perturbação do equilíbrio em idosos com e sem histórico de quedas. Para isso, foram avaliadas vinte e nove mulheres com 60 anos ou mais, fisicamente ativas e não-institucionalizadas e separadas em dois grupos de acordo com o relato de quedas nos 12 meses pregressos ao estudo: Grupo de Idosas Caidoras (GIC) (n=13; 72,4 ± 8,0 anos) e Grupo de Idosas Não-Caidoras (GINC) (n=16; 67,8 ± 6,8 anos). O TRE dos músculos avaliados durante o teste de desequilíbrio postural anterior e posterior não foram significativamente diferentes entre os grupos. Os resultados sugerem que a ativação muscular dos músculos avaliados, tanto durante o desequilíbrio anterior quanto no desequilíbrio posterior, não podem ser considerados um fator determinante para quedas.*

Palavras-chave: *Eletromiografia; Envelhecimento; Equilíbrio postural.*

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INTRODUCTION

A fall is an unintentional change in body position to a lower level that cannot be corrected in a timely manner[1,2]. The incidence of falls increases with age and is higher among women[3].

One of the responses of muscles to aging is a reduction in the internal moment of force, i.e., a decrease in the sum of forces generated by passive and active internal structures that counterbalance the sum of external moments acting in the body, thus generating movement[4]. Comparison of elderly fallers and non-fallers has shown lower internal hip extension and internal ankle dorsiflexion and plantar flexion moments in the former compared to older adults without a history of falls[5,6].

One approach to the evaluation of postural control performance is to analyze the ability of the individual to respond to external perturbations. It is expected that older adults present greater center of pressure and center of mass displacements[7,8] and take longer to activate the necessary musculature to revert these displacements, i.e., they present a greater electromyographic reaction time (ERT)[9]. This parameter can be defined as the magnitude and speed with which muscles are activated to perform movements, to prevent injuries, or to position a joint[10], or even as the elapsed time between the occurrence of the perturbation and muscle activation in a postural perturbation test[11].

Comparison of older and young adults reveals that aging is responsible for an increase in the ERT to reflex responses as well as for a reduction in proprioception, events that directly affect balance and postural control[12,13]. One study showed that women have a significantly longer ERT of the vastus medialis muscle than men during down stair climbing[14].

Considering the hypothesis that female fallers are likely to present a greater ERT, the objective of the present study was to determine the ERT of the internal oblique (IO), rectus femoris (RF), vastus lateralis (VL), tibialis anterior (TA), multifidus, gluteus maximus (GM), biceps femoris (BF), and lateral gastrocnemius (LG) muscles to balance threats in older women with and without a history of falls.

METHODOLOGICAL PROCEDURES

Participants

Twenty-nine physically active and noninstitutionalized female volunteers aged 60 years or older were divided into two groups: older female fallers (n=13) and older female non-fallers (n=16). Fallers were classified according to the history of falls in the last 12 months[15]. The characteristics of the sample are shown in Table 1.

Included in the study were women who reported no pain, fracture of severe soft tissue injury in the last 6 months prior to the study and who had no neurological, cardiovascular or respiratory disorders[16] that would impair participation in the test proposed. Women who reported dizziness or discomfort during the tests were excluded. Another exclusion criterion was a score in the Mini-Mental State Examination (MMSE) lower than the education-adjusted cut-off[17].

The Berg Balance Scale (BBS) was applied to characterize the participants regarding the risk of falls. The study was approved by the local Ethics Committee and all participants signed the free informed consent form.

Instruments

A 16-channel biological signal-acquisition module for telemetry and the Myoresearch 1.07 software (Noraxon®) were used for recording of the electromyographic signal during the tests. For the balance tests, a triaxial InLine 3D accelerometer (Noraxon®) and load cell (Noraxon®), both synchronized to the electromyographic data, were used.

The electromyographic data were acquired using bipolar Ag/AgCl surface electrodes (Meditrace®) measuring 1 cm diameter, with an interelectrode distance of 2 cm. Before placing the electrodes, the skin was shaved and cleaned with alcohol to prevent possible interferences with the electromyographic signal.

The electrodes were placed on the dominant side of the volunteer over the IO, RF, VL, TA, GM, BF and GL muscles according to SENIAM recommendations[19]. Electrodes were also placed over the multifidus muscle[20]. For determination of the dominant side, a ball was positioned in front of the woman was asked to kick the ball forward for three consecutive times. The side used at least twice was defined as the dominant side[21].

The electromyographic signals were processed and analyzed using specific algorithms developed in MatLab 7.0®. The signals were sampled at a rate of 2000 Hz, amplified with a total gain of 2000 times (20 times in the sensor and 100 times in the equipment), and band-pass filtered between 20 and 500 Hz using a Butterworth digital filter (2nd order for high pass and 4th order for low pass). The data were full-wave rectified for the creation of a linear envelope within a window of 200 ms.

The ERT was calculated by the cross-correlation method which considers the point of highest correlation (r value) between the curve of the products of two signals at the time of muscle activation[11,22]. Thus, the signals obtained from the displacement of the accelerometer and EMG activity of the muscles analyzed were used to calculate these correlations.

Procedures

The procedures were shown and repeated until the volunteer understood what was asked of her. At the time of the perturbation, the participant was allowed to take one step forward, if necessary.

The volunteers remained in the static standing position and, with the help of visual feedback, pulled forward the load cell attached to the trunk at 10% of their body weight. The visual feedback was provided by a computer which showed the force that was being performed and the line representing the expected force. At a random time, when the volunteer was able to stably maintain the expected force, the cable attached to the load cell was released so that the perturbation would occur. This procedure was performed in such a way as to cause perturbations in the forward and backward directions in a random manner for each volunteer, with three consecutive perturbations in each direction.

The time of forward and backward perturbations was synchronized with the electromyographic signals through the InLine Force Sensor 500 LB-F/2200N (Noraxon®) and triaxial accelerometer (Noraxon®) attached to the trunk of the volunteer.

Statistical analysis

The Shapiro-Wilk test was applied to determine whether the data showed a normal distribution. Normally distributed data were compared between groups by the *t*-test for independent samples and non-normally distributed data by the Mann-Whitney test. A level of significance of $p \leq 0.05$ was adopted.

RESULTS

Table 1 shows the age, body weight, height, and MMSE and BBS scores obtained.

Table 1. Characteristics of older female fallers and non-fallers

	OFF (n=13)	OFNF (n=16)
Age (years)	72.4 ± 8.0	67.8 ± 6.8
Body weight (kg)	69.3 ± 11.3	70.1 ± 15.0
Height (m)	1.52 ± 0.04	1.55 ± 0.06
Number of medications	2.8 ± 1.4	2.2 ± 1.4
BBS (score)	53.0 ± 2.6	54.8 ± 1.6
MMSE (score)	26.3 ± 3.4	27.0 ± 2.1

The results are reported as the mean ± standard deviation. OFF: older female fallers; OFNF: older female non-fallers; BBS: Berg Balance Scale; MMSE: Mini-Mental State Examination.

No significant differences in age, body weight, height or BBS and MMSE scores were observed between the two groups. Older female fallers reported an average of 1.6 falls in the last 12 months. There was no significant difference in the ERT results between older female fallers and non-fallers in the perturbation test with the load cell. These results are illustrated in Figures 1, 2, 3, and 4.

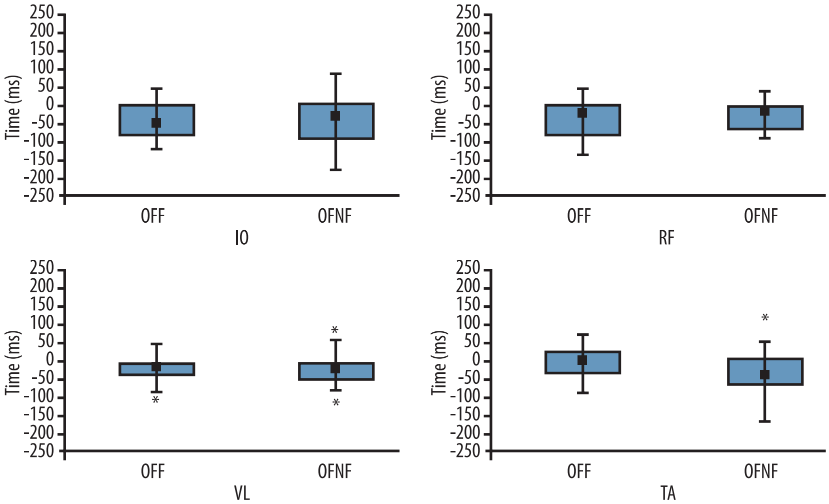

Figure 1. Anterior muscle activation following forward perturbation with a load cell. OFF: older female fallers; OFNF: older female non-fallers; IO: internal oblique; RF: rectus femoris; VL: vastus lateralis; TA: tibialis anterior; ■: median; ж: outliers.

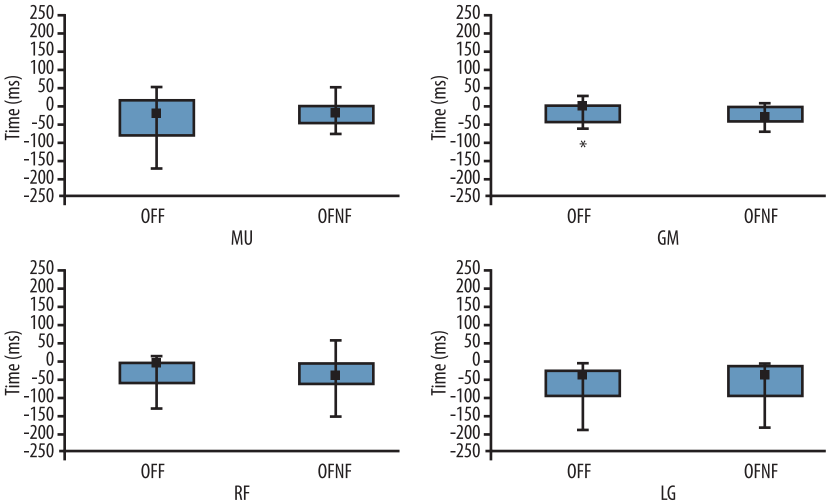

Figure 2. Posterior muscle activation following forward perturbation with a load cell. OFF: older female fallers; OFNF: older female non-fallers; MU: multifidus; GM: gluteus maximus; BF: biceps femoris; LG: lateral gastrocnemius; ■: median; ж: outliers.

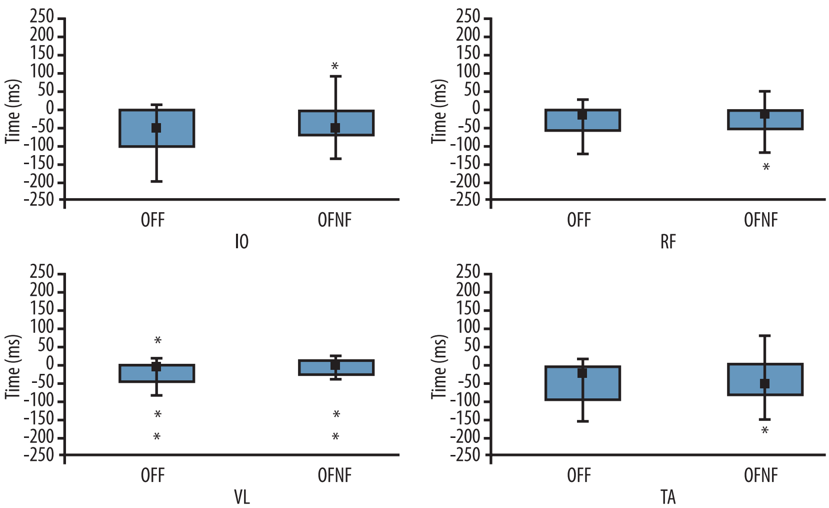

Figure 3. Anterior muscle activation following backward perturbation with a load cell. OFF: older female fallers; OFNF: older female non-fallers; IO: internal oblique; RF: rectus femoris; VL: vastus lateralis; TA: tibialis anterior; ■: median; ж: outliers.

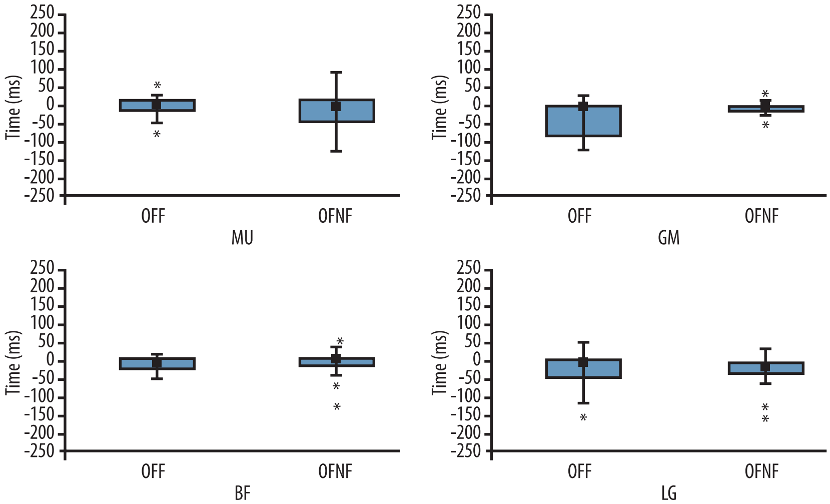

Figure 4. Posterior muscle activation following backward perturbation with a load cell. OFF: older female fallers; OFNF: older female non-fallers; MU: multifidus; GM: gluteus maximus; BF: biceps femoris; LG: lateral gastrocnemius; ■: median; ж: outliers.

DISCUSSION

The objective of this study was to compare ERT to postural perturbations between physically active older female fallers and non-fallers. The hypothesis was that, even when active, older fallers would present compensatory or delayed mechanisms of muscle activation compared to older adults without a history of falls. The understanding of these mechanisms could provide important information about predictors of falls, permitting the development of strategies for the prevention of falls and for rehabilitation.

Previous studies have shown greater ERT of the TA muscle in older fallers compared to older non-fallers[23], and lower ERT in response to postural perturbations in stable older adults compared to unstable ones[9].

During movement, the first component of the neuromuscular response is the short latency, which is mediated mainly by the muscle spindle. Changes in muscle spindle sensitivity can alter the neuromuscular reaction time and short-latency response, causing pain and injuries[10].

The latency of muscle activation in response to balance threats tends to increase after the age of 40, becoming more pronounced at older ages[9]. When submitted to an external perturbation, older adults take longer to activate the necessary musculature to reverse this displacement, indicating a lack of efficacy to respond to unexpected perturbations; these individuals are therefore more susceptible to falls[9].

Toledo and Barela[24] compared the mean activation latencies of the TA muscle between older and young adults. The authors observed that the onset of muscle activation following support surface perturbations occurs on average 20 ms later in older adults compared to young adults. A delay in the activation of the gastrocnemius muscle in response to balance perturbation has also been observed in older adults when compared to a group of young adults[25].

On the basis of these studies, it would be expected that older adults with a history of falls present slower muscle activation in response to a perturbation. However, the present results showed no significant difference in the ERT of the muscle studied (IO, RF, VL, TA, multifidus, GM, BF and GL) to forward or backward perturbation between older fallers and non-fallers. As can be seen in the figures, the distribution of the results obtained for the two groups was similar, showing that The ERT of the muscle analyzed did not depend on the presence or absence of a history of falls.

Studies comparing the neuromuscular responses between older fallers and non-fallers reported no significant difference in temporal muscle activation of knee flexors and extensors, dorsiflexors, or plantar flexors[26,27], in agreement with the present findings. Kirkwood et al.[28], comparing older women with and without a history or recurrent falls during gait, observed no significant difference in the latency of the gastrocnemius, soleus or TA muscle, with the two groups exhibiting similar characteristics.

In the present study, the older women of the two groups maintained a similar stability strategy, a finding that can be explained by the similar characteristics of the groups mainly in terms of the level of physical activity, or by the possible fear of falls due to the previous knowledge of perturbations. According to the literature, regular physical exercise improves postural responses, shortening ERT[29,30]. The question is whether this reduction also occurs in older adults with a history of falls.

However, we found no studies in the literature evaluating hip, knee and ankle flexors/extensors in physically active older fallers and non-fallers that could be compared with the present results. A limitation of this study is the homogeneity of the groups studied.

CONCLUSIONS

The present results led us to conclude that the ERT of the muscles tested in response to forward or backward perturbations is not a determinant factor of falls in physically active older adults.

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