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Electromyographic patterns of lower limb muscles during apprehensive gait in younger and older female adults

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ABSTRACT

Objective: Investigate the influence of apprehensive gait on activation and cocontraction of lower limb muscles of younger and older female adults.
Methods: Data of 17 younger (21.47 ± 2.06 yr) and 18 older women (65.33 ± 3.14 yr) were considered for this study. Participants walked on the treadmill at two different conditions: normal gait and apprehensive gait. The surface electromyographic signals (EMG) were recorded during both conditions on: rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM), biceps femoris (BF), tibialis anterior (TA), gastrocnemius lateralis (GL), and soleus (SO).
Results: Apprehensive gait promoted greater activation of thigh muscles than normal gait ($F = 5.34$ and $p = 0.007$, for significant main effect of condition; RF, $p = 0.002$; VM, $p < 0.001$; VL, $p = 0.003$; and BF, $p = 0.001$). Older adults had greater cocontraction of knee and ankle stabilizer muscles than younger women ($F = 4.05$ and $p = 0.019$, for significant main effect of groups; VM/BF, $p = 0.010$; TA/GL, $p = 0.007$; and TA/SO, $p = 0.002$).
Conclusion: Apprehensive gait promoted greater activation of thigh muscles and older adults had greater cocontraction of knee and ankle stabilizer muscles. Thus, apprehensive gait may leads to increased percentage of neuromuscular capacity, which is associated with greater cocontraction and contribute to the onset of fatigue and increased risk of falling in older people.

1. Introduction

Falls are common in older adults and can decrease quality of life, physical function, and are the major cause of injury and death in this population (Freiberger et al., 2007; Van Dieen and Pijnappels, 2008). About 27% of older non-faller adults and 50% of older faller adults have fear of falling (Chamberlin et al., 2005). The occurrence of a fall increases fear of falling, which can lead to events that further increase the risk of future falls, such as decreased mobility resulting in muscle weakness, contracture, postural hypotension, and thrombogenic events (Ersoy et al., 2009). However, the neuromuscular mechanism resulting in increased risk of falls due to fear of falling is poorly understood, but it might be related with changes in muscle activity and agonist/antagonist cocontraction patterns (Vellas et al., 2001).

The ability to walk efficiently and safely is important to maintain independence and reduce the risk of falls in older adults (Odasso et al., 2005; Callisaya et al., 2010). However, during walking high levels of attention and cognitive resources to assess, plan and execute this task are required (Van Dieen and Pijnappels, 2008; Bridenbaugh and Kressig, 2011). When gait is performed concomitantly with another cognitive activity, such as apprehensive gait, performance of both tasks can be impaired (Van Dieen and Pijnappels, 2008).

Dual-task gait might increase risk of falls because the strength, attention, and balance capabilities may be compromised by the external stimuli (e.g. traffic lights and noises) or internal (e.g. apprehension and fear) factors (Beauchet et al., 2005; Hahn et al., 2005). Several studies showed that older adults have reduced walking speed and increased kinematic parameters variability than younger adults during dual task gait (Brach et al., 2010; Perry et al., 2010; Taylor et al., 2013). However, only few studies investigated muscle activation during dual task gait (Abbud et al., 2009; Hegeman et al., 2012). According to Abbud et al. (2009) when young subjects were performing a cognitive dual task gait (subtracting numbers), thigh and shank muscles activation were reduced. However, Hegeman et al. (2012) did not found significant differences on biceps femoris activation

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between prior, during and after a motor dual task gait (obstacle avoidance) in older adults.

Cocontraction is considered a strategy to maintain stability; however, this is not necessarily an effective compensatory response (Cenciarini et al., 2010). Ishida et al. (2008) reported that older adults use cocontraction to overcome loss of sensory and motor functions. It is likely that increased cocontraction is effective for slow perturbations but not when rapid adjustments are required, such as immediately after tripping (Cenciarini et al., 2010). In addition, increased cocontraction in older adults might be related with increased cost of walking (Hortobágyi et al., 2009; Marques et al., in press a,b). Thus, increased cost of walking in older adults can cause fatigue resulting in increased risk of falling (Hortobágyi et al., 2009; Marques et al., in press a,b). However, to the authors' knowledge no study has examined cocontraction of thigh and shank muscles during dual task in older adults.

Surface electromyographic signals (EMG) are used to assess muscle activation during gait (Roetenberg et al., 2003). The assessment of lower limbs muscle activity can provide important information about the neuromuscular behavior during walking (Schmitz et al., 2009). Age and apprehensive gait may affect the neuromuscular behavior. Thus, the purpose of this study was to investigate the influence of apprehensive gait on activation and cocontraction of lower limb muscles of younger and older women. We hypothesized that older women would have greater muscle activation and cocontraction than younger women during gait, and that the levels of muscle activation and cocontraction would be higher during apprehensive than during normal gait.

2. Methods

2.1. Participants

Data of 17 younger (21.47 ± 2.06 yr) and 18 older women (65.33 ± 3.14 yr) were considered for this study (Table 1). Younger subjects were recruited from a university setting and older subject were recruited from a community group of physical activity for older adults. The sample size was determined based on a pilot study data (power = 0.95, effect size = 1.21, α error = 0.05).

People who had uncontrolled cardiovascular disease, diagnosed dementia or cognitive impairment (defined as a Mini-Mental State Examination score <20), balance disturbance (defined as a BERG balance score <36), emiparesis, pain in the lower limbs or trunk, or a progressive motor disorder were excluded. Also, volunteers who reported dizziness or discomfort during the test were asked to stop immediately and excluded from the sample ($n = 2$, reported dizziness during the test). All participants signed a consent form approved by the Institutional Ethics Committee.

2.2. Instrumentation

EMG signal were recorded on the right leg on: rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM), biceps femoris (BF), tibialis anterior (TA), gastrocnemius lateralis (GL), and soleum using an 8-channel, telemetered electromyogram (Noraxon®, Phoenix, USA). The gait tests were performed on the treadmill Millennium Super ATL (INBRAMED®, Porto Alegre, Brazil).

Table 1
Subjects characteristics.

Variable	Younger ($n = 17$)	Older ($n = 18$)	P
Age (year)	21.47 (±2.06)	65.33 (±3.14)	<0.01*
Weight (kg)	60.68 (±5.93)	64.00 (±1.55)	0.23
Height (m)	1.63 (±0.05)	1.55 (±0.05)	<0.01*
Gait speed ($m\,s^{-1}$)	0.95 (±0.84)	0.70 (±1.92)	0.01*

* $p < 0.05$ Significant differences between younger and older women.

EMG signals were collected at a sample frequency of 1000 Hz, using Ag/AgCl disc electrodes (Miotec®, Porto Alegre, Brazil) with an active area of 1 cm^2 and inter-electrode distance of 2 cm arranged in bipolar configuration. The electrodes were positioned on the participants' right side on biceps femoris (BF), rectus femoris (RF), vastus lateralis (VL), vastus medialis (VM), tibialis anterior (TA), and gastrocnemius lateralis (GL) muscles according to Hermens et al., 2000. Before placing the electrodes, the subject's skin was shaved and cleaned with alcohol to reduce impedance (Hermens et al., 2000).

2.3. Procedures

Before the beginning of the gait trials, the volunteers were familiarized with treadmill walking for 10 min at their preferred gait speed (Dingwell and Marin, 2006). After the familiarization, three different walking trials under two conditions were performed: first normal gait, apprehensive gait and second normal gait.

During normal gait the volunteers were oriented to walk on the treadmill at their self-selected pace for 3 min. For the apprehensive gait trial, the volunteers were oriented to walk on the treadmill for 3 min having an additional attention during walking because obstacles would appear on the treadmill surface what could cause tripping or balance disturbance. The verbal feedback given for the volunteers were standardized and consisted that: "In the next 3 min you should be careful and pay attention because obstacles will appear on the treadmill and you may trip or lose your balance".

2.4. Data analysis

The EMG signal was processed in specific routines developed in Matlab (Mathworks®, Natick, USA) using full-wave rectification, Butteworth bandpass filter of 20–500 Hz, and a Butterworth low pass, fourth order filter with a cut-off frequency of 6 Hz. Then, the linear envelope EMG data were interpolated at 1001 points. The mean of the linear envelope of the EMG signal of the first ten strides was obtained. All the linear envelope values were normalized to the mean activation obtained during the first normal gait trial.

The percent cocontraction between the agonist/antagonist muscles RF/BF, VM/BF, VL/BF, and TA/SO were calculated using the following equation:

$$\%COCON = 2 \times \frac{\text{área comum de A \& B}}{\text{área de A} + \text{área de B}} \times 100\%$$

where % COCON is the percentage of cocontraction between the agonist/antagonist muscles; area A is the area below the processed EMG curve of muscle A; area B is the area below the processed EMG curve of muscle B, common area A & B is the common area of activity of muscles A and B (Candotti et al., 2009).

2.5. Statistical analysis

PASW 18.0 (SPSS Inc.) was used for all statistical analyses and means and standard deviations were used to summarize participant characteristics. Then, the Shapiro–Wilk test was used to determine if the data were normally distributed. ANOVA two-way repeated measures and post hoc of Bonferoni tests were used to compare muscles activation and cocontraction, considering as factors: age (younger and older) and conditions (second normal gait and apprehensive gait). The significance level for all statistical tests was set at $p < 0.05$.