The Effects of Physical Activity in the Anticipatory Postural Adjustments in Elderly People

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Exercise seems to attenuate the postural control system and anticipatory postural adjustments (APAs) decline, but no conclusive findings are available. This study analyses, in elderly people, the exercise effect in APAs during the raising of a load with both arms in the sagittal plane. Twenty eight males over the age of 60 (65.8 ± 4.07 yr old)—9 veterans in exercising, 9 who exercise recently, and 10 sedentary—were asked to raise a load with both arms simultaneously to shoulder level, in standing position, as fast as possible. It was studied the electromyography (EMG) pattern of the main muscles. The APAs were quantified through the time integral of EMG records (iEMG). Anticipatory changes in the postural muscles were seen in all groups. We observed, in the tibialis anterior activity, a higher significant activation in the sedentary compared with the other groups, suggesting that exercise can modulate the postural control system.

Keywords: motor control, older adults, anticipatory postural adjustments, electromyography

The natural process of aging is characterized by functional and morphologic modifications in all body systems and it can be worsened by disease or inactivity (Massion, 1992; Medicine, 1998; Spirduso, 1995). This modification is linked to a degeneration of neural muscular and skeletal mechanisms (Amiridis, Hatzitaki, & Arabatzi, 2003). One of the systems which seems to decline with aging is the postural control system. It was observed that this system affects the balance functions, in particular the anticipatory postural adjustments (APAs), which allow a posture’s correction to the voluntary movement (Aruin, 2003; Aruin & Almeida, 1997; Aruin & Shiratori, 2004; Massion, 1992, 1994; Spirduso, 1995; De Wolf, Splijperg, & Latash, 1998). APAs consisted in background activity changes of the postural muscles before the movement, as result of the feedforward processing of the postural control system (Aruin, 2003; Aruin & Almeida, 1997; Aruin & Shiratori, 2004; Massion, 1992, 1994; Mochizuki, Ivanova, & Garland, 2004; De Wolf et al., 1998).

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The APAs are dependent on the motor action, magnitude, direction, and velocity—being these variables specific to each action (Aruin, Mayka, & Shiratori, 2003; Aruin, 2003; Aruin, Forrest, & Latash, 1998; Aruin & Shiratori, 2004; Chabran, Maton, Ribreau, & Fourment, 2001; Hay & Redon, 2001; Shiratori & Latash, 2001; Splijper & Latash, 2000) - and usually occur 100ms to 150ms before the focal movement (Massion, 1992).

It is worthy of mention that two main muscular strategies exist in the postural control: the reciprocal strategy and the coactivation strategy. Together with the anticipatory increase of agonist activity, a decrease of antagonist activity is expected (e.g., Aruin, 2003; De Wolf et al., 1998). This is called the reciprocal strategy (Aruin & Almeida, 1997; Mochizuki et al., 2004). However, when a cocontraction or simultaneous activation of the joint muscles occurs, it means that the coactivation strategy is used (Aruin & Almeida, 1997; Mochizuki et al., 2004). There is no consensus if the coactivation is considered part, or not, of the APAs, but in general there is an agreement on concerning this coactivation a postural control strategy. Some authors report that a reciprocal activation pattern is necessary for a strategy to be regarded as an APA (e.g., Brown, Haumann, & Potvin, 2003; Mille & Mouchinho, 1998), others assume the coactivation as a given APA, since young adults also use it as a postural response (e.g., Chabran et al., 2001; Mochizuki et al., 2004).

Many motor actions have been studied, in particular during the arm raising in sagittal plane (Aruin, 2003; Aruin & Shiratori, 2004; Gantchev & Diminitrova, 1996; Latash, 1998; Mochizuki et al., 2004; Patla, Ishac, & Winter, 2002). This task can be changed by increasing the moving arm load or by modifying the speed or the direction of movement (for review, see Mochizuki et al., 2004).

It seems that physical exercise can interfere in and modify the diverse systems affected by the aging process or by inactivity, attenuating its decline (Gauchard, Gangloff, Jeandel, & Perrin, 2003; Medicine, 1998). Among other benefits, several studies refer a muscle strength increase, a positive effects in body sway, an improvement in postural stability and in balance (Delecluse et al., 2004; Gauchard et al., 2003; Gustafson, Noaksson, Kronhed, Moller, & Moller, 2000; Medicine, 1998). However, few investigation have been developed concerning the effects of the physical exercise in elderly people APAs.

The present study aims to define which are in senior citizens, the APAs before lifting a load with both arms and the effect of physical exercise upon them.

**Material and Methods**

**Subjects**

The sample compromises 28 males over the age of 60 (66 ± 4 years old, mean body mass 73 ± 11 Kg and mean height 1.7 ± 0.6 m). All individuals lived at their own home, could perform their daily tasks unassisted, and were free of any known neurological or motor disorders. They didn’t take medication that can affect the state of surveillance. This study was approved by the ethical committee from Faculty of Sport, Porto University and all experiments were conducted in accordance with the Declaration of Helsinki. Written consent was obtained from all subjects following an experimental protocol explanation. The senior citizens were separated into two main groups.
Group I was composed of 18 subjects who practice regular physical and sporting activities. Based in the information collected by interview this group was subdivided into two subgroups according to the years of practicing: Group Ia was composed by 9 individuals, veteran in exercising (it means, 24 ± 6 years of practice) that practiced jogging four times a week. Group Ib included 9 individuals recently initiated in physical exercise (it means, 3 ± 1 years of practice of soft gymnastics, swimming and tai-chi) once a week. Group II was composed by 10 sedentary subjects.

**Experimental Protocol and Apparatus**

The experimental procedure involved five movement trials at maximal acceleration. The individuals were asked to stand over a force platform Bertec 4060–15 (1000Hz), with their feet together and with their eyes open. A light-emitting diode (diameter 5mm) was set 1m at eye level and used as the ON-OFF signal indicating each trial beginning. The subjects were instructed to raise as fast as possible a load to shoulder level, with both arms extended, in response to the light-emitting diode. A single load grasped by both hands is used. They were asked to avoid taking a step, bending the knees, or raising the heels. All joints were assumed to be frictionless hinge joints, allowing one degree of freedom in the sagittal plane. The arms movement range was 45°, from 45° of flexion to horizontal. The load was normalized for body size, for body mass and for upper limb height. We defined a normalized strength ($Sn = 0.0369$) based in an previous test, and we used the following equation (for review, see Jaric, 2002): $Load = (Sn \times Body\ mass) / upper\ limb\ height$.

The Group Ia rise 4.7 ± 0.27 Kg, the Group Ib rise 5.2 ± 0.68 Kg and Group II rise 5.2 ± 0.69 Kg, this loads are not differenced. Two or three practice trials were performed before the data collection. The arms average acceleration was measured to estimate the magnitude of perturbation to the body induced by the load lifting.

The arm movement kinematics was assessed through a MotionScope digital camera, placed lateral to the subjects to record the trajectory. The camera sampling frequency was 50Hz. The marker was placed in the right arm at the radius styloid process. The data were recorded in .avi format for posterior treatment and digitising. The arms acceleration was computed based upon numerical differentiation procedures which algorithms are included in the APAS package from Ariel Dynamics Inc. (San Diego, USA). The raw data were low-pass filtered with a digital filter, with an effective cut-off frequency of 10Hz.

The limbs first visible movement was considered the time zero ($t_0$), and the instant at which the task finishes, exactly at shoulders level, was considered the final time ($t_f$). Time zero ($t_0$) was defined both through the video frame at which the first limb acceleration was recorded, and the correspondent time instant at which a perceptible inflection of the Fz ground reaction force curve was recorded (Figure 1).

The EMG activity was recorded using bipolar surface electrodes (with silver/silver chlorite detection surfaces 2cm apart), placed over the muscle bellies, namely the postural muscles—*tibialis* anterior and *soleus*—and the focal muscle—*deltoides* anterior—using standard skin-preparation procedures (Basmajian & Luca, 1985). The sampling frequency of the EMG acquisition was 1000 Hz. The signal was amplified (gain 1100×), filtered through a 20–450 Hz bandpass, using a digital filter with Hamming Windows, and full-wave rectified.
Figure 1 — EMG record from TA (tibialis anterior), SOL (soleus) and vertical ground force during arm raising in a representative subject of each different group (Ia, Ib and II). The shadow area shows the time window used for EMG integration to produce quantitative indices of anticipatory postural adjustments (APAs). Note the similar muscle activity in TA and SOL in Group II.
The kinematics and the EMG records were synchronized in time through an electrical manual firing trigger that produced a signal into the EMG output and simultaneously lightened a LED within the visual field of the video camera. In each trial, the signals were synchronized with the arm movement ($t_0$).

To quantify the anticipatory EMG activity magnitude of the postural and focal movements, the rectified EMG of each muscle was integrated over the time window defined by the interval between -100 to +50 ms (Figure 1) measured from the movement onset ($\text{iEMG}_{\text{APA}}$). These integration intervals were chosen based on previous studies (e.g., Aruin, 2003; Shiratori & Latash, 2001). The onset was determined based in visual inspection, as the point at the baseline upper level above which a progressive increase in EMG activity was observed. For comparison across subjects $\text{iEMG}$ values were normalized to the peak amplitude obtained during the event (-100ms to +50ms) for a particular muscle and a particular subject, as done in other studies (Aruin, 2003; Aruin et al., 2003; Seidler-Dobrin et al., 1998; Soderberg & Knutson, 2000) in alternative to maximal voluntary isometric contraction (MVIC) that, according to Aruin et al. (1998), cannot be readily obtained for some muscles of the body and that is difficult to assess in elderly adults (Seidler-Dobrin et al. 1998). The average value for five trials was calculated and adopted as the representative anticipatory EMG activity. The data recording and its analysis were carried out using the AcqKnowledge 3.2.5 (BIOPAC Systems, Inc) software.

### Statistical Analysis

The statistical analysis was performed using SPSS 12.0 software. The Kruskall-Wallis test and the Mann-Whitney test for independent samples were used to compare the various measures mentioned above (the acceleration of arms movement and EMG activity), according to the type of the physical activity performed. Wilcoxon tests for repeated measures were employed to examine differences in the agonist related to the antagonist muscles. The relationship between the arm acceleration and the $\text{iEMG}$ was evaluated by the Spearman test. The significance was set at $\alpha=0.05$.

### Results

Figure 1 shows an EMG record from TA and SOL and vertical ground force during arm raising in a representative subject of each one of the different groups studied. Table 1 presents the results from the kinematics and the electromyography analysis related to the physical exercise practice.

#### Arm Flexion Perturbation

No statistical differences were found for the arm acceleration between groups. Therefore, the magnitude of the induced perturbation to the body alignment and posture between the groups was assumed to be not different.

#### Muscle Activation Before Arm Movement

The load raising was accompanied by early changes in the leg muscles activity. These changes in the postural muscles activity were initiated before $t_0$. Table 1
presents the results obtained from the anticipatory EMG activity. Higher anticipatory activity values from *tibialis* anterior were obtained for group II compared with group Ia and Ib. The differences between groups Ia and II (*p* < .05), and Ib and II (*p* < .05) were statistically significant.

No significant changes were found in magnitude of the anticipatory EMG activity of the *deltoides* anterior comparing to soleus and *tibialis* anterior. Differences in the APA activity between the agonist (*soleus*) and the antagonist (*tibialis* anterior) were all nonsignificant. Typical in this task, there was a clear anticipatory increase in the *soleus* activity compared with *tibialis* anterior activity. However, it did not occur in group II. There wasn’t also found any significant correlation between arm acceleration and EMG activity.

### Discussion

The current experience was designed to study the effect of the practice of physical exercise in the senior citizens APAs before lifting a load with both arms. This was achieved by having the subjects performing the same motor action confined mostly to perturbations in anterior-posterior direction.

Since the arm acceleration between groups was not significantly different, we assumed that the magnitude of perturbation to the body alignment and posture was also identical, according to similar results and assumptions published in other studies (Aruin, 2003; Woollacott & Manchester, 1993). This allows us to make comparisons between groups, since the APAs have been shown to be dependent on the motor action properties (Aruin et al., 2003; Aruin, 2003; Aruin et al., 1998; Aruin & Shiratori, 2004; Chabran et al., 2001; Hay & Redon, 2001; Shiratori & Latash, 2001; Splijper & Latash, 2000). Thus, the differences obtained in the EMG
are directly related to the independent variable in study, in this particular case to the level of physical exercise practice and not to the arm acceleration.

Many studies reported that, in arm flexion movement, the postural muscles become active before the focal muscles as a feedforward mechanism strategy (e.g., Fujiwara, Toyama, & Kunita, 2003). However, the postural muscles anticipatory activity was different in the muscles of the ventral and dorsal parts of the body (Aruin, 2003). Given that in our study the activity of the postural muscles occurred before the movement of the arm in all groups, we can conclude that strategies used by groups Ia and Ib make part of the feedforward mechanism. Seidler-Dobrin et al. (1998) in similar conditions in which subjects are instructed to move as fast as possible, refer it is inefficient to use a feedback as opposed to a feedforward mode of control.

As mentioned in the introduction, two main muscular strategies exist in the postural control: the reciprocal strategy and the coactivation strategy.

The increased anticipatory activity of the soleus muscle is similar among the groups, being in accordance with other studies that relate an activity increase of the dorsal postural muscle previous to arm raising (Fits, Klip, Eykern, & Hadders-Algra, 1998; Mochizuki et al., 2004).

With regard to the amount of tibialis anterior anticipatory activity, this is greater in group II compared with the groups Ia and Ib \((p < .05)\), appointing out to the recognition of a different strategy, relatively to the APAs, between group II and the groups Ia and Ib. Since the tibialis anterior anticipatory activity tended to be higher compared the soleus muscle anticipatory activity in group II, we suggest that the strategy used for this group is the coactivation. The same idea came up in studies with young individuals (Chabran et al., 2001; Mochizuki et al., 2004) and in individuals with Down syndrome (Aruin & Almeida, 1997), and in studies comparing senior citizens with young adults (Earles, Koceja, & Shively, 2000; Laughton et al., 2003; Seidler-Dobrin, He, & Stelmach, 1998).

Studies have shown that elderly people use as strategy for the postural control, the increase of the muscular activity level around the joints, showing, in such a way, significant increases in the muscular coactivation level in reply to postural disturbances (Laughton et al., 2003; Seidler-Dobrin et al., 1998). According to Melzer et al. (2003), balance is affected specially with aging, which results in slower anticipatory postural muscular responses, particularly during voluntary fast movements (Spirduso, 1995; Woollacott & Manchester, 1993). When the APAs are not efficient, the elderly use strategies such as the coactivation to maintain the balance (Mille & Mouchnino, 1998; Woollacott & Manchester, 1993). The antagonists coactivation increase during the postural oscillation allows to enhance the joints stabilization and, consequently, to reduce the amount of the movement to be controlled to maintain balance (Massion, 1994; Spirduso, 1995). This joint stiffness and muscular activation increase can be justified by an attempt to compensate the muscular strength reduction, through neuromuscular and sensorial systems deterioration, or by alterations in the muscular inhibitory mechanisms (Laughton et al., 2003).

Our results also demonstrate that groups Ia and Ib, devoted to physical exercise, use strategies similar to the APAs. In the case of groups Ia and Ib, a trend for anticipatory activity reduction is verified relatively to the tibialis anterior to soleus, as would be expected in the adequate APAs. The same occurred in several
studies (Aruin, 2003; Aruin & Shiratori, 2004; Chabran et al., 2001; Mochizuki et al., 2004; De Wolf et al., 1998). These results suggest that the practice of physical exercise seems able to delay the decline associated to the natural aging process, demonstrating that the strategies adopted by the groups Ia and Ib approach those of the young adults.

This study emphasizes that the practice of physical exercise affects the muscular strategy used. We observe feedforward strategies in all groups. However, the groups Ia and Ib strategies draw nearer to the adequate APAs.

We conclude that the prolonged practice of physical exercise promotes the best APAs. The practice of physical exercise, even if started later, seems to contradict the postural control decline, typical of the natural aging process. Therefore, individuals that practice physical exercise obtain better results than those who don’t practice it at all. To find more about the nature of the physical exercise effect in APAs, we pretend to analyze what type of physical exercise is more efficient in promoting an adequate APAs it means a reciprocal strategy.

References


