# Trunk Extensor Muscle Fatigue Does Not Affect Postural Control During Upright Static Stance in Young-Adults and Middle-Aged Adults

Giselle Delgado, Chelsea Coghlin, Katelyn Earle, Andrea Holek, and Kate O'Hare

The University of Western Ontario, London, Ontario

# **Abstract**

**Background**. Falls can be extremely detrimental to someone's daily living, as well as life threatening This is especially true for individuals who have back problems, are sedentary, and have other health disorders. The purpose of this study was to investigate the effect of trunk extensor muscle fatigue on static postural control in young healthy adults compared to middle aged participants.

**Methods**. University students (n=10), and middle-aged participants (n=6; 40+ years of age) stood as immobile as possible on a force plate, with their feet together and eyes closed under two conditions; fatigue and no fatigue.

Fatigue was achieved through repetitive extensions of the trunk until a subjective fatigue level was reached. We measured center of pressure (CoP) displacements in the A/P and M/L planes using a force plate to assess standing balance.

**Findings**. We did not observe any significant interaction between age and fatigue indicating that fatigue affected both age groups similarly. The CoP variability was higher for the middle aged compared to the young adults in both the fatigue and no-fatigue conditions.

Interpretation. The results of this study indicate that trunk extensor fatigue does not affect balance differently for young compared to middle-aged subjects. This study also suggests that postural control decreases significantly with increasing age. Our finding that trunk extensor fatigue did not significantly affect the postural control of upright stance contradicts previous studies; this difference may be due to the subject sample in our study.

# Introduction

he implications of increased postural sway can be troubling since the risk of falling increases as we age (1-3). Postural sway can be described as the displacement of the Center of Mass (CoM) in relation to the Base of Support (BoS) (4), which is directly related to postural stability or control, and balance. Our ability to achieve postural stability, or to maintain our CoM within our BoS<sup>(5)</sup>, is influenced by factors such as decreases in muscle mass, decreases in functional base of support, gait deficits, etc<sup>(6, 7)</sup>. This becomes a more difficult task as we age and especially in challenging situations since balance is a multidimensional concept that refers to our ability not to fall<sup>(8-10)</sup>. In addition, muscle fatigue is a complex phenomenon involving a reduction in the force generating capacity of a muscle<sup>(8)</sup>. In order for people to stand upright, muscle activation must be present. This is due to the inherent alignment of the trunk centre of mass with respect to the hip, knee and ankle. Trunk extensor activation is required to maintain static upright posture<sup>(11)</sup>. Another prerequisite for balance control is the ability to generate forces large enough to uphold stability<sup>(12)</sup>. Therefore, fatigue in these postural muscles may lead to difficulties in maintaining upright balance. Many studies have investigated the effects of muscular fatigue on quiet standing within the human body and have found that sway seems to increase whenever sensory or motor components are compromised (e.g. 8, 13)

The mechanisms causing balance impairments due to fatigue are complex. Muscular strength and sensory detection and relay are two important factors in fatigue and postural control. Following fatigue of the



postural musculature, perturbations cause a greater loss of postural control, leading to increased difficulties in balance<sup>(14)</sup>. recovering Other researchers suggested that fatigue leads to a loss of postural control due to a diminished use of sensory information as well as decreased integration of vestibular stimuli (15, 16). Previous research has also found that muscular strength may contribute both directly (through proprioception) and indirectly (with other joint functions) to postural control and body movements via sensory detection<sup>(17)</sup>. Thus it is likely that muscle strength and sensory detection/relay work conjunctively to regulate posture during balance impairments due to fatigue.

Previous research has shown that age reduces the capacity to regulate posture through a loss of muscle mass<sup>(14, 18)</sup>, neural function<sup>(3, 19, 20)</sup> and functional BoS<sup>(21)</sup>. A loss of muscle mass has been identified starting in the third decade of humans, with a significant loss of muscle mass from the fifth decade, especially in the lower body  $^{(9,\ 21,\ 22)}.$  Deficiencies in the ability to maintain postural will increase susceptibility to balance control perturbations following a fatiguing exercise. Younger individuals may be able to compensate for the shortcomings of fatiguing muscle to a greater degree than older individuals. Inabilities to regulate posture due to trunk extensor muscle fatigue in this study could signify that elderly populations may be at a higher risk of falling as a consequence of carrying out potentially fatiguing activities of daily living, such as carrying groceries, holding a small child for prolonged periods of time, lifting objects, gardening, etc.

The abundance of past research indicating that fatique can impair postural control in young healthy individuals has led to the present study, in which we decided to contrast different age groups. In particular, the purpose of this study was to examine the effects of trunk extensor muscle fatigue on postural stability within both a young and middle-aged group. This study targeted the neuromuscular aspects of balance by controlling for somatosensory, vestibular, and visual input. We controlled for somatosensory and vestibular output by recruiting healthy individuals who did not suffer from somatosensory or vestibular problems. Somatosensory input was controlled by not modifying the testing surface (e.g., solid horizontal), and vestibular input by having participants hold their head in an upright position. Visual input was controlled by having all of the participants

stand with their eyes closed. We hypothesized that there would be an increase in postural sway, as measured by CoP variability in the anterior/posterior (A/P) and medial/lateral (M/L) directions, following the fatiguing exercise. Furthermore, we hypothesized that fatigue would cause a greater detriment to the middle-aged than the young participants. To test these hypotheses, ten young adults and six middle-aged adults stood in an upright position with eyes closed, while maintaining balance to the best of their ability for thirty seconds, both pre- and post-fatiguing exercise. A force plate recorded the displacement of the CoP, and variability of the CoP displacement was used as an indicator of postural control.

# **Methods**

#### 2.1. Participants

The recruitment of participants was done with the use of posters outlining the procedures and inclusion criteria of the study. Participation was limited to individuals without a history of low back pain, ankle, knee, or hip injuries in the past two years that may have affected standing balance. Ten physically active (23) graduate and undergraduate level kinesiology students (M = 22 years, SD = 1.8) from the University of Western Ontario and six middle-aged adults (M = 54.3 years, SD = 5.4) above the age of forty voluntarily participated in the experiment. The middle-aged adult group was a combination of four male Kinesiology faculty members and two family members of the experimenters, one of who was a female. The young group consisted of two males and eight females. The Ethics Committee of The University of Western Ontario approved the study and all participants gave their informed consent. None of these participants presented any history of musculoskeletal problems, neurological disease or vestibular impairment.

#### 2.2. Apparatus

Ground reaction force data was sampled for thirty seconds at a sampling rate of 64 Hz using a Kistler force plate (model 9287B). The force plate signals were amplified (AMP 9865c), converted from analogue to digital form through an A/D converter (16 bit, National Instruments), and written to disk using a custom program

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written in LabVIEW (National Instruments).

#### 2.3. Task and procedure

Participants stood as still as possible on the force plate with socks on, feet together, arms at their side, and eves closed. The eves closed condition was chosen in order to remove visual feedback. The participants performed one acclimatization trial and two experimental trials: No Fatigue (NF) and Fatigue (F). The trials were 30 seconds long to ensure that there was enough time for differences to be observed (11, 20, 24). Following the NF trial. the participants performed dynamic trunk extensions until fatigued. Participants lay prone cantilevered over the end of a bench with their lower body supported on it from their Anterior Superior Iliac Spine (ASIS), and their legs held down by an experimenter. The bench was located next to the force plate to reduce the time lag between the fatiguing exercise and the measurements. With their arms folded across their chest, participants raised their body from a comfortable position just above the floor up to the horizontal as many times as possible (until they could not keep up with the pace, or until they could not extend their trunk to horizontal). Participants received encouragement from an experimenter and had to follow the beat of a metronome (40 bpm). When volitional fatigue was achieved, the experimenter carefully released the legs of the participant to allow him or her to get off the bench and to stand on the force plate as soon

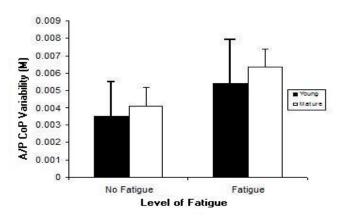


Figure 1. Variability of the position of the COP in the anterior/posterior direction before and after a fatiguing bout of trunk extensions for young individuals compared to middle-aged individuals. Error bars represent one standard deviation. The differences in the A/P CoP with age were statistically significant, but not as a function of fatigue for either age group.

as possible, where repeated measurements were obtained.

#### 2.4. Data analysis

The CoP was calculated from the forceplate data. The standard deviations (variability) of the CoP in the A/P and M/L directions were submitted into a 2 (Age: young and middle-aged adults) x 2 (Fatigue: no fatigue and fatigue) split - plot analysis of variance (ANOVA) with SPSS software. Bonferroni post-tests analyses were also obtained and the level of significance was set at 0.05.

## **Results**

The variability of the CoP in the A/P and M/L directions was not significantly altered by fatigue  $(F(1,14)=4.494,\,p=0.95;\,F(1,14)=0.096,\,p=0.24$  respectively). On the other hand, there was a statistically significant difference between age groups in their CoP variability. Post-hoc tests revealed that the CoP variability was higher for middle-aged compared to young adults  $(F(1,14)=5.051,\,p<0.05$  and  $F(1,14)=8.885,\,p<0.05$ , respectively) in both A/P and M/L directions. In addition, the Age x Fatigue interactions in the A/P and M/L directions were not significant  $(F(1,14)=0.254,\,p=0.38;\,F(1,14)=1.506,\,p=0.76$  respectively).

The average time to fatigue for the young-adult

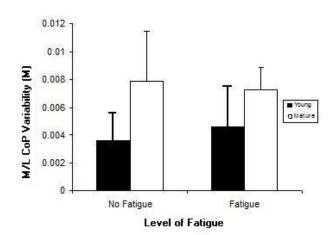


Figure 2. Variability of the position of the COP in the medial/lateral direction before and after a fatiguing bout of trunk extensions for young individuals compared to the middle-aged individuals. Error bars represent one standard deviation. The differences in the M/L CoP with age were statistically significant, but not as a function of fatigue for either age group.



group was 62 s (SD = 10.2 s), and 73 s (SD = 31.7 s) for the middle-aged group. An independent t test for unequal sample variances (F(5,9)=9.659; p=0.0041), showed that the mean times to fatigue were not significantly different (t(5)=0.8247, p=0.4471). The mean variability of the CoP that occurred during the experimental trials for each age group, in the A/P and M/L directions are shown in Figure 1 and Figure 2.

# **Discussion**

The purpose of this study was to determine if postural control during undisturbed upright stance is affected following a fatiguing bout of trunk extension exercises and if the effect changes with participant age. Two hypotheses were postulated: postural control will be reduced in both the M/L and A/P directions following fatigue of the trunk extensors, and the effect of fatigue will be more pronounced in middle-aged adults compared to young adults.

The first hypothesis was not supported in the present study; trunk extensor fatigue did not have a significant effect on postural control during upright stance in either the M/L or the A/P directions. This may suggest that middle-aged adults are able to compensate for fatigue just as well as younger adults. Previous research has shown that fatigue of postural muscles does influence postural control and therefore, these findings are surprising. One study (11) evaluated the ability of young adults to balance following trunk extensor muscle fatigue, and found a statistically significant increase in CoP variability in both A/P and M/L directions (by 86% and 78% respectively). In the present study, after following the same protocol, we found changes in CoP variability in the A/P and M/L directions (+85% and -8.6% respectively) following the trunk extensor muscle fatigue exercise, but these were not statistically significant for either group.

The evidence that fatigue causes a reduction in postural control is abundant and therefore, we believe that other factors were responsible for the lack of statistical significance in the effect that fatigue had on CoP variability in the present study. We believe this to be the case since the time to fatigue differences between groups were not statistically significant. An example of one of the possible factors is that the participants may not have reached sufficient levels of fatigue following the

fatigue protocol; the participants may have discontinued the fatiguing exercise when they began to feel tired rather than at physiological exhaustion. This could be corrected by emphasizing to each participant that it is beneficial to the experiment to exercise to exhaustion, to encourage the participant to continue with the exercise until they are unable to carry on, and also by using EMG to quantify fatigue (25). The higher mean time to fatigue for the middle-aged group (73 s) compared to the young group (62 s) in our study was unexpected, despite that it was not statistically significant. This time to fatigue was also higher than the mean time to fatigue found for the young participants in Vuillerme et al<sup>(11)</sup>'s study (54 s). With that being said, it is also important to note that the effects of fatigue and age still require further investigation<sup>(26)</sup>. An example of a possible factor affecting our data may have been fitness level; baseline fitness levels were not obtained in our study but they were self-described as active individuals; however, we are not sure whether this contributed to the non-statistically significant difference in postural control following fatigue. Athletes have been found to have a higher capacity to maintain postural control<sup>(27)</sup>, therefore it is possible that the relationship between muscular fatique and balance is different in physically fit people. Future research could focus on how muscular fatigue affects balance in special populations and athletes, compared to the general population.

It should be noted that we observed an increase in CoP variability in both the M/L and A/P directions following a fatiguing bout of trunk extensions for the young group. For the middle-aged group, we observed an increase in CoP variability only in the A/P direction, and a decrease in the M/L direction. These changes in CoP variability were not statistically significant, and we believe this was due to a lack of statistical power. At the same time, consideration should be given to the difference in sex breakdown of the two groups since they may have played a role in the (non-statistically significant) difference in our time to fatigue results. Future studies could repeat the present study using more participants, and performing comparisons between the male and female subjects.

We observed that postural control deteriorated with increasing age. This is consistent with previous research that has shown significant changes with regards to functional BoS in adults aged 60 or older<sup>(21)</sup>. A reduction in the size of the functional BoS will require a



greater input from muscle and the nervous system to maintain stability. Furthermore, research has shown that as people age they experience an increase in reflex time, primarily due to a loss in neural and sensory function including peripheral sensation, proprioception, vestibular, visual, and sensori-motor capabilities<sup>(22)</sup>. We suspect that a combination of different aspects of balance such as functional base of support, muscle mass, and neural functioning, which are known to decline with age, would greatly affect an older adult's ability to maintain postural control, and thus resulting in an increase in postural sway, as measured in the present study.

A noteworthy aspect of this study is the relatively low mean age of the middle-aged group (54 years). Similar studies had a mean age of 65 (SD=5)<sup>(7)</sup> or 60+ years old (range 60-91)(21). These studies attest that older populations have a reduced ability to balance; however, they do not address the age at which these detriments in balance begin to develop. The present study observes balance causes deficiencies well before age 65. Other literature (9) that points toward detriments in balance with age, suggests that muscle degeneration is already occurring at 46 years of age and can be reduced by approximately fifteen percent within the following decade. This is also supported in Janssen's study which found that muscle mass begins to decrease by the third decade and even more by the fifth (28). This is concerning since the middle-aged participants in this study are considered to be physically active compared to the average individual, suggesting that balance impairments can occur at earlier ages than 65, however, future research is needed to evaluate this.

Given that trunk extensor fatigue did not significantly affect postural control in this study, it is not surprising that it also did not affect postural control differently for middle-aged compared to young adults. Therefore, the second hypothesis was also not supported, but consideration should be given to increasing the statistical power of studies of this kind.

# **Conclusions**

Overall, the results in the present study did not indicate that trunk extensor fatigue influences postural control in normal stance. As previously mentioned, this could be a due to many factors including experimental error, limited sample size, and control of physical

capabilities. We also found that the fatigue of postural muscles did not reduce postural control to a greater extent in middle-aged adults compared to younger adults. This finding was surprising because, according to previous research, aging yields a deterioration of muscle and neural functioning, which indicates that fatigue should reduce postural control.

Future studies could implement a longitudinal design to collect data on the effects of age on postural control within a specific population, such as individuals with lower back pathology or individuals with a recent history of falling. Another recommendation for a future study is to observe how initial physical capabilities of participants affect the parameters investigated in the present study. MVC of trunk extensor muscles, VO<sub>2max</sub>, and other measures of fitness could provide baseline measures to ensure all participants are relatively equal in muscular and aerobic abilities. As previously discussed, the results that were obtained in this study may not have confirmed the hypotheses because the participants may have been more athletic than the average individual, and thus responded differently to fatigue.

This study may have practical implications in identifying those individuals who experience fatigue in postural muscles quickly, as well as those who have decreased lumbar neuromuscular function, as being at increased risk of falling.

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