Article

Relationship between postural stability and fall risk in young adult after lower limb muscle fatigue

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Abstract

Introduction: Muscle fatigue can reduce body balance and activity of daily living tasks. Therefore, this study aims to identify the correlation between postural stability and fall risk due to muscle fatigue. The components in postural stability include Overall Stability Index (OSI), Anterior-Posterior Stability Index (APSI), and Mediolateral Stability Index (MLSI).

Design and Methods: A total of seven healthy adults aged 31.1±7.4 years were recruited in this study. The sit-to-stand (STS) protocol was used to induce lower limb muscle fatigue, while postural stability and fall risk were assessed using the Biodex Balance System (BBS) before and after muscle fatigue.

Result: The result showed a significant increase in postural stability index after fatigue only for OSI with $p<0.05$, while no significant difference was found on APSI and MLSI with $p=0.157$ and $p=0.109$ respectively. However, the mean score for the postural stability index showed an increase in percentage with 47.8% in OSI, 26.3% in APSI and 46.8% in MLSI. Furthermore, fall risk showed no significant differences with $p=0.149$, but the mean score data increased by 16.7% after fatigue. The correlation between fall risk and OSI was significant with $p<0.05$, while MLSI had a significant negative correlation with APSI ($p<0.05$).

Conclusions: Based on the results, the young adults had reduced overall postural stability but were less affected by fall risk after muscle fatigue. The positive correlation between OSI and fall risk indicated that their overall postural stability can induce the fall risk after muscle fatigue. Therefore, young adults need to be aware of their fatigue symptoms during prolonged exercise that can increase fall risk potential.

Introduction

Fatigue can be defined as lack of energy, exhaustion, an overwhelming sense of tiredness, and difficulties in performing a voluntary activity.[1] Enoka and Duchateau[2] define fatigue as "a disabling symptom in which physical and cognitive function is limited by interactions between performance and perceived fatigability". Muscle fatigue can affect balance, proprioception, coordination, and reduce contractile muscle ability.[3] There are several possibilities for people experiencing muscle fatigue, such as prolonged maintenance of the muscle force,[4] incline walking,[5] prolonged isometric tasks, and repetitive movements.[6]

Standing up and sitting down is an everyday activity often performed spontaneously by healthy subjects.[7] However, repetitive STS activity will produce fatigue and decrease postural stability.[8] Prolonged voluntary contractions of lower limb muscles during the STS also affect motor control and body balance.[9] Although fatigue reduces postural stability, a therapist provides rehabilitation programs for the patients to increase their ability to maintain good postural stability in daily living activities and complex tasks.[10]

In rehabilitation, physical actions such as exercises and repetitive movement also increase patients' ability to perform activities of daily living and recover their physical performance.[11] However, fatigue due to prolonged physical activity negatively affects balance control and increases the risk of falling even after the cessation of exercise.[12] Previous studies showed that elevation in the risk of falls and increasing postural instability are caused by insufficient attention, memory, and executive functions.[13] Arjunan et al.,[4] mentioned that localized muscle fatigue might be a risk factor in causing slip-induced falls. Other studies also reported that fatigue can negatively affect muscle force-generating capacity,[14] balance,[15] and increase the asymmetry between the lower limbs during standing.[16]

In recent years, a few studies have investigated the relationship between postural stability during standing and muscle fatigue.[3,7] However, none examined the relationship between postural stability and fall risk due to muscle fatigue. Therefore, this preliminary study was conducted to identify the relationship between postural stability and fall risk among healthy young adults before and after lower limb muscle fatigue. The results will be beneficial to the young adult in performing an exercise, and therapists in identifying the effect of fatigue due to prolonged muscle activity on the patients. In addition, the results are expected to help young adults plan their prolonged activities and therapists in planning better treatments to increase postural stability and reduce fall risk.

Significance for public health

Understanding the relationship between postural stability and fall risk enables therapists to handle and rehabilitate patients who have a deficit in one of these areas with greater care. This is because postural stability and fall risk showed a significant association in this study, which suggests that a deficiency in one of these aspects might be related to the other. The data in this study can be utilized to educate young adults about the importance of maintaining postural stability to avoid falling. It is recommended that young adults monitor their muscle exhaustion levels throughout a repetitive activity and take a break when fatigue sets in.

Design and Methods

This was a preliminary study conducted to identify the correlation between postural stability and fall risk due to muscle fatigue. The data were collected from 2019 and stopped in 2020 due to the COVID-19 pandemic and the targeted population was healthy adults between the ages of 20 and 40 years. A total of seven participants aged 31.1±7.4 years participated in this study. Participants were excluded when they have any medical history regarding muscular or neurological disorders, lower limb injury, or balance disorders. Before the experiment commenced, the subjects read and signed a consent form after explaining the experimental protocols verbally. Institutional Review Board from University Medical Committee approved the test procedure (MEC 895.7). In addition, this study was registered in a WHO-compliant trial registry (Thai Clinical Trials Registry: TCTR20210805001).

All subjects performed fatigue protocol with repeated STS, the standard chair used in this protocol was a bench without armrests, 44 cm in-depth, 440 cm in width, 46cm in height. STS was performed with patients standing straight, knees completely extended, feet at the same distance apart as the hips, and upper limbs crossed in the anterior region. Subjects' feet were barefoot and shoulder-width apart, the heels and toes were marked on the floor at the same level to guarantee that the feet remained stationary throughout the procedure. The subjects were asked to stand and then sit repeatedly to the metronome's beat until they are unable to complete the procedure. The fatigue protocol was terminated when one of the following conditions were met: i) voluntary exhaustion occurred, ii) repeated STS movement remained below 35 beats/min, or iii) a 30-minute cut-off time was reached.[3]

The subjects' postural stability and fall risk were assessed using Biodex Balance System SD Inc., Shirley, NY (BBS), a computerized screening test. The BBS is a round platform that can move freely and is used to assess an individual's ability to maintain either static or dynamic postural stability as well as the anteroposterior and mediolateral axes. Patients were asked to look at a screen in the front to ensure the markers were in the midpoint of the targeted position. The vertical projection was kept with their center of gravity on the platform, then the Anterior-Posterior Stability Index (APSI), Medial-Lateral Stability Index (MLSI), and Overall Stability Index (OSI) were used to calculate the BBS postural stability score. For the fall risk measurement, the test began with an initial platform setting of 6 and ends with a setting of 2. The BSS was used to measure the degree of tilt in each axis, providing an average sway score and calculated in the BBS's software to identify the fall risk index. All the balance tests required that the subjects stand on the BBS without footwear. The BBS was used to assess the body displacement of sagittal and frontal plane motion, the x-direction represents the horizontal displacements along Medial-Lateral (ML) axes, while the y-direction represents vertical along Anterior-Posterior (AP) axes. Furthermore, the bipedal stance test to measure the postural stability score under the static level, and the fall risk under the dynamic level was accomplished using BBS. The subjects were asked to maintain a static standing position for 20s during the postural stability test which was performed five times with 10s between each, and all the data were averaged. The subjects were told to maintain their foot's placement on the platform throughout the balance test. All data were entered into a database and were verified before the analysis. Subsequently, the data were summarized in means as well as standard deviations or percentages forms. The normality of the variables' distribution was tested using Shapiro–Wilk test due to the small number of subjects, while the Wilcoxon signed-rank test was used in identifying the significant difference before and after fatigue on postural stability and fall risk. Furthermore, Spearman's rho correlation coefficient was used to examine the relationship between the study variables as all variables were not normally distributed. All statistical analysis was performed using the statistical software SPSS26.0 (Version26, IBMCorp., Armonk, NY).

Table 1. Subject's demographic data (mean ± SD).

	Subjects (n=7)
Age (Years)	31.1±7.4
Height (cm)	168.6±2.7
Weight (kg)	65.9±5.3
BMI (kg/cm^2)	23.1±1.8

Results and Discussions

All the participants were recruited before the Covid-19 pandemic started, the age ranged between 20 and 40 years with a mean of 31.1±7.4 years. On average, the mean scores of body mass index ranges (BMI) were normal namely 23.1±1.8. All subjects were instructed to perform experimental protocols and the results were recorded as shown in Table 1.

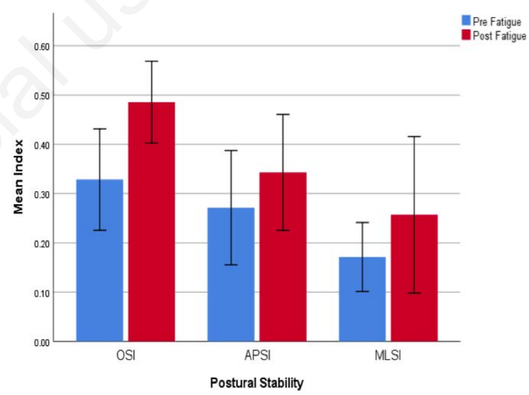

Figure 1. Mean of the postural stability before and after muscle fatigue.

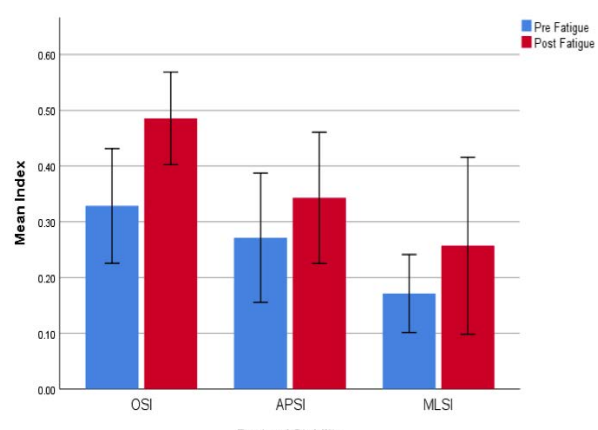

Figure 2. Mean of the fall risk before and after muscle fatigue.

The results showed an increase in postural stability index scores after fatigue with OSI 47.8 %, APSI 26.3%, and MLSI 46.8 %. Figure 1 shows the histogram of the three postural stability indexes scores before and after muscle fatigue. Based on the result, significant differences before and after fatigue were found only on the OSI ($p<0.05$) but not on APSI ($p=0.157$) and MLSI ($p=0.109$). The statistical analyses for this result are summarized in Table 2.

The fall risk analysis results presented in Figure 2 showed that the mean score increased after fatigue, but the increase was not significant as demonstrated by $p=0.149$. Furthermore, the scoring percentage (%) was determined by normalizing the data to the pre-fatigue score and calculating the increasing value in each subject. The histogram showed a 16.7% increase in fall risk after fatigue indicating that fatigue has the potential to increase fall risk. Table 3 presents the statistical analysis for the fall risk test, while Figure 3 shows the Biodex score for postural stability and fall risk. Spearman's rho correlation coefficient was used to assess the relationship between postural stability and fall risk. The results showed that there was a significant correlation between fall risk and OSI with $r= .81$, $p = 0.028$, N=7) but not with APSL $p=0.843$ and MLSI $p=0.640$. However, the APSI and MLSI showed a significant negative correlation with each other as indicated by $r= -.81$, $p=0.028$, N=7. This shows that the score in APSI and MLSI correlated, Table 4 presents the statistical analysis for the correlations.

One of the objectives of this study was to investigate the effect of muscle fatigue on postural stability pre and post fatigue. The results showed that the subjects demonstrated an increase in postural stability but only OSI showed a significant increase after fatigue compared to APSL and MLSI. However, all mean postural stability indexes showed an increase after fatigue. The OSI indicated that fatigue has a significant effect on increasing postural stability. This result aligns with previous studies that showed a relationship between fatigue and postural sway,[8,17] specifically with the anterior-posterior and medio-lateral center pressure.[8] This is presumably due to the effect of the sensorimotor process that can also affect the proprioceptive system and force-generating capacity.[18] Based on the results, the young adult subjects were considered to have good proprioception given that their APSI and MLSI showed no significant increase in postural stability. The subjects in this study have an excellent vestibular system that includes the proprioception, inner ear, and vision which send the sensory information used for balance.[19]

Other factors that contribute to postural stability were minimized by filtering the subjects, hence, individuals on medication, have musculoskeletal conditions, or neurological deficits were not recruited to avoid potential confounding factors affecting balance and falls.[13,20] Horak[21] mentioned that a few components might affect postural stability, such as control of dynamics, biomechanical constraints, cognitive processing, sensory and movement

Table 2. Postural stability index result pre and post fatigue.

	Median	Interquartile Range	SD	p
OSI				
Pre fatigue	0.30	0.20	0.11	0.026
Post Fatigue	0.50	0.01	0.09	
APSI				
Pre fatigue	0.20	0.20	0.13	0.157
Post Fatigue	0.30	0.30	0.13	
MLSI				
Pre fatigue	0.20	0.10	0.08	0.109
Post Fatigue	0.20	0.30	0.17	

p<0.05.

Table 3. Fall risk score pre and post fatigue.

	Median	Interquartile Range	SD	p
Fall Risk				
Pre Fatigue	1.80 1.20	0.81	0.149	
Post Fatigue	2.50	1.10	0.94	

*p<0.05.

Table 4. Correlations between fall risk and postural stability index (OSI, APSI, MLSI).

			Fall Risk	OSI	APSI	MLSI
Spearman's rho	Fall Risk	Correlation Coefficient	1.000	.809*	.093	.217
		p	.	.028	.843	.640
		N	7	7	7	7
	OSI	Correlation Coefficient	.809*	1.000	.000	.490
		p	.028	.	1.000	.264
		N	7	7	7	7
	APSI	Correlation Coefficient	.093	.000	1.000	-.808*
		p	.843	1.000	.	.028
		N	7	7	7	7
	MLSI	Correlation Coefficient	.217	.490	-.808*	1.000
		p	.640	.264	.028	.
		N	7	7	7	7

*p<0.05

strategies, as well as orientation in space. Humans can maintain posture by restoring balance, but this requires a great ability to control the Center Of Mass (COM) above an area of equilibrium,[22] maintain the Center Of Pressures (COP) to the base of support,[23] and control balance strategy during perturbation.[24] Furthermore, the sensory strategy for balance control also demonstrated the important role of integrated visual, vestibular, and proprioception aspects in quiet standing.[19]

The fall risk assessment for the young adult subjects indicated that the mean score percentage increased after fatigue but was not significant. This indicates that young adults have the potential to maintain their fall risk without other factors. However, the result showed a significant correlation between overall postural stability and fall risk after fatigue. In general, postural sway can induce an increase in fall risk after muscle fatigue for young adults. Previous studies that showed increased fall risk and decreased postural control in young adults mentioned the contribution of both physical and cognitive fatigue.[17,25] In contrast, this study only provided 30 minutes cut-off time for the fatigue protocol which did not significantly increase fall risk among young adults. The limited-time in this study might not be sufficient to show the severity of fatigue. This aligns with Kamitani et al.[26] which reported a positive association between fatigue severity and fall frequency. The positive relationship between fall risk and overall stability indicates that increasing postural sway can indirectly increase the fall risk. However, further studies with a more extended period of fatigue protocol are needed.

These results are consistent with previous studies which also reported that fatigue can increase the fall risk.[8,15,20,27–29] A few factors related to fatigue were mentioned including lower limb amputee, pain, diseases, and repetitive movements. In other studies, most of the risk factors associated with falls were primarily elderly patient cohorts and not young adults.[5,30–33] Furthermore, a higher rate of falls was detected in older adults with more severe fatigue than in those who reported milder fatigue,[26] but the cohort population in this study is younger compared to that of previous studies, with an age range of 20 to 40 years old. The results did not show a significant increase in fall risk in younger subjects, but the mean scores indicated a rise in fall risk by 16.7%. Nevertheless, this minimum risk needs to be considered as a potential of increasing falling. This implies that the age factor can be one of the components in identifying the fall risk.

Considering that this is a preliminary study, it has several limitations, first, only seven participants were recruited due to the COVID-10 pandemic and only focused on healthy young adults. Therefore, it is suggested that further studies be conducted on a larger amount of subjects with different age populations. Second, this assessment needs to be carried out for different levels of body mass index, as well as gender and condition of patients. It can also be a pilot study to identify the correlation between muscle fatigue and fall risk in different conditions and situations. This study protocol can be used for lower-limb amputees to analyze their adaptation during muscle fatigue and develop a rehabilitation program.

Conclusions

Fatigue of the lower limb muscles can impair overall postural stability of the body. Therefore, understanding the relationship between postural stability and fall risk enables therapists to handle and rehabilitate patients who have a deficit in one of these areas with greater care. This is because postural stability and fall risk showed a significant association in this study, which suggests that a deficiency in one of these aspects might be related to the other. By using a therapy method to improve one of these aspects, the other characteristics can also be improved concurrently. Therefore, the results have significant implications for monitoring fall risk and postural stability due to acute muscular exhaustion caused by recurrent multi-joint exercises and repetitive activities, mainly in the lower limb muscles. Additionally, the data can be utilized to educate young adults about the importance of maintaining postural stability to avoid falling. It is recommended that young adults monitor their muscle exhaustion levels throughout a repetitive activity and take a break when fatigue sets in.

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Availability of data and materials: All data generated or analyzed during this study are included in this published article.

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