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Original Article

Correlation between postural stability and fall risk in trans-femoral amputees due to muscle fatigue

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Abstract. [Purpose] This study aimed to establish a connection between postural stability and falling in individuals with transfemoral amputation (TFA), particularly with muscle fatigue. [Participants and Methods] Fourteen participants were recruited. Muscle fatigue was induced using a sit-to-stand (STS) fatigue protocol. Pre-fatigue and post-fatigue assessments were conducted using the Biodex Balance System (BBS). [Result] The findings of the study revealed significant increases in the postural stability index between the pre-fatigue and post-fatigue conditions for the TFA group, particularly in the overall stability index (OSI) and anterior-posterior stability index (APSI) components. The mean postural stability index scores for the TFA group exhibited a percentage increase of 65.2% for OSI, 52.7% for APSI, and 50% for medial-lateral stability index (MLSI). Furthermore, the TFA fall risk index surged by 61.4%. Regarding the relationships observed, a significant correlation emerged between fall risk and both OSI and APSI. [Conclusion] These findings underscore the impact of muscle fatigue on postural stability and an increase in fall risk among TFA. By mitigating the effects of muscle fatigue, therapists can play an important role in reducing the risk of falls and promoting better postural stability in this population.
Key words: Muscle fatigue, Postural stability, Fall risk

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INTRODUCTION

Muscle fatigue has been used to characterise a loss in muscles' ability to perform motions with optimum strength as a consequence of excessive muscular exercise[1]. According to Enoka and Duchateau[2], fatigue is a complicated condition marked by restrictions in both physical and mental skills caused by the combination of performance, sensitivity to tiredness, and subjective sense of weariness. Muscle tiredness has been linked to a number of undesirable outcomes in human performance. These impacts include a slower decision-making response time[3, 4], a loss in muscular strength[5, 6], worse capacity to manoeuvre around obstacles[7], an increase in the risk of falling among older people, and a drop in lower limb strength[7]. Many studies on muscular fatigue have been conducted, although the majority of them have focused on the elderly[7, 8]. At the same time, research on muscle fatigue and its relationship to fall risk and postural stability is very sparse. None of them look at the potential link between fall risk and postural stability in transfemoral amputees.

Active engagement in physical activities such as exercises and repetitive motions has been proven in the context of rehabilitation to improve patients' ability to do normal tasks and regain their physical functions[9]. Nonetheless, extended participation in these activities may cause weariness, which can impair the ability to maintain a stable body posture and

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increase the risk of falling, especially if it leads to a loss of physical strength[10, 11]. Concurrently, it has been noted in other research that tiredness may have a detrimental impact on the muscles' ability to create force[12], postural stability[13], and can result in asymmetry between the lower limbs when standing[10]. According to Arjunan et al.[4] localised muscle exhaustion may have a role in the incidence of slips and falls. Prior study has also shown that poor attention, memory, and executive skills might increase the risk of falling and worsen postural stability[14].

Patients with lower limb loss will need more rehabilitation sessions after receiving a prosthesis to recover to a high level of daily function[15]. The majority of amputee patients are mainly elderly adults with vascular disease and diabetes[16]. Amputations are becoming more common in the United States, with younger and middle-aged people and males bearing the brunt of the burden owing to trauma such as car accidents[17]. According to statistics from the Centres for Disease Control and Prevention, around 28.7% of senior people have a fall within a year[18]. Similarly, it has been shown that around 50% of people with amputations fall at least once every year. Furthermore, it has been shown that 40.4% of these falls result in damage, necessitating rehospitalization[19]. Furthermore, it has been shown that a considerable majority of people with lower limb amputations, particularly 56.1%, have experienced falling. Furthermore, 26.8% of people in this category have reported being injured as a direct consequence of these falls[20]. However, evidence on the prevalence of falls among physically active young adult amputees is still lacking. Falls may result in a variety of injuries, such as dislocated joints, shattered bones, muscle tears, and sprains[21].

Controlling our postural stability is a critical necessity for properly engaging in our everyday activities and handling a variety of complicated tasks[22]. Participating in physical activities, whether formal exercise or ordinary duties, may help us retain functional mobility in our lower extremities[14]. Previous research has demonstrated that therapies including posture-challenging activities have a favourable effect on lowering the risk of falls in healthy adults[23]. Furthermore, longer bouts of physical exercise have been demonstrated to improve patients' recovery and general health[24]. Given the foregoing, the purpose of this study is to look at the relationship between postural stability and the tendency to fall in people who have had a transfemoral amputation (TFA), both before and after the onset of lower-extremity muscular fatigue. The findings of this research might considerably help therapists comprehend the consequences of extended muscular activity-induced exhaustion on people. This discovery will allow therapists to create treatment techniques that are more effective in increasing postural stability and lowering the risk of falls in people who have had transfemoral amputations.

PARTICIPANTS AND METHODS

This study enlisted fourteen participations. Seven of the total sample size had undergone unilateral transfemoral amputation (TFA), while the remaining seven had no significant health issues. TFA participants were chosen from the BioApps Prosthetics Orthotics Centre at the University of Malaya using the following criteria: (1) male participants; (2) participants with a BMI in the normal range of 18.5 kg/m^2 to 24.9 kg/m^2; (3) participants aged 18 to 50 years; (4) participants with no history of peripheral vascular disease or any neurological or musculoskeletal disorders; (5) participants with a minimum of two years of experience with a permanent prosthesis; and (6) participants with an ambulation status of Medicare Functional Classification Level 3 or higher. These criteria were developed in order to rule out additional factors that could cause fatigue. If the participants experienced pain in their residual limbs during the experiment, they were ruled out. Following a verbal explanation of the experimental procedures, participants were required to view and sign a consent form prior to the start of the experiment. The University Medical Committee (MEC 895.7) granted ethical approval. The current study was properly authorised in accordance with World Health Organisation guidelines, and it was registered in the Thai Clinical Trials Registry under the identifier TCTR20210805001. The sample size for the research study was determined using the representative sample methodology and the Krejcie and Morgan sample size technique[25]. The sample size for this study was determined based on the identifiable population, which consisted of participants recruited at the University of Malaya Medical Centre through Bioapps Sdn Bhd.

The participants completed the sit-to-stand (STS) task as part of the fatigue protocol. The fatigue protocol used in this study was adapted from a previous study by Bryanton and Bilodeau[26]. The protocol included the following steps in order: The participants were placed on an armless bench that measured 44 cm deep, 440 cm wide, and 46 cm tall. The participants' feet were separated by the width of their shoulders and were not wearing any footwear. The researchers used floor markings to indicate the exact positions of the heels and toes of the feet, effectively preventing any unintentional movement during the fatigue protocol. Before attempting to stand, participants were instructed to sit comfortably and upright with their arms crossed across their chests. For each round of the sit-to-stand (STS) task, participants were instructed to stand up from the bench in an extended, upright stance. After a brief interval, they were to return to their original seated position, ensuring that their feet remained in constant contact with the force platform. The STS repeats were timed using an audible metronome set to beat at a rate of 35 beats per minute. The first beat started the rise, and the second beat started the descent. Participants had 30 minutes to complete the task, or until one of the following conditions were met: (a) they were unable to maintain the required tempo for five consecutive beats; (b) they had reached a point of voluntary tiredness; or (c) the planned 30-minute time limit had passed[26].

The Biodex Balance System SD Inc., Shirley, NY, USA (BBS) was used to assess the participants' ability to maintain balance as well as their proclivity to fall. This computerised evaluation was performed both before and after fatigue. The BBS is a circular platform with free mobility. It can assess a person's ability to maintain both static and dynamic postural stability by taking the anteroposterior and mediolateral dimensions into account. During the test, participants stood unaided on the BBS platform, crossing their arms over their chests for comfort. A vertical screen was set up in front of them, instructing them to keep their centre of gravity vertically projected halfway across the platform. The BBS postural stability ratings are the anterior-posterior stability index (APSI), medial-lateral stability index (MLSI), and overall stability index (OSI). The number of frontal and sagittal plane foot movements was indicated by these scores. The technique was used to determine fall risk using the same guidelines as the postural stability test. As part of the regular fall risk assessment, the platform settings were gradually reduced from level 6 to 2. Static stability was tested for 20 seconds during the assessment of postural stability and fall risk. After completing five test trials, each separated by a 10-second rest period, the data was averaged.

All of the collected data was thoroughly verified and entered into a database before beginning the statistical analysis. The demographic data and clinical assessments were summarised using means, standard deviations, and percentages. The Shapiro–Wilk test was used to determine whether the research variables' distributions conformed to normality. The Wilcoxon signed-rank test was used to identify differences in postural stability and fall risk between pre- and post-fatigue conditions. Because all of the variables had non-normal distributions, Spearman's rho correlation coefficient was used to investigate their relationships. For statistical analysis, the programme SPSS26.0 (Version 26, IBM Corp., Armonk, NY, USA) was used.

RESULTS

The experimental findings demonstrated that all mean postural stability indices (OSI, MLSI, and APSI) increased after fatigue for both TFA and normal groups. For the TFA participants, the OSI climbed 65.2%, the APSI 52.7%, and the MLSI 50%. In the meanwhile, the normal participants also demonstrated an increase in the mean score for the postural stability index, which resulted in 47.8% for the OSI, 26.3% for the APSI, and 46.8% for the MLSI. However, a significant rise after fatigue for TFA was identified only on the OSI ($p=0.016$) and APSI ($p=0.039$), whereas there was no significant increase in the APSI ($p=0.059$). The normal patients displayed a major gain in OSI ($p=0.026$), but the APSI ($p=0.157$) and MLSI ($p=0.109$) scores did not reveal a meaningful increase.

The result showed the increase in fall risk, revealing a considerable spike of 61.4% among those with TFA and a comparably lesser increase of 16.7% among normal participants. This data implies that weariness may increase the likelihood of suffering a fall, particularly in the TFA group. Furthermore, the scoring percentage (%) was derived by standardising the data to the pre-fatigue score, used as the baseline for the group of normal participants, and then measuring the degree of the rise for each group. The fall risk score revealed a large spike after tiredness, exhibiting a significant increase with a $p=0.018$ for the TFA group. Nevertheless, in the context of the normal participants who were in excellent health, the observed increase did not establish statistical significance, as indicated by a $p=0.149$.

In order to analyse the link between postural stability and fall risk among participants with transfemoral amputations (TFA), the Spearman's rho correlation coefficient was utilised. The findings demonstrated a considerable association between fall risk and the overall stability index (OSI) ($r=0.770$, $p=0.043$, $N=7$), indicating a meaningful positive link as well as the anterior-posterior stability index (APSI) ($r=0.805$, $p=0.029$, $N=7$). The study also indicated that the correlation coefficient between OSI and APSI is $r=0.837$, showing a substantial positive link. This association is statistically significant, with $p=0.019$. In a similar fashion, the APSI and MLSI rows expose correlation coefficients between APSI and other postural stability measures and between MLSI and other measurements, respectively. Notably, a correlation value of $r=0.917$, $p=0.004$, between MLSI and OSI is detected, showing a substantial positive link. Table 1 gives a full overview of the correlations.

Table 1. Correlation between fall risk and postural stability for transfemoral amputation (TFA)

			Fall risk	OSI	APSI	MLSI
Spearman's rho	Fall risk	Correlation Coefficient	1.000	0.770*	0.805*	0.588
	OSI	Correlation Coefficient	0.770*	1.000	0.837*	0.917**
	APSI	Correlation Coefficient	0.805*	0.837*	1.000	0.548
	MLSI	Correlation Coefficient	0.588	0.917**	0.548	1.000

*p<0.05 level (2-tailed), **p<0.01 level (2-tailed).
OSI: overall stability index; APSI: anterior-posterior stability index; MLSI: medial-lateral stability index.

DISCUSSION

This research set out to determine how postural stability is altered by muscle exhaustion, both before and after tiredness develops. The findings demonstrated that postural sway increased among participants who underwent transfemoral amputations, notably in terms of the overall stability index (OSI) and the anterior-posterior stability index (APSI). In general, among TFA participants, tiredness had a major influence on increased postural sway. This conclusion is similar with recent research[26, 27] that connected tiredness to postural sway, focused on the centre pressure in the anterior-posterior and mediolateral dimensions[26]. The postural stability index, especially for APSI and MLSI, did not substantially rise in the case of the normal participants. The findings show that the young adults in the healthy participants group had proprioception that was in excellent functioning condition. The normal participants in this research possessed a superb vestibular system made up of elements including proprioception, the inner ear, and vision, which collectively offer the sensory information essential for maintaining postural stability[28].

The fall risk score increased in both groups of participants. However, the considerable differences between pre-fatigue and post-fatigue were only found in TFA. These results are in accordance with existing research, which shows that weariness increases the likelihood of falling[7, 26, 29, 30]. However, the bulk of the risk indicators for falls were based on senior patient cohorts rather than young amputees. Other variables that have been evaluated include age, lower limb strength, and diseases that are associated to the risk of falling[31–33]. However, our TFA cohort sample is younger than previously explored, with an age range of 20 to 45 years old. Even though our research comprised younger people, the findings revealed an increase in the chance of falling. As a consequence, age is not a major factor of the risk of falling among TFA.

The findings demonstrated that normal persons might preserve their fall risk even in the absence of extra influencing factors. The findings, however, demonstrated a considerable connection between overall postural stability and fall risk after feeling weary. Overall, it was revealed that among normal young people, swaying of the posture increased the likelihood of falling after creating muscular exhaustion. Numerous studies have demonstrated that physical and mental weariness may increase the risk of falling and reduce postural control in young people[27, 34]. On the other hand, the 30-minute fatigue protocol in the research did not substantially increase the risk of falls among healthy young people, particularly in terms of the anterior-posterior stability index (APSI) and mediolateral stability index (MLSI). This study’s 30-minute time constraint could not have effectively showed how weary participants were. This conclusion is in accordance with study by Kamitani et al.[29], which demonstrated a clear association between the degree of weariness and the chance of falling. An increase in postural sway may indirectly increase the possibility of falling because of the positive association between fall risk and overall stability, however this notion needs additional investigation and requires a longer fatigue protocol.

A rigorous screening technique was employed to remove any confounding variables in order to ensure the accuracy of our research in determining postural stability. As a consequence, those who were taking medication, had musculoskeletal difficulties, or exhibited evidence of neurological abnormalities were purposely excluded out of the participants pool. This deliberate technique sought to get rid of elements that might impact balance and produce situations when individuals fall[35]. An relationship between the degree of tiredness and the incidence of falls in older persons has been found by an earlier research[29]. A greater incidence of falls was reported in persons who were more weary than in people who were more rested. However, the findings of our research did not demonstrate a substantial elevation in the fall risk score among young, healthy respondents. However, the mean scores did suggest a modest (16.7%) elevation in the fall risk. Even though this little rise seems minor, it’s vital to notice it as a potential marker of increased fall risk.

As a preliminary investigation, this study has significant limitations that should be addressed. The limits of the COVID-19 pandemic were principally responsible for the limited participant count of fourteen, and the young adult group remained the exclusive focus. Overall, the findings reveal a critical link between fall risk and postural stability measures in TFA participants. The presented correlation coefficients show the significance of these metrics in estimating fall risk in this specific population by revealing the direction and degree of these relationships. Strong “p” values and statistically significant correlations further verify the reality of these linkages. It is crucial to note that the limited sample size calls for careful interpretation and may emphasise the need for further thorough study to corroborate these results. The evaluation should also take into consideration a broad variety of criteria, including age, body mass index, gender, and numerous health conditions. To obtain objective data on fatigue conditions, we suggest that future research will use several parameters, such as electromyography, heart rate variability, and blood lactate concentration. Besides that, researchers also can use more quantitative research for the stability assessment to record accurate outcomes with standardized types of equipment. This experiment may operate as a pilot study to examine relationships between muscular tiredness, the risk of falling, and postural stability in diverse scenarios and contexts. A research design like this may be utilised to examine how lower-limb amputees adapt to muscle exhaustion and build rehabilitation strategies that are especially customised to their requirements.

In conclusion, lower limb muscular exhaustion may decrease postural stability and increase fall risk for TFA. Understanding the considerable correlation between postural stability and fall risk will assist therapists treat and rehabilitate patients who suffer from a deficiency in one of these characteristics since there is a significant relationship between them in this research. It indicates that the existence of a fault in one of these characteristics may signal a deficiency in the other areas. Using a therapy method to improve one of them may result in improvement in the others. Therefore, the findings may have substantial implications for monitoring fall risk and postural stability owing to acute exercise-induced muscle exhaustion from recurrent multijoint activities, particularly lower limb muscles. This data may also be used to train TFA to maintain their postural stability to avoid falling. On the other hand, they also need to alert their muscles to weariness during repeated activity and rest if fatigue arises.

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Conflict of interest

There are no conflicts of interest to declare.

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