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Functional Performance of Older Persons with Normal, Pronated and Supinated Foot

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Graphical abstract

Muscle strength	Foot postures	Balance Performance	
		r	p value
Lower extremity strength (LES)	Normal	**-.655**	**.000****
	Pronated	-.093	.626
	Supinated	-.337	.069
Ankle plantarflexors strength (APS)	Normal	.249	.184
	Pronated	**.464**	**.010***
	Supinated	.225	.233

*Significant at p<0.05. **Significant at p<0.01.

Abstract

Aging process is accompanied with muscle degeneration that may affect functional performance, especially those with foot deformities. This study aimed to investigate the muscle strength [lower extremity (LES), ankle plantarflexors (APS)] and balance performance, and determine the relationship of muscle strength with balance performance in older persons with different types of foot posture. A cross-sectional study was conducted among 90 community-dwellers, age ≥60-year-old. Types of foot (normal, pronated, supinated) were identified using the Foot Posture Index (FPI) (each group, n=30). The LES and APS were measured using the 30-sec chair-rise and heel-rise tests, respectively. Balance performance was measured using the four square step test (FSST). Analysis showed significant differences in APS (p=0.012) and balance performance (p=0.049) among different types of foot posture. Participants with supinated (13.81±4.32 rep) foot, had the lowest APS followed by normal (14.53±4.62 rep) and pronated (16.60±4.27 rep) foot. The pronated foot (15.26±5.62 s) had a longer duration to complete the FSST, followed by the supinated (13.22±2.99 s) and normal (12.77±2.82 s) foot. No significant difference was found in LES (p>0.05) among types of foot. It was found that balance performance was significantly correlated with LES in the normal (r=-0.655, p=0.00) foot, as well as with APS in the pronated foot (r=0.464, p=0.010). This study revealed that older persons with pronated foot are more vulnerable to functional performance decline. Hence, they may be at risk of falls and mobility impairment. Intervention targeted for the ankle and foot may differ depending on the types of foot.

Keywords: Balance, foot posture, muscle strength, pronated, older persons, supinated

1.0 INTRODUCTION

Foot problems are common in older persons [1,2]. Among all, foot pain is highly prevalent and has a significant detrimental impact on mobility and quality of life of older persons [3]. According to Molgaard *et al.* [4], the prevalence of foot pain was 30.4% with a total of 55.9% reporting pain in the foot, leg or back lasting more than 1 day within the previous month. Therefore, as a prevention, it is suggested that more attention should be focused on identification of foot deformity in order to provide client-centred intervention and thus prevent the occurrence of the foot pain rather than curing the pain.

The foot plays an essential role in all weight-bearing activities by absorbing shock, accommodating to uneven ground surface and helping in a momentum generation to propel the body forward [5]. A normal foot may have strong ligaments and normal height of one transverse and two longitudinal arches. However, according to Razeghi and Bhatt [6], the contour and biomechanics of the foot significantly vary between individuals, although they are having numerous similarities in terms of characteristics. In contrast, a study has shown that there will be changes in the function and structure of the foot with the increasing age [7] in which the foot arches become less pronounced, contributing to a slight loss of height. Muscles are less toned and less able to contract because of changes in the muscle tissue and nervous systems. In addition, foot and ankle characteristics have been shown to be important determinants of balance and functional ability in older people [8]. The contribution of foot deformities towards balance control may be worsened due to the normal aging process and physical inactivity that may generally affect the lower extremity. This is supported by Carty *et al.* [9], who revealed that lower limb weakness, especially the hip flexors and knee extensors, are associated with increase odds of requiring multiple steps compared with single steps to recover from forward loss of balance across a range of initial lean magnitude

Most previous studies on determining foot characteristics such as pain and toe deformities were without identifying the nature of the foot posture [10-13]. In contrast, it is arguable that functional disability due to a loss of muscular strength and power is more important than changes in lean muscle mass alone [14]. It is believed that functional capacity, specifically balance, such as the ability to walk at a reasonable speed for a moderate duration, are vital components of independence [15]. Previous study by Spink *et al.* [8], have found that foot and ankle characteristics, particularly the plantarflexors strength are important determinants of balance and functional ability in older people, however, this study did not report whether they classified the foot of the subjects into normal, pronated or supinated. Failure to identify the foot types may misguide therapist, especially when prescribing flexibility and strength training exercises. As such, it is the interest of this current study to classify the types of foot posture into normal, pronated, supinated. Therefore, the aim of this study was to measure the lower extremity and ankle plantarflexors muscle strength and balance performance, and determine whether balance performance is associated with muscle strength in older persons with different types of foot posture.

2.0 METHODOLOGY

This is a cross-sectional study that recruited 90 older women from the community. The participants were divided into three groups according to their types of foot posture which was assessed using the foot posture index, into normal, pronated and supinated. Each group comprised of 30 participants. The recruitment was done until each group reached a minimum number of 30 samples. The sample size was calculated using the Gpower 3 software. A sample size of 26 participants was shown to be sufficient to detect an effect size of 80% power and alpha 0.05. We increased the sample size to 30 each, anticipating about 20 to 30% of withdrawal while they were being assessed. However, upon reaching 30 participants, all of them completed the measurements. The criteria for participants to be included in the study were; (1) aged ≥ 60 years old, who were able to follow commands, (2) able to walk more than 10 meters with or without aid, (3) free from the history of orthopaedic conditions such as rheumatoid arthritis, severe osteoarthritis, acute fracture/injury or pain at the lower limb area and (4) free from a diagnosis or self-reported foot pain, previously and at the time of the study. The ethics approval was obtained from the University's Research Ethics Committee, and all participants signed written informed consents prior to measurements.

Participants's age (years), body weight (kg), height (m) and body mass index (kg/m^2) were recorded. The type of foot posture was determined using the foot posture index. While the 30 seconds chair rise test and heel rise-test were used to determine the participants' functional ability. The four square step test was used to measure dynamic balance performance. All measurements were performed by two or three research assistants who were trained in the measurements and had a bachelor degree in physiotherapy.

The foot posture index (FPI) was used to classify the participants types of foot posture, using a six scoring system [16]. The participants were required to stand with both feet shoulder width apart, while the assessor observed their foot from all planes which were frontal plane, sagittal plane and posterior aspect. The FPI six scoring system includes six components of palpation of fibular head, supra- and infra-lateral malleolar curvature, calcaneal frontal plane position, prominence in the region of the talonavicular joint, congruence of the medial longitudinal arch and abduction or adduction of the forefoot on the rearfoot. Each component scores ranging from -2 to +2. The summation from the score obtained was calculated to classify the participants into their respective groups [Normal (0 - +5), pronated (+6 - +9), and supinated (-1 - -4)].

Examination of the foot posture has been reported using normalised navicular height, arch index and radiological measurements [17]. However, compared to the other methods, we used the FPI as it is simple and quick to perform and allows a multiple segment, as well as multiple plane evaluation [16]. Furthermore, the FPI is not influenced by gender or BMI [18], and has been shown to be valid as a clinical instrument for use in screening studies [19].

The functional lower extremity strength (LES) was tested using the 30-second chair rise test [20] that involves a sit-to-stand movement. We chose the sit-to-stand test as it has been claimed to reflect a multi-dimensional functional movement involving more than just lower limbs [21]. The test is conducted using a chair (without arms) with seat height of 17 inches (43.2 cm), placed against a wall to prevent it from moving. The participants were instructed to sit in the middle of the chair, with the back straight and arms crossed at the wrist and held against the chest, while maintaining feet flat, shoulder width apart on the floor. The researcher demonstrated the procedure to the participants then they were allowed 2 practice trials prior to the real test. At the signal "go" the participant rose to a full stand and then returned back to the initial seated position. The participants were encouraged to complete as many full stands as possible within 30 seconds. The score is the total number of stands within

30 seconds (more than halfway up at the end of 30 seconds counts as a full stand). Incorrectly executed stands were not counted.

We used the standing heel-rise test to measure the ankle plantarflexors strength (APS) of the dominant leg. The plantarflexion movement of the ankle is a result from the combined action of the soleus and gastrocnemius muscles in the calf [22]. The participants were instructed to stand straight and to rise and lower on the balls of their feet in rhythm with the metronome, which was set at a rate of one heel-rise every 2 seconds. Each subject was allowed to touch the examiner with a single finger for balance. The test was terminated if the subject leaned or pushed down on the examiner, the subjects' knee flexed, the plantar flexion range of motion, decreased by more than 50% of the starting range of motion, or the subject quit or asked to stop. The participants were instructed to perform as many repetitions as possible. There were three testers for each subject. One tester provided the finger support, one tester observed the subject laterally for any extraneous trunk lean or knee flexion, and one tester observed the ankle range of motion. This protocol followed the procedure as described by Lunsford and Perry [23].

The four square step test (FSST) was used to test balance performance. This test clinically assesses the participants' ability to step over objects forward, sideways, and backwards [24]. The current researcher suggested that the FSST is more challenging than the FRT, as it (FSST) requires the participants to lift up the leg and coordinate their movement, as fast as possible. The participants were instructed to step over four canes set-up like a cross on the floor with the tips of the canes facing together. At the start of the test, the participants stood on the upper left square (in square 1, facing square 2). Then the participants started stepping clockwise (Square 1, square 2, square 4, square 3, return to square 1 with both feet). After that, participants continued stepping counterclockwise (Back to square 3, square 4, square 2, and end in square 1 with both feet). The assessor demonstrated the procedure once and allowed the participants to perform one practice trial prior to administering the test. Then the participants performed two trials, and the better time (in seconds) was taken as the score.

Data analysis was performed using the SPSS 20.0 software. Analysis was conducted to present the means and standard deviations for age, body mass index (BMI), LES, APS and balance performance. The normality test indicated that all variables of interest were normally distributed, thus, the parametric tests were used for further analysis. The one-way ANOVA was used to determine the mean differences in the variables of interest for all types of foot. The correlation analysis was done using the Pearson's correlation to determine the strength of the relationship between balance performance and LES as well as APS. The significant level was set at $p < 0.05$.

3.0 RESULTS

Ninety participants completed the study, with each group comprised of 30 subjects. There were no significant differences in age (F=2.355, p=0.101), body mass index (F=1.241, p=0.294) and LES ((F=1.092, p=0.579) among the normal, pronated, and supinated. However, significant differences were found in APS (F=8.817, p=0.012) and balance performance (F=6.020, p=0.049) among the different types of foot posture. The participants with pronated foot showed the highest score for APS but the longest time to complete the balance performance test. Table 1 shows the mean comparisons of all variables in participants with normal, pronated and supinated foot.

Correlation analysis using the Pearson correlation (Table 2) showed that balance performance was significantly negatively correlated with LES in the normal foot (p=0.000). While, balance performance was significantly positively correlated with APS only in the pronated foot (p=0.010).

Table 1 Mean comparisons between normal, pronated and supinated foot

Variables	Mean (SD)			F value	P-value
	Normal (n=30)	Pronated (n=30)	Supinated (n=30)		
Age (Years)	65.17 (4.62)	66.30 (4.51)	67.93 (5.68)	2.355	.101
BMI (kg/m²)	25.78 (3.88)	23.72 (6.61)	24.93 (2.83)	1.241	.294
LES (Rep)	12.1 (2.88)	11.53 (1.99)	12.53 (3.23)	1.092	0.579
APS (Rep)	14.53 (4.62)	16.60 (4.27)	13.81 (4.32)	8.817	**0.012***
Balance (Sec)	12.77 (2.82)	15.26 (5.62)	13.22 (2.99)	6.020	**0.049***

*Significant at p<0.05. BMI: Body mass index; LES: Lower extremity strength; APS: Ankle plantarflexors strength.

Table 2 Correlation between muscle strength and balance performance among different types of foot posture

Muscle strength	Foot postures	Balance Performance	
		r	p value
Lower extremity strength (LES)	Normal	**-.655**	**.000****
	Pronated	-.093	.626
	Supinated	-.337	.069
Ankle plantarflexors strength (APS)	Normal	.249	.184
	Pronated	**.464**	**.010***
	Supinated	.225	.233

*Significant at $p<0.05$. **Significant at $p<0.01$.

4.0 DISCUSSION

The main objective of this study was to compare the functional muscle strength (LES and APS) and balance performance among older persons with different types of foot posture. To the best of our knowledge, this is the first study that has attempted to investigate the muscle strength of the lower limb and balance performance based on the types of foot, classified as normal, pronated and supinated, in older persons.

In the current study, we found no significant difference in the LES among participants with different types of foot, which corroborates previous findings [25]. However, the mean for the LES for all three types of foot was much lower than the cut-off scores for moderately active older persons, that is, between 14 to 15 repetitions for older persons, between 60 and 74 years old [26]. We can further explain that none of the participants in this study participate in any kinds of physical activity or exercise that is aimed to improve fitness level. Therefore, we can conclude that, decline in the lower extremity muscle strength is generalized among older persons due to normal aging changes. Furthermore, we can also argue that, the test that was used to measure lower extremity strength could be influenced by a range of sensorimotor and psychological factors [21], which were beyond the scope of this study. Therefore, the types of foot may have less influence on the performance of the muscle strength, especially in the knee region.

Interestingly, we found a significant difference in APS among different types of foot posture. Our result shows that the supinated foot produces the lowest repetition for heel rise, which means that they stopped performing heel rise when they get fatigued. We also believe that generalized tightness around the foot and ankle may cause the older persons to generate muscle force in a slight uncontrollable manner due to muscle imbalances, in order to perform the correct movement required by the test. A supinated foot lacks joint mobility and pronation action to dissipate forces, and thus has less ability for shock absorption [27]. In addition, a supinated foot normally presents with decreased gastrocnemius, soleus and Achilles tendon flexibility [28]. Thus, there will be more tension to the plantar fascia that may not be able to control or produce a proper heel strike.

On the contrary, the pronated foot scored the highest repetitions which can be interpreted that this type of foot retains its strength or endurance. According to Rao *et al.* [29], during gait, ankle muscles contribute between 40 to 70% for forward propulsion compared to metabolic costs only 7 to 26%. Thus, it shows that ankle muscles, especially the gastrocnemius is responsible to generate force during walking far more than hip muscles, however, this may be affected the types of foot.

Next, we also found a significant difference in balance performance among the types of foot. Our finding shows that the supinated foot took a shorter time to complete the FSST compared to the pronated foot. Loss of plantarflexors strength has been linked with difficulties rising onto the toes [30], as should be expected in this current study, the participants with lower APS should present with longer duration to complete the FSST. However, based on the movement of the FSST, it requires more of a sidestepping action rather than ankle push-off and heel-strike, that may explain why the ankle plantarflexion movement was ignored. However, based on the current findings, the pronated foot took an average of more than 15 seconds to complete the FSST that may classify them at risk for multiple falls [24]. Further analysis shows that balance performance was significantly negatively correlated with LES in the normal foot, but significantly positively correlated with the APS in the pronated foot. This finding is also partially aligned with a previous study [8], who found a significant association between foot and ankle strength, range of motion, posture, balance performance and functional tests in elderly. However, the current study, classified the participants according to their types of foot, unlike the previous study [8]. This may indicate that the weaker the muscle the longer time to complete the task or vice versa. The current finding may support a recent systematic review [31] that concluded the existence of a relationship between pronated foot and increased lower limb motion during gait, however, this was not conclusive due to heterogeneity between studies and small effect sizes.

Several limitations can be highlighted from this study. Firstly, the small sample size could be related to the lack of significant findings in some of the variables. Furthermore, the subjects for this study were recruited among elderly women who were community ambulant, therefore this finding cannot be generalized to frail older persons especially those living in the residential aged care. We also could not identify whether the cause of the foot deformities was idiopathic or as part of the consequences of aging, as this may require a longitudinal study that follows an individual since younger age. Finally, we suggest that in the future, specific muscle strength need to be included in the study such as the ankle plantarflexors, dorsiflexors and the intrinsic muscles as these muscles are involved in maintaining the arches and functions of the foot.

5.0 CONCLUSIONS

In conclusion, weakness of lower extremity strength and the ankle plantarflexors may affect balance performance, mainly in older persons with pronated foot. Simply speaking, changes in the anatomical structure of the foot, may cause muscle weakness or muscle tightness, and in turn affect the dynamic balance of an older person.

Strong evidence suggested that foot and ankle exercise can improve certain fall risk-related motor outcomes and reduce falls [32]. However, healthcare providers dealing with falls management in older persons must be careful when prescribing foot and ankle exercise, should be based on a valid and reliable foot assessment. Based on the findings of the current study, types of foot must be determined prior to exercise prescription. For instance, for an older person presenting with pronated foot, may require specific strengthening exercise for the muscles of the foot and ankle. Similarly for older persons with supinated foot, may require specific flexibility or stretching exercises for the foot and ankle muscles. An inappropriate exercise prescription could be detrimental to the older persons with foot deformities.

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