ISSN- O: 2458 - 868X, ISSN–P: 2458 – 8687
National Library of Medicine - ID: 101731606

International Journal of Medical Science and Innovative Research (IJMSIR)
IJMSIR : A Medical Publication Hub
Available Online at: www.ijmsir.com
Volume – 9, Issue – 1, January – 2024 , Page No. : 83 – 91

Relationship between foot posture, hip abductor strength, and endurance in Nurses

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Citation this Article: Aishwarya Balachandra Shenoy, Ruth Boyle, Soni Srikantaiah, "Relationship between foot posture, hip abductor strength, and endurance in Nurses", IJMSIR - January - 2024, Vol – 9, Issue - 1, P. No. 83 – 91.
Type of Publication: Original Research Article
Conflicts of Interest: Nil

Abstract

Background: Prolonged standing posture at work leads to static contraction and also a reduction in the blood supply to the muscles particularly in the back and legs leading to muscle fatigue, and thereby affecting muscle endurance. Foot deviations also create alterations in the movement of lower extremities and can also magnify the risk of injury. This study has analyzed, if there is a relationship between foot posture (cavus, neutral, and planus) and hip abductor strength and endurance in a nurse's job that demands prolonged standing and walking.

Aim: This study was to correlate foot posture with Hip Strength and Endurance in Nurses.

Method: Nurses were recruited from the Hospitals and based on the sample size calculation and inclusion criteria, 22 nurses participated in the study. Measurement of foot posture was done using Arch Index (AI), hip abductor strength was evaluated using Humac Norm Isokinetic dynamometer, and hip endurance was evaluated using hip abductor endurance test (gluteal endurance measure-abduction). Statistical analysis of the data was done using Spearman's correlation to explore the relationship between foot posture and hip abductor strength as well as the relationship between foot posture and hip abductor endurance.

Result: The results of the study found a moderate negative relationship between the type of arch and hip abductor strength (ρ- -.384) and a weak negative relationship between the type of arch and hip endurance (ρ- -.227) However these were not statistically significance with p value was found to be greater than 0.05 signifying no statistical relationship between the three variables.

Conclusion: The results of the current study show that there is a moderate correlation between foot posture and hip abductor strength whereas a weak correlation was found between foot posture and hip abductor endurance in nurses. This partially implies that the type of arch may not have any effect on the Hip abductor strength and endurance.

Keywords: Foot posture, Arch Index, Hip abductor isometric strength, Hip abductor endurance, Nurses, Prolonged standing.

Introduction

Standing has been associated with versatility because of the mobility of the posture and the degree of freedom. However, this posture can lead to discomfort if it is

sustained for a long time.[1] The physical demands of nursing cause a great deal of stress, especially to the lower extremities of nurses. Typically, nurses walk 8 to 9.6 kilometers in a 12-hour shift, causing more stress on the feet and ankles than the general population and white-collar professionals.[2]

The risks associated with standing for long durations in the nursing profession at work lead to static contraction and reduction in the blood supply, oxygenation, and supply of nutrients to the muscles mainly in the lower back and lower limbs leading to muscle fatigue.[1,3,4]

Among the muscles of the lower limb surrounding the hip joint, hip abductors are widely regarded as the most important because they function as pelvic stabilizers (especially in single-limb positions). The hip abductor muscles include the Gluteus Medius (GM), gluteus minimus, and tensor fasciae lata (TFL).[5]

Hip abductor strength and endurance serve a vital role in the stability of the trunk and hip during ambulation as it transfers forces from the lower extremity to the pelvis and also contributes to medial-lateral balance in standing and walking. In the frontal plane, hip abduction strength is crucial to control the hip adduction demand moment.

As a consequence of hip abductor weakness, individuals may adopt movement strategies that compensate for these weaknesses by compensating with lower back, hip, and knee motions.[6]

According to some researchers, GM serves an important role in manipulating hip movement in a variety of ways. In an open chain, abduction and external rotation of the hip joint are controlled by the GM, predominantly by its intermediate and posterior fibers, whereas during the deceleration phase of closed chain activities, there is a centrifugal contraction of these fibers to control abduction and internal rotation of the hip joint. The angle of abduction of the hip joint and that of external rotation will increase if the GM strength is inadequate during landing.[7,8]

Since nurses stand and walk for prolonged periods, they tend to maintain a constant foot posture. The feet serve as levers and support the body's weight when performing work. Foot muscles maintain balance when the body's weight is in its center. Foot deviations create alterations in lower extremity movements and can also magnify the possibility of injury. The relationship between the foot and the increased risk of lower limb injury can originate from abnormal activity of muscles.[1]

A study done by Sadler et al found a significant correlation between foot posture and GM muscle activity. It was found that there is an inverse relationship between them i.e. A lower FPI score or a cavus foot type has higher levels of GM muscle activity (EMG) when compared to neutral and planus foot type during a short period of level ground during shooed walking.[9]

The GM must contract to keep the lower extremities in good alignment during heel kicks while running or walking. When the GM is weak, the hip joint adducts while causing internal rotation of the femur, knee, and tibia. This excessive internal rotation of the leg causes increased pronation of the foot.

The muscles that prevent excessive pronation are not strong enough to counteract these forces from the hips and lower legs. Thereby increasing the risk of overpronation and injury. Earlier studies have also shown a relationship between foot posture and EMG activity levels of hip abductors (GM predominantly).[10]

Literature is abundant on these individually in sports and the older population but literature is scarce in both foot posture assessment and its relation with hip abductor strength and endurance in a nursing population. Since nurses spend much of their time weight-bearing, it becomes crucial to evaluate the functions of these

muscles as their job demands prolonged standing and walking in improper footwear.

Determining if there is a relationship between foot posture and hip abductor strength and endurance in a nurse's job that demands prolonged standing and walking in improper footwear would help prevent its further implications on lower limb injury and other work-related musculoskeletal disorders.

An observation study aimed to explore the distribution of foot loading during gait in nurses using Baropodometric gait analysis (BGA) along with a Nordic musculoskeletal questionnaire (NMQ) evaluated the musculoskeletal disturbances. An asymmetry was observed in the load of the fourth and the fifth metatarsal heads when compared between the right and the left foot and in the load of the left and right lateral part of the heel with the BGA test. Therefore, it was concluded in this study that asymmetric distribution of foot load during gait leads to discrepancy between the loads on the three main support points of the foot which may affect their work productivity.[11]

GM, foot posture, and their relationship in prolonged standing.

A study was conducted on asymptomatic individuals to inspect changes in the trunk and hip muscle activation patterns during prolonged standing while performing simulated occupational tasks. Participants stood for 2 hours in a constrained area while they completed a series of four different simulated occupational tasks in blocks of 30 minutes. The conclusion was that the participants who developed LBP during prolonged standing demonstrated activation of both the left and right GM muscles versus synergistic, reciprocal activation of these muscles in those who did not develop LBP.[12]

An evaluation of the body of literature on the subject was conducted by Powers et al to determine if abnormal hip mechanics contribute to injury development in different ways. The biomechanics of the knee can be altered by weak hip abductors, which can cause either knee valgus or varus,) according to the study resulting in excessive strain on the anterior cruciate ligament (ACL), medial collateral ligament (MCL), or lateral collateral ligament (LCL). This may result in increased lateral pressure on the patella and increased tension in the iliotibial band. Friel et al discussed that inversion ankle sprains may result when hip muscles do not exert effective control, resulting in errors in foot placement. When balance is challenged at a level that cannot be rectified by ankle and foot muscles alone, the GM is unable to counteract the increased lateral sway that occurs.[13]

In another study done by Salavati et al. that fatigue of the muscles around the hip causes a considerably higher decline in stability than fatigue of the ankle muscles. The studies by Mullen et al also found that eccentric hip abduction fatiguing significantly impaired the performance of men and women in a static balance test for the single leg and a dynamic balance test. Since fatiguing regimes affect multiple muscles simultaneously balance changes may at least partially be due to the fatigue of other structures. [14]

The relationship between foot type and GM activity during gait was studied. Foot type was determined using the Foot Posture Index (FPI) and GM muscle activity was measured with surface EMG during shod walking in 50 adults. They were then fitted with foot orthoses for four weeks. The study found that people with a cavus foot type showed higher levels of GM muscle activity compared to neutral and planus-type feet during a limited period of level ground walking with a shoe or shod walking.[9]

GM and measurement of its strength and endurance

To measure GM strength and endurance before and after 2 hours of prolonged standing tasks among individuals

who did and did not develop pain in the lower back, a study was conducted by Paul W.M. Marshall et al. Continuous EMG was collected from GM during the 2-hour protocol for analysis of co-activation on both sides. The study concluded that hip abduction strength decreased for both groups following prolonged standing, with no between-group difference. Side-bridge endurance and hip abduction strength were significantly lower when associated with higher GM co-activation but not pain levels.[15]

Another study was conducted to develop a lower extremity muscle strength testing protocol and measure the test-retest reliability of isometric torque and peak isokinetic measures. This study done by Katrina A. McQuoid et al reports the test-retest reliability of the protocol alpha version, including isokinetic and isometric measurements of the hip movements like flexion, extension, abduction, and adduction, knee movements like flexion and extension, and ankle plantar flexion and dorsiflexion bilaterally in young healthy persons using the Cybex Norm Isokinetic Dynamometer (HUMAC, CSMI, Norwood MA). It was conducted to be a reliable measure of strength.[16]

A cross-sectional study aiming to investigate the intra- and inter-rater reliability of two clinical gluteal endurance measures (GEMs) convenient for use was conducted in a healthy population. The study concluded that high intra-rater reliability was demonstrated by both GEMs (ICC 0.87-0.94) and inter-rater reliability (ICC = 0.99). This seminal study by Bryan Jason Lehecka (2018) of GEM-A and GEM-B found both measures to be reliable and valid measures of gluteal endurance. [17]

Since there was very little scientific evidence available regarding the relationship between Foot posture and hip abductor strength and hip abductor endurance, it was clear that this study had aimed to correlate foot posture with Hip strength and Endurance in Nurses.

Figures and Tables

The Ethical clearance for this study was obtained from the Institutional Scientific and Ethical Committee and according to inclusion criteria age of nurses between 25 – 45 years and more than 1 year of experience were included and exclusion criteria with a history of lower limb trauma, surgery, pregnant nurses and hip pain or injury were excluded. Sample size was estimated, based on the study by Stephen et al, 2014 titled “The relationship among foot posture, core and lower extremity muscle function and postural stability” and assuming an expected correlation of 0.4 between the foot posture and hip abductor strength and endurance, the minimum sample size for a H0 of 0.63, α of 0.05 and a power of 95 %, the sample size was estimated to be 22 and by convenient sampling method 22 samples size was taken for the study. The objectives of the study were explained and written consent was taken from the nurses before enrolling them in the study. We aimed to correlate foot posture with Hip Strength and Endurance in Nurses and the outcome measures used were Arch Index (AI) to measure foot posture, Isometric testing for hip abductor using Humac Norm Isokinetic Dynamometer, and Hip abduction endurance test to hip abductor endurance.

The procedure of testing:

Arch index: As per the guidelines of the Arch index which is the relation between the mid-foot area which is divided by the sum of the area of the whole foot and the toes are excluded [18] foot posture was measured.

Hip abductor endurance: For spatial reference, the subject was lying sideways with the back lightly touching a wall behind. The top lower extremity hip and knee were in neutral, resting on the bottom lower extremity. To

allow the plantar surface of the foot to rest on the wall behind, the knee and hip of the bottom extremity were flexed to 90° and 45°, respectively. For pelvic monitoring, the top arm was rested on the top iliac crest. With the subject's head resting on a pillow with the trunk in a neutral position, the bottom arm rested in a comfortable position. The subject's lowermost extremity was abducted to 30°. The subject was asked to actively maintain 30° of abduction of the hip as long as possible. Time was not revealed to the subject before all the tests were complete. The test was terminated when a height loss of more than one-fourth of the starting position height was witnessed over a period of three seconds, or when the limb was in contact with the resting surface.[17]

Figure 1: Assessing Hip Abductor Endurance

Hip abductor strength

Preparation of Machine: Calibration of the dynamometer was performed and the machine was set by attaching the hip and knee adapter to the dynamometer in a way to allow hip abduction of the dominant leg. The seat was reclined to allow the patient to lie on the side lying. In the Humac Norm Software, the pattern was chosen as 'hip abduction/adduction', and the mode was set as 'Isometric testing' with the isometric angle at 0°. Number of trial repetitions was set to 2 repetitions. Test repetitions were set to 3 repetitions with a work period of 5 seconds and 10 seconds of rest between each repetition.

Procedure for testing and position for hip abductor strength

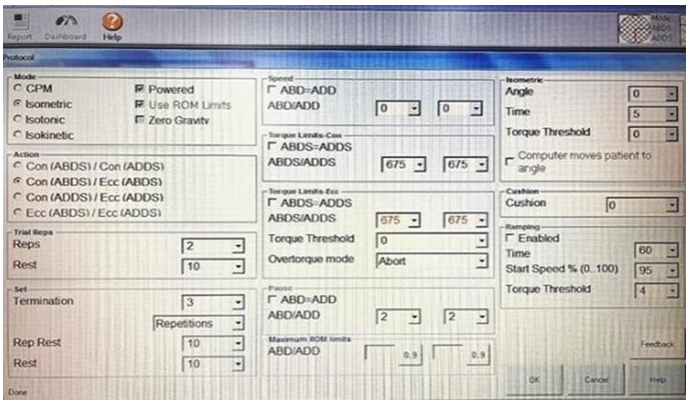


Figure 2: Software settings for assessing hip abductor isometric strength

Figure 3: Assessing hip abductor strength using isokinetic dynamometer

Figure 4: Assessing Hip abductor strength using isokinetic dynamometer

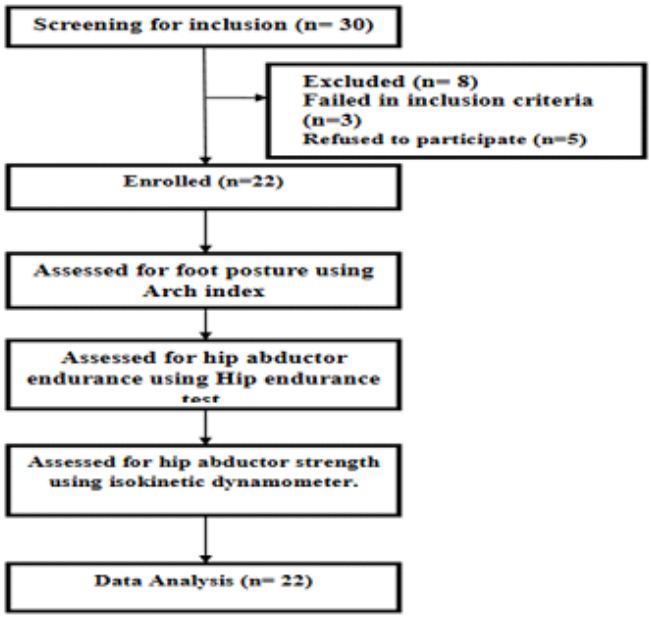
The subject was positioned on the side-lying and the side to be tested on top. The untested knee was flexed to 90° to improve stability. The dynamometer arm for placed

proximal and lateral to the knee joint and the axis of rotation was set at the greater trochanter. The subject was then secured with two straps at the iliac crest and one on the distal thigh of the untested limb. The test was then started and the patient was asked to abduct the hip against the dynamometer arm for 3 repetitions, 5 seconds each of maximal isometric effort.

Result

This study conducted, assessed the foot posture, hip abductor strength, and hip abductor endurance in nurses to find if there was a relationship between the three.

Strobe diagram



The participants in this study presented predominantly with normal arch and high arch. There were 10 with a normal arch, 8 with a high arch, and only 4 with a low arch. Foot type was based on the arch index value where ≥0.260 were considered low arch; indices between 0.210 and 0.260 were considered normal and the ones ≤ 0.210 were considered high arch.

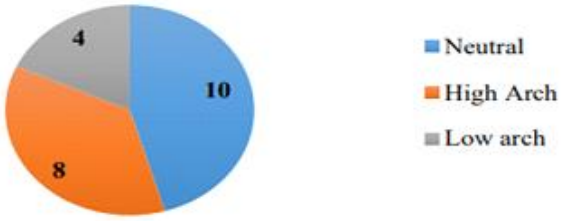


Figure 5: Arch Type distribution

The values of Arch index, Hip abductor strength, and Hip abductor endurance were expressed in terms of median and inter-quartile range as the data was not normally distributed.

Table 1: Value of Arch Index, Hip abductor strength and endurance

VARIABLE	MEDIAN	INTERQUARTILE RANGE
ARCH INDEX	0.22055	(0.207, 0.25) 0.04286
HIP ABDUCTOR STRENGTH (Nm)	61	(52, 65) 13
HIP ABDUCTOR ENDURANCE(sec)	72.25	(61.3, 85.5) 24.2

The relationship between arch index (AI) and each of the baseline hip abductor strength and hip abductor endurance variables was investigated using Spearman's correlations as the data was not normally distributed. (Table 2) The p-value was kept at <0.05

Table 2: Correlation between Arch Index, Hip abductor strength, and Hip abductor endurance.

SPEARMAN'S RHO		Hip strength	Hip endurance
Arch Index	Correlation Coefficient	-.384	-.227
	Sig. (2-tailed)	.078	.309
	N	22	22

Between AI and hip abductor strength, there was a moderate negative correlation found. (ρ = -.384) This means that the higher the AI score, the lower is the hip

abductor strength. (Table 3; Figure 2) However, the correlation was statistically not significant. (p >0.05)

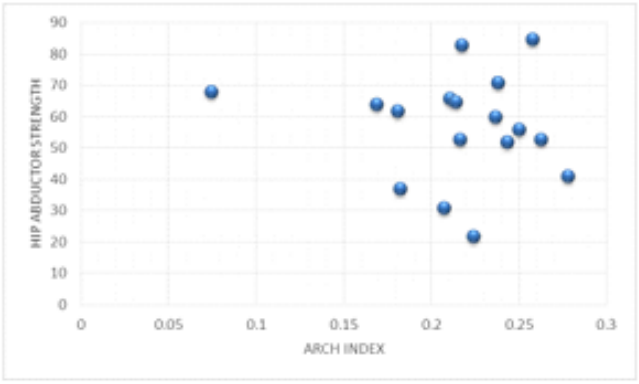


Figure 6: Scatter plot for Spearman's correlation between Arch index and hip abductor strength.

The results also showed that AI and hip abductor endurance showed a weak negative correlation. (ρ = -.227) This suggests that as the AI score increases, hip abductor endurance reduces. The results were however statistically not significant. (p> 0.05)

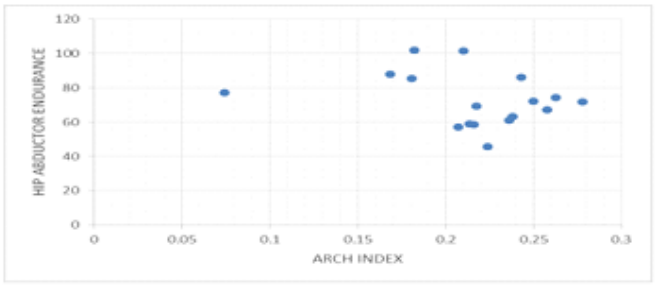


Figure 7: Scatter plot for Spearman's correlation between Arch index and hip abductor endurance.

Discussion

Nursing professionals are considered to have a high risk of WMSDs, namely prolonged standing and long walks along with a high prevalence of MSDs compared to other professional fields. Biomechanical data support that over-pronation or over-supination of feet can influence lower extremity alignment as well as excessive foot postures. As the body functions in a closed kinetic chain, any biomechanical variation of the ankle joint cannot be limited only to the ankle and its surrounding structures and may affect the muscle characteristics of other lower limb joints. In the stance limb, in case of hip abductor weakness, it causes a drop in the pelvis of the swing limb. The knee adduction moment and medial joint compressive forces increase with moving away from the stance knee, leading to progressive deterioration of muscle strength. During weight-bearing movements, weak hip abductor muscles may affect force generation, which impairs knee joint loading. There is minimal actual evidence to support the concept of foot arch being associated with Hip abductor strength and endurance in a prolonged standing profession. We, therefore, sought to assess the foot arch and Hip abductor strength and endurance and to explore if there is a relationship between the three. The foot posture which when related to the hip abductor strength and endurance was weakly correlated. However, it was found that there was no statistically significant correlation between the foot arch and hip abductor strength and hip abductor endurance. The participants were hypothesized to have a high arch (low value based on AI) and low hip abductor strength low hip abductor endurance and vice-versa. This theoretical hypothesis was supported by an EMG study conducted by Sadler et al where it was found that individuals having high arch foot type exhibited higher levels of GM muscle activity on EMG when compared to neutral and planus-type feet during level ground walking with shoes.9 It was also supported by another study that found that cavus and supinated feet were characterized by a lack of motion that may have caused an increased level of activity and a later activation of lower leg lateral muscles and pelvis as compensation for a higher vertical loading rate. Higher levels of muscle activity of the muscle over a long period due to the maintenance of a constant foot posture due to prolonged standing and walking could lead to fatigue in those groups of

muscles.[19] The results however show that participants with a high arch had high abductor strength and endurance. This correlation was however statistically not significant. The significance of the correlation would have been affected due to a smaller sample size and smaller effect size. The findings of this study are in accord with a previous study that concluded that people with increased pronation at the foot had reduced hip abductor strength relative to adductors. The participants presented predominantly with normal arch and high arch. There were 10 with a normal arch, 8 with a high arch, and only 4 with a low arch. Foot type was based on the arch index value where ≥0.260 were considered low arch; indices between 0.210 and 0.260 were considered normal and the ones ≤ 0.210 were considered high arch. Further analysis was also performed to understand if a particular type of foot posture showed any difference in hip abductor strength and hip abductor endurance when compared to another type of foot posture. The statistical analysis demonstrated a significant difference between low arch and neutral foot posture, as well as, high arch and neutral foot posture, while there was no significant difference was observed in hip abductor endurance between high arch and low arch foot posture found. However, the distribution of samples in each type of foot type was inadequate to draw a strong conclusion. The design of the present study limits to guarantee that hip abductor strength produces a change in the foot posture however from a biomechanical understanding, strengthening of the hip abductors could be beneficial for preventing and treating a lower limb injury.

Conclusion

The results of this study show that there is a moderate correlation between foot posture and hip abductor strength whereas as a weak correlation between foot posture and hip abductor endurance in nurses. This partially implies that the type of arch may not have any effect on the Hip abductor strength and endurance.

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