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Diagnostic Methods

Iliopsoas muscle thickness and pelvic alignment in pronated and normal foot postures

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ABSTRACT

It is hypothesized that the subtalar hyperpronation may provoke the development of a biomechanical chain of events in lower extremity alignment. Several studies have shown that pelvic alignment may alter in the presence of immediate foot hyperpronation induced by external forces. It is unknown whether these alterations are presented in chronic foot hyperpronation or not. It is also unknown if these potential postural changes could affect iliopsoas muscle size. Therefore, it appears necessary to carry out thorough research in this study. Twenty nine females with pronated foot posture and twenty seven females with normal foot posture participated in this study. The iliopsoas muscle was measured using ultrasound imaging (USI). Pelvic angle (PA) was measured using reflective markers and digital photography. Intrarater reliability of USI for the iliopsoas muscle thickness was also measured. The results indicated that the iliopsoas muscle thickness and the PA were not different in individuals with pronated foot compared to the normal foot group. However, a good intrarater reliability of USI was found for measuring the iliopsoas muscle thickness.

1. Introduction

The ankle and foot complex, consisting of 28 bones and 25 component joints, is well-designed to act as a linkage between the supporting surface and the lower extremity (Arnold et al., 2014). Acting as a functional unit, the subtalar joint connects the foot and shank (Khamis and Yizhar, 2007). Correct function of the subtalar joint during weight bearing activities is essential to dampen the rotational forces imposed by body weight (Levangie and Norkin, 2011).

Occurring across the three cardinal planes, protonation of the subtalar joint is associated with calcaneal eversion and talus adduction and plantarflexion (Pinto et al., 2008; Rockar Jr, 1995). Hyperpronation as an abnormal function of the subtalar joint is characterized by excessive and prolonged rearfoot protonation during weight bearing activities such as gait (Khamis and Yizhar, 2007). As the talus fits tightly into the ankle joint mortise, motion of the subtalar joint may affect tibial rotation during the gait cycle. Transverse motion of the talus during subtalar joint protonation is coupled with internal rotation of the tibia, while the tibia is externally rotated during supination (Tiberio, 1987).

Hyperpronation of the subtalar joint may result in excessive internal rotation of the tibia even in the midstance phase of gait, preventing tibial external rotation. This movement is necessary to accomplish the “screw-home” mechanism as a prerequisite for the terminal knee extension. Consequently, internal rotation of the femur may occur to complete knee extension and lock the knee. In other words, the rotation of the tibia is associated with rotation of the femur in a similar direction (Duval et al., 2010; Khamis and Yizhar, 2007).

The iliopsoas muscle, consisting of the two major portions of psoas major and iliacus, provides stability and mobility to the trunk,

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pelvis and the lower limb (Andersson et al., 1995). With different origins, psoas major and iliacus merge at the level of L_5-S_2 vertebrae and insert into a common tendon on the lesser trochanter of the femur (Anderson, 2016; Andersson et al., 1995).

Internal rotation of the femur resulting from hyperpronation of the subtalar joint is supposed to change iliopsoas muscle tension (Botte, 1981; Pinto et al., 2008) with regard to the insertion of the muscle to the femur. On the other hand, these postural changes may lead to the head of femur becoming posteriorly located, exerting pressure on the posterior portion of the acetabulum. The posterior pressure of femoral head on the acetabulum may lead to anterior tilt of the pelvis over the time.

As a safe, valid, non-invasive and readily accessible method, real-time ultrasound imaging has been used for objective measurement of muscle size in different muscle groups (Ashnagar et al., 2019; Dieterich et al., 2014; Giles et al., 2015; Silva et al., 2013; Worsley et al., 2014). It has been shown that ultrasound imaging is a valid tool for measuring the size of the iliopsoas muscle (Mendis et al., 2010). However, most of the studies on iliopsoas size measurements have focused on the iliopsoas musculotendinous unit (Anderson, 2016; Guillin et al., 2009) or isolated measurement of the psoas major muscle at the level of lumbar spine using ultrasound imaging (USI) (Ikezoe et al., 2011; Takai et al., 2011).

It is hypothesized that hyperpronation of the subtalar joint may cause a chain of mechanical events up to the pelvis (Duval et al., 2010; Khamis and Yizhar, 2007; Pinto et al., 2008). However, the impact of these postural modifications on iliopsoas muscle size has not been studied. Therefore, the objectives of this study were to investigate the thickness of the iliopsoas muscle as well as pelvic alignment in individuals with pronated foot compared to normal foot posture. Another aim of this study was to assess the intrarater within-session reliability of ultrasound imaging measurement of the iliopsoas muscle thickness.

2. Method

2.1. Participants

29 females with a pronated foot (FPI score more than 5) and 27 healthy females with a normal foot type (FPI score equal or less than 5) as controls were purposely recruited through posters placed in university communities. Being a reliable and valid tool, the six-item foot posture index (FPI) was used to classify the pronated and normal foot groups (Cornwall et al., 2008; Redmond et al., 2006). None of the participants had a recent trauma, lower limb fractures, surgical history or pain in the lumbar region or lower limb for at least 3 months prior to their participation in this study. This study was approved by the ethical committee of Tehran University of Medical Sciences and all participants signed a consent form before the research proceeded.

2.2. Ultrasound measurement

Participants were asked to lie supine on an examination plinth. A pillow was placed under their knees in order to form 15° knee flexion and 5° hip flexion. Two-dimensional B-mode USI (HS-2600 by Honda Electronics Co, Japan) with a 50 mm, 5 MHz linear array transducer (HLS-475M by Honda Electronics Co, Japan) was used to capture images from the iliopsoas muscle. An adequate amount of transmission gel was used in order to achieve acoustic coupling. The linear transducer was located at the inguinal crease exactly over the hip joint. the identified femoral head, as a crescent of echogenic brightness on the screen, and the pulsing femoral artery, were visible on the screen to orientate the iliopsoas muscle boundaries (Mendis et al., 2010). The ultrasound images of the iliopsoas muscle were obtained and measured by a trained physiotherapist in the use of rehabilitative USI who was blind to the group allocations. Three images were captured with the probe removed between each scan. The captured images were saved in JPEG format for subsequent analysis using Image J software (National Institute for Health, Bethesda, MD, USA).

Muscle thickness of the iliopsoas was defined and measured as the distance between the superficial and the deep fascia of the muscle along with the most superficial border of the femur. The thickness was measured using a straight-line tool of the software (Fig. 1).

2.3. Pelvic angle measurement

The pelvic angle (PA) was measured using digital photography in sagittal plane whilst the reflective markers were attached to the ASIS and PSIS. Because of the presence of excessive soft tissue in the lumbar area in females, a custom-made marker was adhered to the 5 cm plastic stem and used for PSIS.

The participants were asked to stand on a 50 cm high table while their feet were positioned shoulder-width apart, toes facing forward in an equal distance from the center of the table and upper extremities crossing over their chest and look forward. A Canon PowerShot SX710HS (Canon Inc., Tokyo, Japan) digital camera (20.3 megapixels) was mounted on a tripod and at 3 m distance away from the center of the table. The tripod was adjusted at 80 cm height and leveled by a bubble level. The leveled camera was positioned while the optical axis of the camera was perpendicular to the center of the box (Ashnagar et al., 2017).

The PA was measured, as the angle formed between the lines from ASIS to PSIS with the horizontal line, using the angle tool of the Image j software (Lima et al., 2015; Lopes et al., 2014).

Since the PSIS marker was attached to the 5 cm plastic stem, the real position of the PSIS on the body was found using trigonometric functions. The mathematical procedure was previously described in details (Ashnagar et al., 2017).

The PA was measured three times and the average of the trials was calculated and used for data analysis. Intrarater reliability of the PA measurement using digital photography was previously investigated and showed good results (0.75 < ICC<0.9) (Ashnagar et al., 2017).

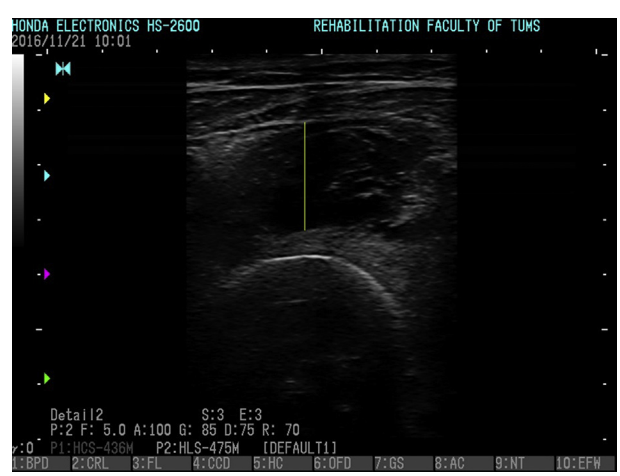

Fig. 1. Ultrasound measurement of the thickness of the iliopsoas muscle. The vertical line represents iliopsoas muscle thickness.

2.4. Statistical analysis

The statistical analyses were carried out using SPSS 22.0 (SPSS Inc., Chicago, IL). To assess the intratester reliability of ultrasound measures, the interclass correlation coefficient (ICC) with 95% confidence intervals (CI), standard error of measurement (SEM) and minimal detectable change (MDC) were computed. The ICC values were interpreted according to Portney and Watkins (Portney and Watkins, 2000). Independent *t*-test was used to assess the significant differences in the iliopsoas muscle thickness and PA between the pronated and normal foot groups. Significance Level was defined at $P < 0.05$.

3. Results

Twenty nine females with pronated foot (age: 24.24 ± 4.02 years, height: 161.34 ± 6.82 cm, weight: 60.62 ± 8.47 kg, BMI: 23.23 ± 2.6 kg/m^2) and twenty seven females with normal foot type (age: 24.33 ± 4.95 years, height: 164.3 ± 3.85 cm, weight: 61.06 ± 8.38 kg, BMI: 22.61 ± 2.98 kg/m^2) participated in this study.

The ICCs with 95% CI, SEMs, and MDCs for the intrarater reliability of ultrasound measures for the iliopsoas muscle thickness are presented in Table 1. Intrarater within-session reliability was excellent and The SEM values were relatively low for both iliopsoas muscle thickness in both pronated and normal foot groups (Table 1).

Means and SDs of three measurements for the iliopsoas muscle thickness and PA as well as a comparison of both pronated and normal foot groups were presented in Table 2. The thickness if iliopsoas muscle and PA were not significantly different between pronated and normal foot groups (Table 2).

4. Discussion

The main goal of this study was to compare the iliopsoas muscle thickness in individuals with pronated and normal foot types using ultrasound imaging. The intrarater within-session reliability of ultrasound imaging measure for the iliopsoas muscle thickness was also assessed.

Another aim of this study was to assess the PA in both pronated and normal foot groups using digital photography and reflective markers.

The results of this study revealed that iliopsoas muscle thickness was not different in individuals with pronated foot compared to the normal foot group.

To the best of our knowledge, no study was conducted yet to assess the size of the iliopsoas muscle in individuals with a pronated foot.

The psoas major muscle, as an important part of the iliopsoas, originates from the lateral aspects of the lumbar vertebrae and merges with the iliacus muscle at the level of L_5-S_2 vertebrae (Penning, 2000). This muscle plays an important role in preventing the lumbar spine from buckling and control lumbar lordosis (Hadjipavlou et al., 1996). Taken together, it seems that the psoas major muscle size may be related to the lumbar spine posture. However, as we did not assess the lumbar spine curvature in this study, it is not known that whether all the participants had normal lumbar lordosis or not. In other words, the size of the iliopsoas muscle may be affected by the posture of the lumbar spine as the psoas major arises from the lumbar vertebrae. Further studies were needed to confirm this hypothesis.

The findings of this study showed a good intrarater reliability of ultrasound imaging measurement for the iliopsoas muscle thickness. Only one study was assessed the validity and intrarater within-session reliability of the ultrasound imaging for iliopsoas muscle size. The results of Mendis et al. showed that ultrasound imaging is a valid and highly reliable tool for the assessment of the cross-sectional area of the iliopsoas muscle in healthy subjects (Mendis et al., 2010). Despite the high values of the ICCs found in the Mendis et al. study, the confidence interval was somewhat wide for this muscle (95% CI: 0.43–0.96).

To measure the cross-sectional area of a muscle, the operator should manually trace the outline of a given muscle, while the distance between the superficial and deep fascia of a given muscle along with the specified landmark, were measured easily for the muscle thickness. It seems that the possibility of occurring errors in the cross-sectional area measurements is somewhat high due to manually depicting of the entire outline of a muscle.

In addition, the results of Abe et al. study revealed a highly and significantly correlation between muscle thickness and cross-sectional area (Abe et al., 1997). It seems that the ultrasound imaging measurement of the iliopsoas muscle thickness can be used as an alternative method for the muscle cross-sectional area; however, further studies are needed to assess the validity of the iliopsoas thickness measurement using ultrasound imaging with a "gold standard" such as MRI.

The findings of this study showed that the PA was not significantly different in individuals with pronated foot compared to the normal foot group. Previous studies suggested that foot hyperpronation may lead to the changes in the lower extremity alignment and pelvic position (Khamis and Yizhar, 2007; Pinto et al., 2008). According to the "ground up" approach, any biomechanical malalignment in distal structures may affect the proximal ones (Hollman et al., 2006). Khamis and Yizhar found that internal shank rotation, internal hip rotation, and anterior pelvic tilt were increased while the foot hyperpronation was induced by standing on the wedges at various angles (Khamis and Yizhar, 2007). Additionally, Pinto et al. found the average pelvic anteversion of 1.57°

Table 1
Intratester within-session reliability for iliopsoas muscle thickness in pronated (n = 28) and normal foot (n = 26) groups.

	Intraclass Correlation coefficient	95% confidence Interval	p-value	SEM	MDC
Normal foot	0.989	0.979–0.995	≤0.001	0.2	0.55
Pronated foot	0.990	0.982–0.995	≤0.001	0.25	0.69

Abbreviations: SEM, standard error of measurement; MDC, minimal detectable change.

Table 2
Comparison of the iliopsoas muscle thickness (mm) and pelvic angle° between individuals with pronated (n = 29) and normal foot (n = 28) groups.

	Pronated foot Mean ± SD	Normal foot Mean ± SD	Mean difference (95% CI)	p-value
Iliopsoas thickness(mm)	19.25 ± 2.46	18.15 ± 1.87	−1.1 (−2.29–0.08)	0.067
Pelvic angle°	6.22 ± 5.17	4.6 ± 4.21	−1.63 (−4.14–0.88)	0.2

and 1.41° while calcaneal eversion was increased bilaterally and unilaterally, respectively, by using wedges tilted 10° medially (Pinto et al., 2008). The findings of these studies suggested that the alteration of lower extremity alignment, up to the pelvic girdle, could be occurred due to the foot posture and the forces acting on foot.

It should be noted that in these studies, the hyperpronation was induced by wedges (external forces) to the normal subjects to assess the immediate effects of hyperpronation on the pelvis. In other words, postural changes of the pelvis did not reflect the prolonged adaptive effects of hyperpronation. While the compensatory postural modifications may occur in the lower extremity alignment over the time, the results of these studies could not be generalized to the common pronated foot postures. Furthermore, using medially tilt wedges results in calcaneal eversion, only induced changes in the frontal plane; thus, it could not represent the triplanar hyperpronation.

This study had some limitations. The study was conducted only on young, healthy females with pronated and normal foot types; therefore, a generalization of the results to males or other age ranges is not logical. In addition, a proposed method of pelvic measurement, using a reflective marker with the stem, did not compare with a criterion standard; thus, further studies were required to validate this method. Since the only young females were studied in this study, it seems that the chronicity of the hyperpronation malalignment was not enough to induce proximal changes. Further studies are recommended in older populations with chronic foot malalignments.

5. Conclusion

In conclusion, the findings of this study showed that the iliopsoas muscle thickness and the PA were not different in young females with pronated foot compared to the normal foot group. The results of this study showed a good intrarater within-session reliability of ultrasound imaging for measuring the iliopsoas muscle thickness.

Declaration of competing interest

None.

CRediT authorship contribution statement

Zinat Ashnagar: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing. **Mohammad-Reza Hadian:** Conceptualization, Supervision, Validation, Funding acquisition, Visualization, Methodology, Project administration, Writing - original draft. **Gholamreza Olyaei:** Visualization, Methodology, Project administration, Writing - original draft, Funding acquisition. **Saeed Talebian:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Supervision, Validation, Visualization, Writing - original draft. **Hassan Saeedi:** Conceptualization, Data curation, Investigation, Methodology, Validation, Visualization. **Mir Saeed Yekaninejad:** Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision. **Rahimeh Mahmoodi:** Data curation, Formal analysis, Investigation.

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