OPEN ACCESS
Turkish Journal of Kinesiology

ORIGINAL RESEARCH

The relationship between pronated foot and lower extremity, pelvic, and lumbar alignment in asymptomatic young adults: A cross-sectional study

Hatice Gül[1], Suat Erel[2], İbrahim Karaca[2]

[1] Department of Physiotherapy, Vocational School of Health Services, Akdeniz University, Antalya, Türkiye. [2] Faculty of Physiotherapy and Rehabilitation, Pamukkale University, Denizli, Türkiye.

Received: January 22, 2025

Accepted: February 24, 2025

Published: February 28, 2025

Keywords: Biomechanics, compensation, flatfoot, medial longitudinal arch, postural alignment.

Abstract

The relationship between foot pronation and the alignment of the lower extremities, pelvis, and spine remains contentious in the literature. The aim of this study was to investigate the relationship between pronated foot and lower limb, pelvis and lumbar region alignment in asymptomatic young adults. The study included 96 feet of 48 participants aged 18-25 years with no pain complaints. The arch structure was evaluated with the Staheli index calculated from the footprint. The alignment of the lower extremities, pelvis and lumbar region were evaluated from photographs using posture evaluation programs. Spearman's correlational analysis was used to examine the correlations between continuous variables, and the Mann Whitney U-test to compare independent group differences, with $p<0.05$ considered statistically significant. The Staheli index showed a weak positive correlation with the calcaneo-tibial angle ($r=0.26$, $p<0.05$) but no significant correlations with other biomechanical parameters of the proximal segment. Statistically significant differences were determined between the pronated foot group (n=49) and the control group (n=47) in respect of the Staheli index and the calcaneotibial angle ($p<0.05$). Lower extremity, pelvic and spine alignment values were similar between groups. These results showed that arch structure was not related to alignment in the proximal segments. The only exception was the calcaneotibial angle, which is a foot-related biomechanical parameter. The study results were similar to findings in the literature stating that foot pronation will not cause any changes in alignments of proximal body regions. Conducting this study in asymptomatic adults, in whom biomechanical compensations have already occurred during growth process, may offer valuable insights into the potential relationship between foot pronation and proximal alignment.

Introduction

The foot plays an important role in transferring body weight to the ground and transmitting reaction forces from the ground to the trunk. Disruption of the normal alignment of the foot may cause structural or functional disorders in the upper segments over time. Similarly, an effect on the proximal segments may eventually affect distal alignment (Bittencourt et al., 2012). Generally, this malalignment in the pronation direction in the foot is described as causing increased subtalar joint pronation, tibial and femoral internal rotation, and knee valgus alignment. In the light of this information, many healthcare professionals and researchers believe that flat feet are an important risk factor for musculoskeletal disorders (Neal et al., 2014; Moisan et al., 2023).

The relationship between foot pronation and lower extremity and trunk alignment in asymptomatic healthy individuals has been discussed in the literature. Some studies have reported that foot pronation has an effect on many components of body alignment in healthy individuals (Khamis & Yizhar, 2007; Pinto et al., 2008, Abdel-Raoof et al., 2013; Ingle et al., 2020). Some of these studies have investigated the acute effect of medial wedge-induced hyperpronation and stated compensatory effect of

✉ H. Gül, E-mail: haticegul@akdeniz.edu.tr
Turk J Kinesiol, 11(1), 53-60. doi: 10.31459/turkjkin.1624898

pronation on proximal alignment (Khamis & Yizhar, 2007; Pinto et al., 2008). However, another study that used the same wedge-induced method stated that foot pronation does not affect pelvic and spinal alignment in healthy individuals (Duval et al., 2010). There are also studies evaluating the long-term effects of pronation in individuals with excessive foot pronation. Among these studies, there are some that have indicated that foot pronation has no effect on alignment factors or affects only one or two components (Tyagi et al., 2024; Duval et al., 2010; Bayiroğlu et al., 2024; Nguyen et al., 2009; Gandhi & Salvi, 2017; Pradhan et al., 2021). The relationship between foot arch structure and lower extremity, pelvis and spine alignment in asymptomatic individuals is not fully understood and additional studies are needed in this field. Therefore, to be able to better understand this issue, there is a need to investigate the relationship between pronated foot, and alignment of the lower extremities, pelvis and lumbar region.

Studies in which hyperpronation is induced with a medial wedge have reported that the effects of short-term position change in the foot on the upper segments can be observed (Khamis & Yizhar, 2007; Pinto et al., 2008). However, studies investigating the effect of a real structural disorder on the upper segments developmentally may provide clearer information about the compensatory alignment of the body.

Prevention strategies focus on early disease detection, risk factor reduction, and slowing disease progression (Gutenbrunner et al., 2023). When determining the need for preventive rehabilitation interventions in individuals with asymptomatic flatfoot, consideration should be given not only to foot pronation but also to the kinetic chain (Moisan et al., 2023). In this context, there is a need to investigate the relationship between foot posture and proximal alignment in asymptomatic flatfoot. Additionally, comparative studies involving healthy control subjects and individuals with flatfoot are necessary to examine the effect on the kinetic chain. In a previous study comparing individuals with pronation and hyperpronation, the absence of a healthy control group was stated as a limitation (Bayiroğlu et al., 2024). Although previous studies have provided information about the relationship of foot pronation with the lower extremities, pelvis and spinal region, there is disagreement in the literature about this research topic. Therefore, the aim of this study was to investigate the relationship between pronated foot and lower limb, pelvis and lumbar region alignment.

Methods

This cross-sectional, observational study was approved by the Clinical Research Ethics Committee of Akdeniz University (KAEK-902, December 13, 2023). The research was conducted in the period February 2024 - December 2024. All the study procedures were in accordance with the principles of the Declaration of Helsinki. Participants were included in the study after an informed consent form was signed.

Participants

The research sample comprised 96 feet of 48 university students (mean age: 20.81±2.02, aged; mean body mass index: 22.41±3.16; mean Staheli index: 80±17.99). The participants were selected using a convenience sampling method based on inclusion and exclusion criteria. Participants were categorized into two groups based on their Staheli index values, with 49 feet assigned to the pronation group and 47 feet to the control group. The control group was formed of healthy volunteers without obesity, gait disorder, or foot pain. The study exclusion criteria were defined as a history of lower extremity injury (fractures, strains, sprains, dislocations), the use of walking aids, the presence of functional limitations in independent walking, a history of spinal trauma or surgery, the presence of congenital abnormalities, or muscle contractures.

Procedure

Demographic data such as age, height, gender, and body mass index (BMI) were recorded. The arch structure of all the study participants was evaluated with the Staheli index calculated from the footprint. The alignment of the lower extremities, pelvis and lumbar region were evaluated on anterior, posterior and lateral view photographs using SCODIAC and APECS programs.

Staheli index

The Staheli arch index (Figure 1) is defined as the ratio of midfoot-width to hindfoot-width in a footprint, as an indicator of foot arch development (Staheli et al., 1987). Footprint measurements were performed on a floor measurement platform designed by the researcher with the subject in the natural anatomic position. Staheli index values between 60 % and 79 % were classified as normal arch structure and ≥80 % as pes planus. The height of the medial longutudinal arch decreases as the Staheli index value increases. It has been determined that Staheli index has good diagnostic abilities and is suitable for assessing flatfoot (Chen at al., 2011).

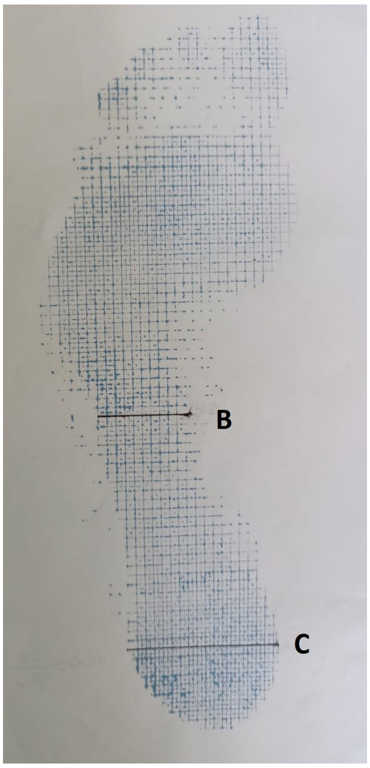

Figure 1. Staheli index=B/C×100%

Alignment of the lower extremities, pelvis and lumbar region

The alignment of the lower extremities, pelvis and lumbar region were evaluated using SCODIAC and APECS programs applied to the photographs taken from the anterior, posterior and lateral sides of the subjects. The calcaneo-tibial angle, tibio-femoral angle, sacral slope angle, and lumbar slope angle were measured in the SCODIAC program. This software is available online and free to download. The photographic measurements revealed very good reliability in respect of sagittal parameters (Stolinski et al, 2017) and a moderate level of test-retest reliability for the calcaneotibial and tibio-femoral angles (Fortin et al., 2012) (Figure 2).

The APECS posture analysis program was used to calculate the pelvic tilt angles in the sagittal plane. APECS is available for download in Google Play Store. APECS performs posture assessment with markers placed on the photograph. A rapid analysis of anthropometric characteristics of posture is provided by APECS and it uses standardized anatomic angles for postural assessment. The APECS program has been shown to be a reliable and valid method in previous studies (Trovato et al., 2022; Welling et al., 2023) (Figure 3).

Each participant was photographed with a camera placed on a tripod fixed at a height of 90 cm and a distance of 300 cm (Stolinski et al., 2017). The photographs were taken in a well-lit environment with a 90° camera angle. All the study participants were informed before the photographs were taken and the right and left anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), right and left lateral and medial malleolus, midpoint of the patella and ankle were labelled with a marker. The subject was asked to stand in a position in which they felt comfortable with equal weight transfer on both feet during while the photographs were taken.

Subjects were instructed to place their feet in the anterior direction. All the biomechanical parameters obtained from the digital photographs were calculated with the software program. These programs uses interactive click-on markers with the computer mouse. The assessor selects a specific marker from the graphic interface and places it directly on the corresponding marked anatomic reference point labelled by the assessor. The program then automatically calculates the angles of the markers corresponding to the calculation of the selected index (Figure 2 and Figure 3).

Data Analyses

Data analyses were performed using SPSS vn. 25.0 software (IBM SPSS Statistics 25, Armonk, NY, USA). Conformity of the data to normal distrbution was examined with the Kolmogorov-Smirnov test. Continuous variables were expressed as mean ± standard deviation (SD) values and categorical variables as number (n) and percentage (%). Spearman’s correlational analysis was used to examine correlations between continuous variables. The correlation analysis was conducted with a significance level set at $p<0.05$. A correlation coefficient between 0.1-0.29 was considered low, 0.30-0.49 as moderate, 0.50-0.69 as high, and ≥ 0.70 was considered very high. The Mann-Whitney U Test was used to compare independent group differences. A value of $p<0.05$ was considered statistically significant.

A priori power analysis ($\alpha = 0.05$, power level $\beta = 0.80$, with 0.30 effect size) revealed a minimum sample size of 82 feet was required to analyze the correlation between pronated foot and lower extremity, pelvic, and lumbar alignment. The power analysis was conducted using G*Power (version 3.1; Franz Faull, Universitat Kiel, Germany).

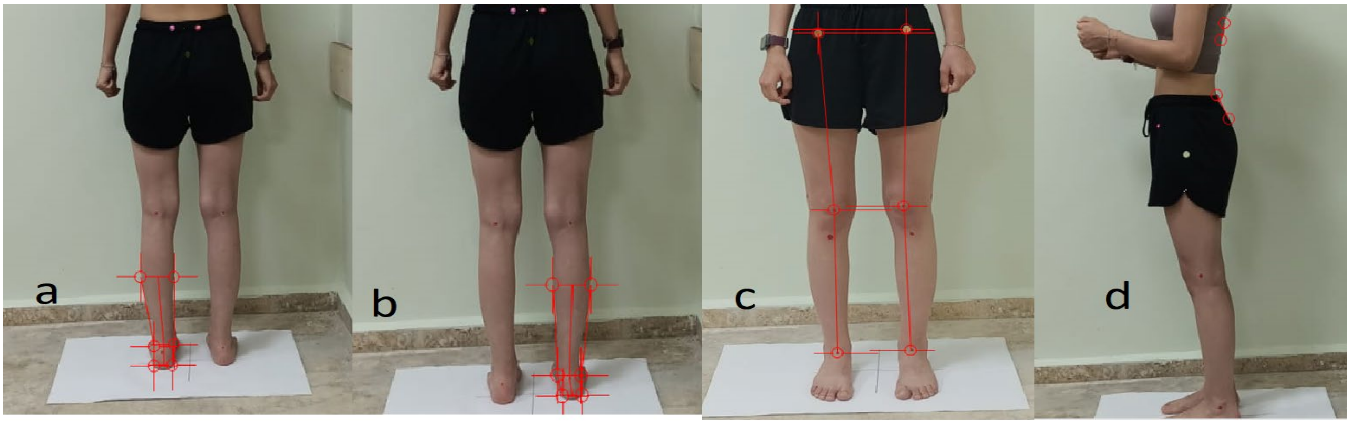

Figure 2. Measurement of lower limb, sacral and lumbar regions alignment with SCODIAC **a.** Left calcaneotibial angle**, b.** Right calcaneotibial angle**, c.** Tibiofemoral angle**, d.** Lumbar lordosis and sacral slope angle.

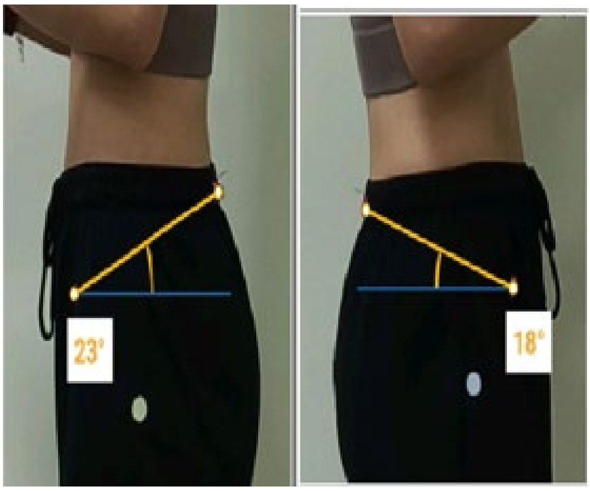

Figure 3. Measurement of right and left pelvic tilt angle with APECS.

Results

Evaluations were made of 96 feet of 48 participants. Of the participants, 83.3% (n=40) were female and 16.7% (n=8) were male. Demographic characteristics and foot, leg, pelvic, lumbar alignment properties of the study participants are presented in Table 1.

Correlation analysis revealed significant relationships between certain variables examined in the study. The Staheli index was seen to have a weak positive correlation with the calcaneo-tibial angle. An increase in arch flattening is related to a slight increase in calcaneal eversion (r=0.26; $p<0.05$). No statistically significant correlation with other parameters, including the tibio-femoral angle, anterior pelvic tilt angle, sacral slope, and lumbar slope ($p>0.05$). It was determined that as the Staheli index increased, so the calcaneal angle also increased. The calcaneo-tibial angle showed no significant correlation with the tibio-femoral angle, anterior pelvic tilt angle, sacral slope, or lumbar slope ($p>0.05$; Table 2).

The tibio-femoral angle exhibited a weak positive correlation with the sacral slope (r=0.22; $p<0.05$) and anterior pelvic tilt angle (r= 0.18; $p<0.05$), but no significant association with lumbar slope ($p>0.05$). The anterior pelvic tilt angle was weakly positively correlated with the sacral slope (r=0.28; $p<0.05$) and the lumbar slope (r=0.21; $p<0.05$). A strong positive correlation was determined between the sacral slope and lumbar slope (r=0.77; $p<0.05$; Table 2).

Table 3 presents the comparison of biomechanical features between the pronation and control groups. The Staheli index was significantly higher in the pronation group compared to the control group ($p<0.05$). Similarly, the calcaneotibial angle was significantly greater in the pronation group than in the control group ($p<0.05$). No significant differences were observed between the pronation group and control group in respect of the tibiofemoral angle, anterior pelvic tilt angle, sacral slope, and lumbar slope. These findings indicated that lower extremity, pelvic and spinal alignments were relatively similar in the two groups ($p>0.05$).

Table 1
Demographic characteristics of the participants and biomechanical features of the lower limb, pelvic, and lumbar regions.

Variables	Mean±SD	Median (Min-Max)
Age (years)	20.81±2.02	20.50 (18-25)
Height (cm)	166.37±7.21	165 (154-185)
Weight (kg)	62.12±10.72	59.50 (43-85)
Body mass index (kg/m²)	22.41±3.16	22.75 (16.40-29.6)
SI	80±17.99	80 (60-145)
CTA (°)	6.71±4.20	6.10 (0.10-18.10)
TFA (°)	6.51±3.17	6.40 (0-15.10)
APTA (°)	13.71±5.58	13 (3-25)
SS (°)	26.07±7.77	25.20 (6.70-47.10)
LS (°)	43.63±9.36	41.85 (20.50-64)

°: Degree; SI: Staheli Index; CTA: Calcaneotibial angle; TFA: Tibiofemoral angle; APTA: Anterior Pelvic tilt angle; SS: Sacral slope; LS: Lumbar Slope.

Table 2
Spearman's Correlational analysis of biomechanical features of the lower limb, pelvic, and lumbar regions.

Variables	SI	CTA (°)	TFA (°)	APTA (°)	SS (°)	LS (°)
	r (*p*-value)					
SI	1	0.26 **(0.00)***	0.07 (0.47)	-0.01 (0.91)	-0.07 (0.49)	-0.06 (0.57)
CTA (°)		1	0.02 (0.81)	0.02 (0.83)	-0.17 (0.10)	0.02 (0.81)
TFA (°)			1	0.18 **(0.03)***	0.22 **(0.01)***	0.13 (0.10)
APTA (°)				1	0.28 **(0.00)***	0.21 **(0.02)***
SS (°)					1	0.77 **(0.00)***
LS (°)						1

*°: Degree; SI: Staheli Index; CTA: Calcaneotibial angle; TFA: Tibiofemoral angle; APTA: Anterior Pelvic tilt angle; SS: Sacral slope; LS: Lumbar Slope; *p < 0.05.*

Table 3
Comparison of biomechanical features between pronation and control groups.

Variables	Pronation Group (n=49 feet)	Control Group (n=47 feet)	*p* *
	Median (Min-Max)	Median (Min-Max)	
SI	93 (80-145)	71 (60-79)	**0.00**
CTA (°)	6.50 (1.10-18.80)	5.1 (0.10-17.90)	**0.04**
TFA (°)	6.10 (0-15)	6.65 (1-15.10)	0.93
APTA (°)	14 (3-25)	12 (3-25)	0.92
SS (°)	25.2 (6.70-47.10)	27.60 (13.50-47.10)	0.28
LS (°)	41.7 (25.30-60.30)	42 (20.50-64)	0.48

*°: Degree; SI: Staheli Index; CTA: Calcaneotibial angle; TFA: Tibiofemoral angle; APTA: Anterior Pelvic tilt angle; SS: Sacral slope; LS: Lumbar Slope; *Mann Whitney U test.*

Discussion

Many healthcare professionals view flatfoot as a deformity and a risk factor for musculoskeletal issues, even without symptoms. It is widely believed that feet outside certain criteria compensate biomechanically, thereby increasing the risk of injury. Therefore, the relationship between the arch of the foot and the alignment of the proximal segments continues to be of interest to healthcare professionals. The current study was conducted with the purpose of examining this relationship, and the results showed no correlation between the arch structure of the foot and the alignment of proximal segments. The findings of the current study showed that arch structure was not related to alignments in the proximal segments, with the exception of the calcaneotibial angle, which is a biomechanical parameter related to the foot. These results may be attributed to the fact that the study population consisted of asymptomatic adults. These results provide information that the morphological structure of the arch of the foot alone should not be the sole focus in the clinical decision-making for preventive rehabilitation applications planned for asymptomatic pes planus and its effect on body alignment.

In a previous study, differences were found between the groups with and without flatfoot in respect of the foot-related biomechanical measurements such as talar declination, intermetatarsal, hallux abductus and calcaneal cuboid angles and static calcaneal stance eversion. No significant effect or risk factor was detected related to the proximal segments (Shibuya et al., 2014). That study suggested that calcaneal alignment is altered in individuals with pronated feet, similar to the current study results.

Several studies have identified a relationship between foot pronation and increased Q-angle (Tyagi et al., 2024; Khamis & Yizhar, 2007; Ingle et al., 2020). In contrast, Nguyen et al. (2009) stated that navicular drop was not a significant independent predictor of quadriceps angle. In another study, no statistically significant relationship was found between the tibiofemoral angle, pelvic tilt, and the degree of flatfoot (Gandhi & Salvi, 2017). The current study results are consistent with those of previous studies regarding the relationship between pronated foot and tibiofemoral angle (Nguyen et al., 2009; Gandhi & Salvi, 2017). The inconsistency in the literature may be attributed to differences in methodology and variations in the arch structure among study participants, and the use of different measurement methods makes it difficult to compare the results.

The relationship between foot posture and pelvic alignment remains complex and somewhat controversial. While some studies have found significant correlations between foot pronation and pelvic tilt (Khamis & Yizhar, 2007; Pinto et al., 2008; Pradhan et al., 2021), others have not identified such relationships (Khamis et al., 2015; Panaet et al., 2021; Duval et al., 2010; Tyagi et al., 2024) similar to the current study results. This discrepancy may stem from methodological differences, such as variations in participant characteristics, measurement techniques, or biomechanical compensations, which influence the observed relationships. Moreover, this discrepancy highlights the complex interplay of factors contributing to postural alignment, suggesting that foot posture alone may not have a direct or consistent impact on pelvic alignment in all populations. Further research is necessary to clarify these relationships, considering variables such as other compensatory mechanisms.

Valgus alignment has been shown to be weakly correlated with an increase in anterior pelvic tilt in healthy subjects (Hodel et al., 2023). In the current study, a weak positive relationship was found between tibiofemoral angle and pelvic tilt. The positions of the foot during the evaluation led to the same results in the analyses. As in the previous study, all the current study subjects were instructed to place their feet straight, in the anterior direction (Hodel et al., 2023).

It was concluded in a previous study that pronated feet affect spinal alignment, and the lumbar lordosis index was found to be increased in subjects with pronated foot (Ingle et al., 2020; Abdel-Raoof 2013). The current study results did not demonstrate a significant difference in lumbar lordosis angle between the subjects with pronated and normal feet. This discrepancy may indicate that the impact of foot posture on lumbar alignment is less direct or may be influenced by compensatory mechanisms elsewhere in the kinetic chain. Further studies are necessary to explore the biomechanical pathways connecting foot posture and spinal alignment in greater detail.

It has been stated that lumbar spine posture depends on the pelvic alignment in a standing position, and therefore, anteversion of the pelvis may lead to hyperlordosis. As the pelvis is tightly connected to the lumbar spine at the sacro-iliac joint by an extensive fibrous connection, anterior tilt of the pelvis could increase the lumbar lordosis (Egund et al., 1978; Levine et al., 1996). However, the degree of pelvic tilt at which low-back posture is affected has not been identified in some studies (Walker et al., 1987; Youdas et al., 1996; Beninato et al., 1993). In the current study, the anterior pelvic tilt angle, sacral slope and lumbar lordosis angles were correlated as in previous studies.

The current study findings indicated that the morphological characteristics of the foot arch alone are insufficient to guide clinical decision-making for preventive rehabilitation strategies aimed at asymptomatic pes planus and its impact on body alignment. However, this does not suggest that proximal body regions should be overlooked in individuals with pronated feet. It is possible that compensatory mechanisms involving soft tissues may be influenced. In asymptomatic individuals, forces might be absorbed or compensated by soft tissues before affecting the knee, pelvis, or spine. There is a need for further research including the evaluation of soft tissue involvement to provide a more comprehensive understanding. As the current study sample consisted of young adults, it should be taken into account that there may be different alignment effects due to loading in older age groups. The limitation of the study is that it is a cross-sectional study, providing only a one-time assessment of alignment differences. Longitudinal studies are needed to determine whether foot pronation has an effect on proximal alignment over time. As this study was performed on individuals with normal feet and asymptomatic flatfoot, healthcare professionals should be cautious about the potential role of the foot in influencing upper segment dynamics in symptomatic individuals. The inclusion of cases with symptomatic pes planus in future studies may help identify factors that are clinically significant. Future research should include individuals with normal feet, as well as those with symptomatic and asymptomatic flatfoot, together with detailed assessment methods of both contractile and non-contractile structures. Such studies would provide a more comprehensive understanding of how arch structure influences the proximal regions of the body. To achieve this, it would be particularly valuable to employ path analysis, which is a statistical modeling technique designed to examine direct and indirect relationships within complex systems. This method would allow for the quantification of both the direct effects of foot posture on variables such as pelvic alignment and lumbar lordosis, and the indirect effects mediated through other components of the body structures. With the application of this approach, future studies will be able to better elucidate the multifaceted interactions between foot posture and overall biomechanical function.

Understanding the biomechanical structure of each part of the body is crucial to prevent and treat musculoskeletal disorders. Although the current study results seem to support the literature that asymptomatic pes planus is an anatomic variation that does not require treatment, the potential consequences of pes planus cannot be neglected. Considering the treatment costs, there is a need for the development of clinical decision-making methods to be used when making decisions about a treatment program, supported by assessments of both contractile and non-contractile structures, which reveal the effect of the flatfoot on the proximal segments.

Acknowledgments

We thank all participants for their participation in this study.

Authors' Contribution

Study Design: HG, SE; Data Collection: HG; Statistical Analysis: HG, SE, İK; Manuscript Preparation: HG, SE, İK; Funds Collection: None.

Ethical Approval

The study was approved by the Clinical Research Ethics Committee of Akdeniz University (KAEK-902, December 13,2023) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

Funding

The authors declare that the study received no funding.

Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

References

Abdel-Raoof, N., Kamel, D. & & Tantawy, S. (2013). Influence of second-degree flatfoot on spinal and pelvic mechanics in young females. *Int J Ther Rehabil,* 20(9), 428-434. doi: 10.12968/ijtr.2013.20.9.428

Bayiroğlu, G., Pişirici, P., & Feyzioğlu, Ö. (2024). The effect of different subtalar joint pronation amounts on postural stability, function and lower extremity alignment in healthy individuals. *Foot (Edinburgh, Scotland),* 60, 102123. doi: 10.1016/j.foot.2024.102123.

Beninato, M. H., Hudson, K. R., & Price, K. S. (1993). A study of the correlation among lumbar lordosis, pelvic tilt, hamstring and hip flexor muscle length. *J Orthop Sports Phys Ther,* 17, 61.

Bittencourt, N. F., Ocarino, J. M., Mendonça, L. D., Hewett, T. E. & Fonseca, S. T. (2012). Foot and hip contributions to high frontal plane knee projection angle in athletes: a classification and regression tree approach. *J Orthop Sports Phys Ther,* 42(12), 996–1004.

Chen, K. C., Yeh, C. J., Kuo, J. F., Hsieh, C. L., Yang, S. F. & Wang, C. H. (2011). Footprint analysis of flatfoot in preschool-aged children. *Eur J Pediatr,* 170, 611-617. doi: 10.1007/s00431-010-1330-4

Duval, K., Lam, T. & Sanderson, D. (2010). The mechanical relationship between the rearfoot, pelvis and low-back. *Gait Posture,* 4, 637-640. doi: 10.1016/j.gaitpost.2010.09.007

Egund, N., Olsson, T. H., Schmid, H. & Selvik, G. (1978). Movements in the sacroiliac joints demonstrated with roentgen stereophotogrammetry. *Acta Radiol Diagn,* 19, 833-846.

Fortin, C., Feldman, D. E., Cheriet, F., Gravel, D., Gauthier, F. & Labelle, H. (2012). Reliability of a quantitative clinical posture assessment tool among persons with idiopathic scoliosis. *Physiotherapy,* 98(1), 64-75.

Gandhi, N., & Salvi, R. (2017). Correlation between pronated foot and pelvic inclination, femoral anteversion, quadriceps angle and tibial torsion. *Int J*

Physiother, 4(4), 229-235. doi: 10. 15621/ijphy/2017/v4i4/154718

Gutenbrunner, C., Nugraha, B., & Meyer, T. (2023). Prevention aiming at functioning-describing prevention in the context of rehabilitation: a discussion paper. *Int J Environ Res Public Health,* 20(7), 5399. doi: 10.3390/ijerph20075399.

Hodel, S., Flury, A., Hoch, A., Zingg, P. O., Vlachopoulos, L., & Fucentese, S. F. (2023). The relationship between pelvic tilt, frontal, and axial leg alignment in healthy subjects. *J Orthop Sci, 28*(6), 1353-1358. doi: 10.1016/j.jos.2022.10.002

Ingle, P. V., & Puntambekar, A. (2020). Influence of pronated foot on lumbar lordosis and thoracic kyphosis and Q angle in young adults. *Int J Sci Res Publ,* 10(6), 2250-3153. doi: 10.29322/IJSRP.10.06.2020.p10268

Khamis, S., Dar, G., Peretz, C. & Yizhar, Z. (2015). The relationship between foot and pelvic alignment while standing. *J Hum Kinet,* 46, 85-97. doi: 10.1515/hukin-2015-0037

Khamis, S., & Yizhar, Z. (2007). Effect of feet hyperpronation on pelvic alignment in a standing position. *Gait Posture,* 25(1), 127-134. doi: 10.1016/j.gaitpost.2006.02.005

Levine, D. & Whittle, M. W. (1996). The effects of pelvic movement on lumbar lordosis in the standing position. *J Orthop Sports Phys Ther,* 24, 130-135. doi: 10.2519/jospt.1996.24.3.130

Moisan, G., Griffiths, I., & Chicoine, D. (2023). Flat feet: deformities or healthy anatomical variants? *Br J Sports Med,* 57(24), 1536-1537. doi: 10.1136/bjsports-2023-107183

Neal, B. S., Griffiths, I. B., Dowling, G. J., Murley, G. S., Munteanu, S. E., Franettovich Smith, M. M., Collins, N. J., Barton, C. J. (2014). Foot posture as a risk factor for lower limb overuse injury: a systematic review and meta-analysis. *J Foot Ankle Res,* 7, 55. doi: 10.1186/s13047-014-0055-4

Nguyen, A. D., Boling, M. C., Levine, B., & Shultz, S. J. (2009). Relationships between lower extremity alignment and the quadriceps angle. *Clin J Sport Med,* 19(3), 201-206. doi: 10.1097/JSM.0b013e3181a38fb1

Panaet, E. A., Grigore, V., Man, M. C., Dolinschi, C. M., & Alexe, D. I. (2021). Effect of paediatric flat foot on the sagittal alignment of the pelvis and spine. *Discobolul-Physical Education, Sport & Kinetotherapy Journal,* 60(4), 475-484, doi: 10.35189/dpeskj.2021.60.4.10

Pinto, R. Z., Souza, T. R., Trede, R. G., Kirkwood, R. N., Figueiredo, E. M. & Fonseca, S. T. (2008). Bilateral and unilateral increases in calcaneal eversion affect pelvic alignment in standing position. *Man Ther,* 13(6), 513-519. doi: 10.1016/j.math.2007.06.004

Pradhan, D., Korada, H., Kumar, S., & Salma, A. (2021). Correlation of foot posture with balance and pelvic tilt in healthy runners. *Physiotherapy Quarterly,* 29(4), 18-21. doi: 10.5114/pq.2021.105748

Shibuya, N., Kitterman, R. T., LaFontaine, J., & Jupiter, D. C. (2014). Demographic, physical, and radiographic factors associated with functional flatfoot deformity. *J Foot Ankle Surg,* 53(2), 168-172. doi: 10.1053/j.jfas.2013.11.002

Staheli, L. T., Chew, D. E. & Corbett, M. (1987). The longitudinal arch. A survey of eight hundred and eighty-two feet in normal children and adults. *J Bone Joint Surg Am,* 69(3), 426–428.

Stolinski, L., Kozinoga, M., Czaprowski, D., Tyrakowski, M., Cerny, P., Suzuki, N. & Kotwicki, T. (2017). Two-dimensional digital photography for child body posture evaluation: standardized technique, reliable parameters and normative data for age 7-10 years. *Scoliosis Spinal Disord,* 12, 38. doi: 10.1186/s13013-017-0146-7

Tyagi, A., Mohanty, P. & Pattnaik, M. (2024). Exploring the complex interplay: Correlation between pronated foot and pelvic inclination, femoral anteversion, quadriceps angle, tibial torsion and talus head position in asymptomatic adults *Medical Science, 28,* e40ms3320. doi: 10.54905/disssi.v28i147.e40ms3320

Trovato, B., Roggio, F., Sortino, Zanghì, M., Petrigna, L., Giuffrida, R., Musumeci, G. (2022). Postural evaluation in young healthy adults through a digital and reproducible method. *J Funct Morphol Kinesiol,* 7(4), 98. doi: 10.3390/jfmk7040098

Walker, M. L., Rothstein, J. M., Finucane, S. D. & Lamb, R. L. (1987). Relationships between lumbar lordosis, pelvic tilt, and abdominal muscle performance. *Phys Ther,* 67, 512-516.

Welling, A., Gurudut, P., Shirodkar G, Shetye N, Khan S. (2023). Validation of non-radiographic APECS software in comparison with standard radiographic measurement of full-length lower limb hip–knee–ankle angle in elderly obese women. *Physiother Quart,* 31(1), 90-94. doi: 10.5114/pq.2023.119865

Youdas, J. W., Garrett, T. R., Harmsen, S., Suman, V. J. & Carey, J. R. (1996). Lumbar lordosis and pelvic inclination of asymptomatic adults. *Phys Ther,* 76, 1066-1081. doi: 10.1093/ptj/76.10.1066