Journal of Inonu University Health Services Vocational School
İnönü Üniversitesi Sağlık Hizmetleri Meslek Yüksekokulu Dergisi

e-ISSN: 2147-7892 | Volume 13, Issue 2 (2025) 428-440 | doi: 10.33715/inonusaglik.1642246

Research Article

COMPARISON OF FOOT BIOMECHANICS AND FUNCTIONS IN UNIVERSITY STUDENTS WITH AND WITHOUT REGULAR EXERCISE HABITS

Kader ELDEMİR[1] *Sefa ELDEMİR*[2]
Ayşenur Canan BENLİ[3] *Mustafa Oğuz KETHÜDAOĞLU*[4]
[1,2,3,4]*Sivas Cumhuriyet University, Faculty of Health Sciences, Sivas*

Article Info

Received: *18 February 2025*
Accepted: *05 May 2025*

Keywords

Biomechanic,
Exercise,
Foot Deformities,
Physical Activity,
Students

ABSTRACT

The foot, a complex structure for the human skeleton, plays a crucial role in providing contact with the ground and facilitating walking. The impact of regular exercise on foot biomechanics and function in young adults remains unclear. This study aims to compare foot biomechanics and function in university students who engage in regular exercise habits with those who do not. A total of 102 students were divided into two groups: having exercise habits (n=51), defined as engaging in moderate-intensity exercise at least three times per week, and not having exercise habits (n=51). Foot biomechanics were assessed using navicular drop (ND), metatarsal width, hallux valgus angle, and subtalar angle. Foot function was evaluated using the Foot Function Index (FFI). Demographic characteristics were similar between the groups ($p>0.05$). The right-side ND was significantly lower in the regular exercise group ($p=0.030$). No significant differences were observed in other biomechanical measurements or FFI scores ($p>0.05$). The ND is lower in university students with exercise habits; however, no difference was found between the groups in other foot biomechanical measurements and foot function. Regular exercise promotes navicular height in young individuals, but further studies are needed to demonstrate its effects on foot biomechanics.

INTRODUCTION

The foot, one of the most complex structures of the human skeleton, is very important. It provides contact with the ground and allows walking (Earls, 2021). It serves two primary functions: supporting body weight and transferring it to the ground, and acting as a lever to facilitate forward movement during walking (Earls, 2021). Comprising 26 bones, the foot's complexity is further enhanced by ligaments, muscles, and tendons that enable movement and stability (Gülçimen & Ülkü, 2008). Any anatomical, physiological, or kinesiological changes in these structures can significantly impact foot biomechanics and function (Card & Bordoni, 2023).

Foot problems are frequently encountered in society and significantly affect daily life activities (Budiman-Mak, Conrad, Mazza & Stuck, 2013). The incidence of foot problems can reach up to 80%, leading to reduced independence, lower quality of life, and mental health

Kader ELDEMİR ✉, *fztkader2015@gmail.com*
Sivas Cumhuriyet University, Faculty of Health Sciences, Sivas

How to cite this article: Eldemir, K., Eldemir, S., Benli, A. C. & Kethüdaoğlu, M. O. (2025). Comparison of Foot Biomechanics and Functions in University Students with and Without Regular Exercise Habits. *İnönü Üniversitesi Sağlık Hizmetleri Meslek Yüksekokulu Dergisi*, 13(2), 428-440. doi: 10.33715/inonusaglik.1642246

challenges, particularly among young individuals (Menz, Jordan, Roddy & Croft, 2010; Yaliman, Şen, Eskiyurt & Budiman-Mak, 2014). Moreover, an injury or deformity occurring in the foot may also cause problems in structures located in the upper segments, such as the knee, hip, and spine (Eldemir et al., 2025; Sarı, Otman, & Akman, 1995).

Previous evidence has reported that pes planus deformity reduces balance and physical performance in young individuals (Kızılcı & Erbahçeci, 2016; Şahin et al., 2022) and negatively affects walking parameters and quality of life in children (Kothari, Dixon, Stebbins, Zavatsky & Theologis, 2015). Similar findings were reported that foot posture affects postural stability (Cote, Brunet, Gansneder & Shultz, 2005). In another study, the navicular drop test measurement is associated with static balance and physical function, social function, and general health from the sub-dimensions of the quality of life in sedentary young adults (Aktan & Kutlay, 2022).

Physical inactivity, a major concern in the 21st century, is increasingly common among young populations (Park, Moon, Kim, Kong & Oh, 2020). Most individuals spend most of their time sitting, especially at home, work, and transportation. With increasing technological developments, the time spent in front of screens is increasing in all segments of society, and, accordingly, the rate of sedentary life is also increasing (Can, 2019). It is known that problems in musculoskeletal system development will occur over time in a physically inactive population, especially in young individuals.

Research on the effects of physical activity, exercise, and sports on foot biomechanics reveals inconsistent and limited evidence. While some studies suggest that sports (e.g., volleyball) may alter foot structure (Ekanem et al., 2024; Sirgo Rodríguez & Aguado Jodar, 1991), others report normal changes in athletes from sports like football (López et al., 2005). The divergent findings across these studies can be attributed to differences in the types of sports examined. Repetitive loading in high-impact sports may lead to biomechanical impairments, such as an increased prevalence of pes cavus among athletes, likely due to prolonged stress on the foot arch (Ekanem et al., 2024). Short-term changes were observed in metatarsal width in volleyball players, which can be linked to the sport’s high-intensity jumping and landing movements that place significant stress on the forefoot (Sirgo Rodríguez & Aguado Jodar, 1991). In contrast, football players exhibited near-normal foot biomechanical properties, possibly due to the sport’s specific demands, such as running and kicking, which may promote adaptive changes without causing significant structural alterations (López et al., 2005). These variations suggest that sport-specific loading patterns and training adaptations are critical in shaping foot biomechanics.

These conflicting results suggest that more research is needed. To the best of our knowledge, no studies investigate foot biomechanical properties and function in young adults who do or do not exercise regularly. We hypothesize that young adults who exercise regularly exhibit different foot biomechanical properties compared to their sedentary counterparts, suggesting that physical activity enhances foot biomechanics and functions. This study compares foot biomechanics and function in university students with or without regular exercise habits. Our research questions are as follows:

Research question 1. Are the biomechanical properties of the foot different in university students with and without regular exercise habits?

Research question 2. Are the foot functions different in university students with and without regular exercise habits?

MATERIAL AND METHOD

Aim and Type of the Research

This study was designed as a cross-sectional and comparative analysis.

Population and Sample of the Research

Participants who met the inclusion criteria were invited to the Department of Physiotherapy and Rehabilitation of the University. One hundred and two students were included in the study. They were recruited into two groups: regular exercise participants (Group 1, n = 51) and non-exercise participants (Group 2, n = 51). The inclusion criteria were (1) 18-36 years of age and (2) not having foot or ankle surgery. The exclusion criteria were (1) any history of deformity or injury that may affect lower extremity evaluations, and (2) refusing to participate in tests and surveys.

Sample size calculation was calculated using the left side subtalar angle scores in a similar comparative study (López, Alburquerque, Santos, Sánchez & Domínguez, 2005). For this purpose, the G*power software (version 3.1.9.7; Heinrich Heine Universitaet, Dusseldorf, Germany) was used (Faul, Erdfelder, Lang & Buchner, 2007). Accordingly, in the power analysis performed to determine the sample size, Cohen's d effect size was found to be 0.692, and the number of individuals to be included in the study was determined as at least 92 with a 5% type 1 error and 95% power. It was decided to include at least 102 people in the study, assuming a 10% dropout rate.

Data Collection and Data Analysis

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 23.0 (SPSS, Chicago, IL). The normality of data was assessed by the Shapiro–Wilk test. Assessment statistics were reported as mean±SD for normally distributed scale variables, median (interquartile range [IQR]) for non-parametric variables, and frequency (%) for categorical variables. The Chi-square test or Fisher test was used to compare categorical variables between the groups. The Samples t-test or Mann–Whitney U test was used to analyze the differences between the groups. All the tests were conducted at the 5% significance level.

Assessments

As demographic information, data for age, height, height, body mass index, sex, dominant side, and exercise frequency were collected. Regular exercise habits, navicular drop, metatarsal width, hallux valgus angle, subtalar angle, and foot function were assessed for all participants.

Navicular drop (ND): The ND test was measured in a sitting position without weight on the foot and in a standing position with weight on the foot. During the measurement, the navicular tubercle was marked by palpation, and the distance between it and the ground was recorded in millimeters. The amount of navicular drop was determined by taking the difference between the two measurements. Pronation of the foot will indicate a tendency towards pes planus, and supination will indicate a tendency towards pes cavus. For the ND test, 5-9 mm is considered normal, 10 mm and above is considered pronation, and 4 mm and below is considered supination (Cote et al., 2005).

Metatarsal width: In this evaluation used to select forefoot width, the distance between the medial surface of the first metatarsal head and the lateral surface of the fifth metatarsal head was measured and recorded. Measurements were repeated in a sitting position without weight bearing on the foot and in a standing position with weight on the foot. The distance between the two malleoli was recorded in millimeters (Morrison, Durward, Watt & Donaldson, 2005).

Hallux valgus (HV) angle: It is the angle between the longitudinal axis of the proximal phalanx of the big toe and the longitudinal axis of the first metatarsal. First, the pivot point of the goniometer was placed at the first metatarsophalangeal joint, with one arm parallel to the first metatarsal bone and the other arm parallel to the proximal phalanx (Nix, Russell, Vicenzino, and Smith, 2012). Then, the angle between the two axes was measured and recorded in degrees while the subject put weight on the foot. An angulation of 5-15 degrees is normal (Gentili, Masih, Yao & Seeger, 1996).

Subtalar angle: It is the angle between the longitudinal axis of the hindfoot (calcaneus) and the vertical midline of the distal third of the lower leg. The midline of the calcaneus and the midline of the lower leg were marked with a pencil while the individual was lying in the prone position. The angle between these two lines was measured with a goniometer in the prone and standing position and recorded in degrees (Cho, Park & Nam, 2019). Angular valgus of up to four degrees is normal (Ahn, Bok, Kim & Park, 2017).

Foot Function Index (FFI): The FFI consists of three sub-parameters. These are pain, disability, and activity limitations and have 23 items. The pain subtitle contains nine items and measures the severity of foot pain in different situations. The disability subtitle contains nine items and evaluates a person's difficulty performing functional activities due to foot problems. The activity limitation subtitle contains five items and measures the person's activity limitation due to foot problems. Participants are asked to mark the appropriate place for each question on a visual analog scale ranging from 0 to 10 (no pain - the most severe pain possible), considering their condition in the last week. After the scores of all questions are added, the total index score is calculated by dividing it by the maximum score that these questions can receive and multiplying the obtained number by 100. The total score varies between 0 and 100, while high scores on the scale indicate increased foot disability (Budiman-Mak, Conrad, Mazza & Stuck, 2013; Yagci, Erel & Okunakol, 2020).

Limitations of the Research

This study has some limitations. Firstly, parameters related to the foot, such as muscular strength, endurance, and flexibility, could not be evaluated. These parameters may affect foot function and biomechanics. Secondly, functional assessments such as balance, walking, and physical fitness were not examined. Thirdly, although our study included sufficient participants, it is based on the measurement results of students from only one university. Therefore, this situation limits its generalizability. Fourthly, this study is cross-sectional. Since cross-sectional studies collect data at a single point, they cannot track changes over time or establish the temporal sequence required to infer causal relationships. Finally, regular exercise habits were questioned verbally, requiring trust in the participants' statements. In future studies, studies that include individuals whose regular exercise habits are monitored may help to better demonstrate the effectiveness of the exercise. Future studies can be conducted considering all these limitations.

Ethical Considerations

This study was approved by the Ethics Committee of Sivas Cumhuriyet University (approval number: 2024-12/31) and conducted according to the Declaration of Helsinki.

RESULTS

One hundred and two individuals (Group 1; 51 and Group 2; 51) were included in the study. There was no significant difference between the groups regarding demographic information (p>0.05). Additionally, a group of participants were exercising regularly at least three days a week (3.58±1.45 days), and the non-exercising group did not exercise regularly (Table 1).

Table 1. Demographic characteristics of participants

	Regularly Exercising Participants (n=51) Mean±SD	Non-Exercising Participants (n=51) Mean±SD	p
Age (years)	21.76±2.70	21.31±1.72	0.318
Height (cm)	169.96±8.79	171.11±9.49	0.525
Weight (kg)	68.52±12.04	68.65±16.59	0.965
BMI (kg/m^2)	23.56±2.63	23.23±4.25	0.636
Sex, Female/Male (Female %)	26/25 (49%)	25/26 (51%)	0.843
Dominant side, right/left (right %)	45/6 (88.2%)	47/4 (92.2%)	0.505
Exercise frequency (day/ hours, in a week)	3.58±1.45/1.56±0.72	-	-

BMI: Body mass index. Values are presented as mean ± SD or percent, p<0.05.

ND right-side was lower in the regular exercise group (p=0.030) (Figure 1). There was no significant difference in other foot evaluations and FFI (p>0.05) (Table 2). It was observed that the ND scores of all individuals were within normal values (Nielsen et al., 2009).

Table 2. Comparison of Regularly Exercising Participants and Non-Exercising Participants

		Regularly Exercising Participants (n=51) Mean±SD Median (IQR)	Non-Exercising Participants (n=51) Mean±SD Median (IQR)	p	Test Statics
ND (cm)	Right	5.00 (3.40-6.90)	6.00 (4.40-7.80)	0.030*	U: 975.0
	Left	6.40 (4.40-8.30)	6.50 (4.90-8.40)	0.825	U: 1264.5
Metatarsal width-non weight bearing (mm)	Right	93.30 ± 7.20	92.53±7.85	0.606	t: 0.517
	Left	91.60 (87.00-96.40)	91.10 (87.00-94.90)	0.700	U: 1243.0
Metatarsal width-weight bearing (mm)	Right	96.60 (91.70-101.90)	94.10 (91.20-99.20)	0.478	U: 1194.5
	Left	94.80 (92.20-100.40)	94.40 (90.40-98.60)	0.574	U: 1216.5
Metatarsal width-difference (mm)	Right	3.90 (2.40-5.20)	3.60 (2.60-4.60)	0.468	U: 1192.0
	Left	3.60 (2.40-4.90)	3.30 (2.00-5.10)	0.486	U: 1196.0
HV angle (°)	Right	15 (10-18)	15 (10-19)	0.952	U: 1291.5
	Left	12 (10-18)	12 (10-16)	0.778	U:1258.5
Subtalar angle (°)	Right	7 (5-9)	7 (5-10)	0.869	U: 1276.0

	Left	11 (9-15)	10 (9-15)	0.861	U:1239.5
FFI (0-100)	Right	15 (5-33)	11 (2-23)	0.283	U: 1140.5
	Left	9 (2-31)	12 (1-24)	0.957	U: 1292.5

FFI: Foot Function Index, HV: Hallux Valgus, ND: Navicular drop. The variables are presented as Mean ± Standard deviation (SD) or Median (Interquartile range- IQR) accordingly normality. *: p<0.05. t: The student's t-test, U: Mann-Whitney U test

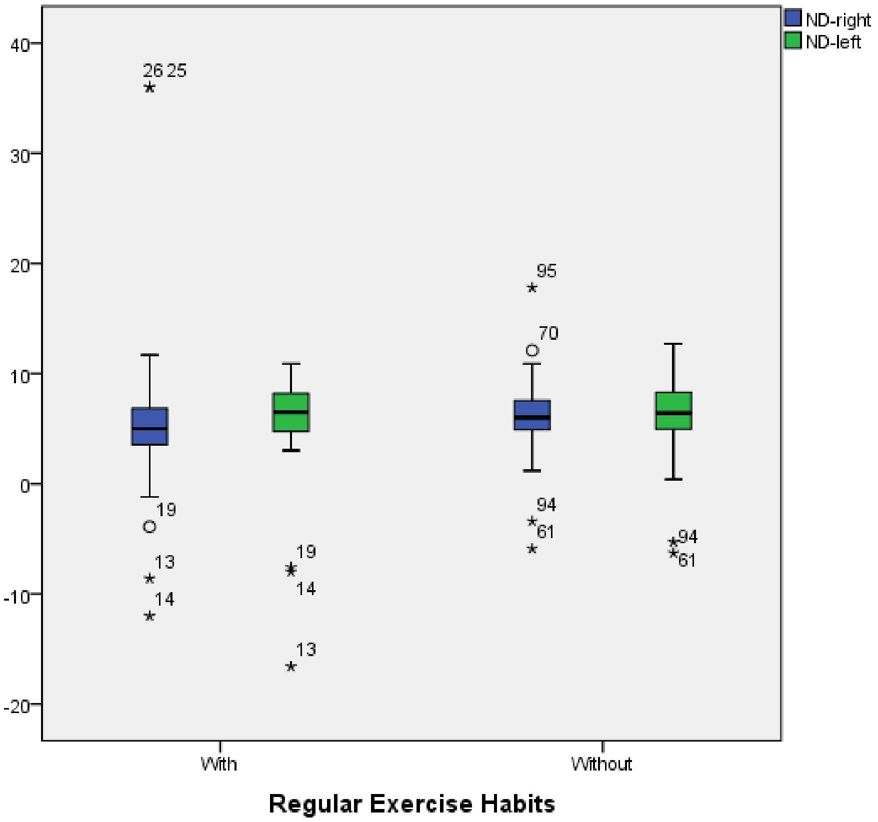

Figure 1. Box and Plot Chart for ND values

DISCUSSION

This study aimed to compare the foot biomechanics and function of university students with or without regular exercise habits. Our results showed that foot biomechanics evaluations, except right-side ND, and foot functions were similar between groups.

The excessive arch deformation was assessed using ND. ND right-side was statistically lower in the regular exercise group in this study. The foot exercises correct the foot alignment and prevent injuries (Okamura et al., 2020). A previous study reported that a 4-week foot exercise training improved foot alignment as assessed by the ND test (Mulligan & Cook, 2013). Although participants in the regular exercise group did not do any specific exercises for the feet, they generally did exercises for aerobic capacity, muscle strength, and endurance. These exercises can improve foot muscle strength, so the ND score was lower in the regular exercise on both dominant and non-dominant sides. To support our thought, a biomechanical assessment study can be performed in which muscle strengths, especially the tibialis posterior, will be evaluated. Previous studies have determined that ND is linked to several lower-extremity overuse injuries, such as medial tibial stress syndrome and patellofemoral pain syndrome (Haun, Brown, Hannigan & Johnson, 2020). Neither group in our study had lower extremity injuries, and the test results were among the normal values (Nielsen et al., 2009). Another study investigated the risk factors of injury among people with or without doing active sports (Komisak, 2021). Researchers determined that their ND scores increased as the participants' foot functionality decreased. It has been reported that as the ND test score increased, the foot biomechanics were negatively affected. The ND score of the non-exercising group was higher than that of the regularly exercising group. As a result, the ND scores in our study are consistent with all these studies, and a smaller ND change was seen in regularly exercising individuals. Based on this, regular exercise may significantly contribute to maintaining navicular height.

Metatarsal width shows the response of the forefoot structures to loading (Barroco et al., 2011). A norm value for metatarsal width has not yet been investigated in the literature. In rehabilitation, the symptomatic foot is often compared with the asymptomatic foot (Deben & Pomeroy, 2014). There was no pathology among the participants recruited for the study. Therefore, there may not have been a difference between the groups. On the other hand, it is stated that metatarsal width is directly correlated with body weight. (Altuntaş & Uzun, 2022). However, in this study, body weight was similar in both groups (p=0.965). In this respect, our results seem to be consistent with the literature. This is the first study to compare metatarsal width in individuals with and without regular exercise habits. On the other hand, to better understand the effects of exercise habits, long-term studies investigating different exercise approaches in more detail are needed in future studies.

The HV is a foot deformity involving lateral deviation of the hallux and medial deviation of the first metatarsal head. The HV angle, defined as the angle between the longitudinal axis of the big toe's proximal phalanx and the first metatarsal's longitudinal axis, normally ranges from 5° to 15° (Cavalheiro, Arcuri, Guil & Gali, 2020). Accordingly, our study observed that the HV angles in the groups that did regular exercise and those that did not were between normal values. Since HV was within normal values, there may have been no difference between the groups. Although the exact cause of HV remains unclear, several factors have been proposed as potential contributors. These include extrinsic factors such as inappropriate footwear (e.g., high heels, narrow shoes, etc.), excessive body weight, and intrinsic factors like sex, age, hypermobility, and bony abnormalities (Perera, Mason & Stephens, 2011). Previous studies have shown that HV is more common among women, and its prevalence increases with age (Akinbo, Aiyegbusi, Owoeye & Ogunsola, 2011; Bayar, Erel, Şimşek, Sümer & Bayar, 2011;

Tutuş, Polat, Işık & Göker, 2024). Furthermore, body mass index (BMI) is associated with HV (Tutuş et al., 2024). In the study conducted by Bortone et al. (2021), it was reported that as body weight increases, the hallux valgus angles also increase (Bortone et al., 2021). On the other hand, one study found that as height increases, HV decreases (Albo et al., 2021). Since both groups in our study have similar demographic characteristics regarding sex, age, and BMI, it can be considered normal that no significant difference was found in the HV.

The subtalar angle is important for both the flexibility of the foot and maintaining optimum stiffness. Subtalar joint pronation is associated with decreased medial arch, producing the clinically described pes planus deformity (Sahan et al., 2022). A previous study reported that the subtalar angle may be greater in the dominant extremity (Oskouei, Malliaras, Hill, Clark & Perraton, 2022). Our study showed no difference between the groups regarding the dominant extremity. The lack of difference between the two groups may be because the dominant extremity of both groups is the same.

Another important evaluation in this study was foot function using the FFI. Our results show that the FFI score was similar between the groups. However, the right FFI scores of the non-exercise group were lower than those of the left and right sides of the exercise group. It has been shown that regular foot exercises decrease pronation pathology in the foot and provide functional improvement, according to FFI (Gupta et al., 2023). No pathology was detected in the individuals participating in our study. Therefore, there may not have been a difference between the groups. In future studies, comparing individuals with foot problems with those without foot problems may provide a better understanding of the effects of regular exercise.

This is the first study investigating foot biomechanics and function in university students with and without regular exercise habits. Previous studies have generally focused on athletes (Ekanem et al., 2024; Lopez et al., 2005; Sirgo Rodríguez & Aguado Jodar, 1991). These studies have reported that athletes' foot biomechanics may be impaired due to repetitive loading. It has been reported that the incidence of pes cavus is increased in professional athletes and that metatarsal width increases in volleyball players (Ekanem et al., 2024; Sirgo Rodríguez & Aguado Jodar, 1991). Unlike these studies, the participants in our study were not athletes, and they were exercising. Exercise consists of repetitive movements targeting one or more physical fitness parameters and aims to preserve body biomechanics (Dasso, 2019). Therefore, no pathology may have occurred in the group that regularly exercises.

CONCLUSION

Our study is the first to investigate foot biomechanics and function in university students with and without regular exercise habits. Our results showed that foot biomechanics evaluations, except right-side ND, and foot functions were similar between groups. This study showed that regular exercise promotes navicular height in young individuals, but more comprehensive studies are needed to demonstrate its general effects on foot biomechanics.

Acknowledgment

Researchers would like to thank all the participants in this study.

Declarations

Funding

No funding was received for conducting this study.

Competing interests

The authors declare that they have no competing interests.

REFERENCES

Ahn, S. Y., Bok, S. K., Kim, B. O. & Park, I. S. (2017). The effects of talus control foot orthoses in children with flexible flatfoot. *Journal of the American Podiatric Medical Association*, 107(1), 46-53 https://doi.org/10.7547/15-045.

Akinbo, S., Aiyegbusi, A., Owoeye, O. & Ogunsola, M. (2011). Prevalence of hallux valgus among youth population in Lagos, Nigeria. *Nigerian Postgraduate Medical Journal*, 18(1), 51-55 https://doi.org/10.4103/1117-1936.170323.

Aktan, A. K. & Kutlay, Ö. (2022). The Relationship between Body Mass Index and Pes Planus, Balance, Quality of Life and Pain Levels in Sedentary Female and Male. *Value in Health Sciences,* 12(1), 58-64 https://doi.org/10.33631/sabd.1055295.

Albo, E., Campi, S., Zampogna, B., Torre, G., Papalia, G. F., Diaz Balzani, L. A., ... Denaro, V. (2021). Results of simultaneous unicompartmental knee arthroplasty and anterior cruciate ligament reconstruction: a systematic review. *Journal of Clinical Medicine*, 10(19), 4290 https://doi.org/10.3390/jcm10194290.

Altuntaş, E. & Uzun, A. (2022). Estimating height and body weight using foot measurements. *Middle Black Sea Journal of Health Science, 8*(1), 74-86. https://doi.org/10.19127/mbsjohs.1030302.

Barroco, R., Nery, C., Favero, G., Mombach, R., Nascimento, O., Jorge, S., ... Abreu, F. (2011). Evaluation of metatarsal relationships in the biomechanics of 332 normal feet using the method of measuring relative lengths. *Revista Brasileira de Ortopedia (English Edition),* 46(4), 431-438 https://doi.org/10.1016/S2255-4971(15)30258-5.

Bayar, B., Erel, S., Şimşek, İ. E., Sümer, E. & Bayar, K. (2011). The effects of taping and foot exercises on patients with hallux valgus: a preliminary study. *Turkish Journal of Medical Sciences*, 41(3), 403-409. https://doi.org/10.3906/sag-0912-499.

Bortone, I., Moretti, L., Bizzoca, D., Caringella, N., Delmedico, M., Piazzolla, A. & Moretti, B. (2021). The importance of biomechanical assessment after Return to Play in athletes with ACL-Reconstruction. *Gait & Posture*, 88, 240-246 https://doi.org/10.1016/j.gaitpost.2021.06.005

Budiman-Mak, E., Conrad, K. J., Mazza, J. & Stuck, R. M. (2013). A review of the foot function index and the foot function index–revised. *Journal of foot and Ankle Research*, 6(1), 5 https://doi.org/10.1186/1757-1146-6-5.

Can, S. (2019). Sedentary Behavior, Number of Steps and Health. *Turkish Journal of Sports Medicine*, 54(1), 071-082 https://doi.org/10.5152/tjsm.2019.118.

Card, R. K. & Bordoni, B. (2023). *Anatomy, Bony Pelvis and Lower Limb, Foot Muscles*. Treasure Island:StatPearls Publishing PMID: 31536304

Cavalheiro, C. S., Arcuri, M. H., Guil, V. R. & Gali, J. C. (2020). Hallux valgus anatomical alterations and its correlation with the radiographic findings. *Acta Ortopédica Brasileira*, 28, 12-15 https://doi.org/10.1590/1413-785220202801226897.

Cho, Y., Park, J.-W. & Nam, K. (2019). The relationship between foot posture index and resting calcaneal stance position in elementary school students. *Gait&Posture,* 74, 142-147 https://doi.org/10.1016/j.gaitpost.2019.09.003.

Cote, K. P., Brunet, M. E., Gansneder, B. M. & Shultz, S. J. (2005). Effects of pronated and supinated foot postures on static and dynamic postural stability. *Journal of Athletic Training,* 40(1), 41 PMID: 15902323

Dasso, N. A. (2019). How is exercise different from physical activity? A concept analysis. *Nursing Forum* https://doi.org/10.1111/nuf.12296.

Deben, S. E. & Pomeroy, G. C. (2014). Subtle cavus foot: diagnosis and management. *JAAOS-Journal of the American Academy of Orthopaedic Surgeons*, 22(8), 512-520 https://doi.org/10.5435/JAAOS-22-08-512.

Earls, J. (2021). *Understanding the Human Foot: An Illustrated Guide to Form and Function for Practitioners*. London:North Atlantic Books.

Ekanem, A. U., Edem, G. D., Okon, K. A. & Victor, E. Q. (2024). Assessment of Plantar Arch Index and the prevalence of foot deformity among athletes and non-athletes students at the University of Uyo, Nigeria. *African Anthropologist*, 22(2) https://doi.org/10.4314/aa.v22i2.5.

Eldemir, S., Benli, A. C., Bazencir, M., Sekreter, H. E., Öcal, İ. & Kethüdaoğlu, M. O. (2025) Investigation of relationships between navicular drop, hallux valgus angle, and subtalar angle with balance, knee muscle strength, and single-leg hop in university students. *Journal of Inonu University Health Services Vocational School*, 13(1), 192-203 https://doi.org/10.33715/inonusaglik.1583918.

Faul, F., Erdfelder, E., Lang, A. G. & Buchner, A. (2007). G* Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, 39(2), 175-191 https://doi.org/10.3758/BF03193146

Gentili, A., Masih, S., Yao, L. & Seeger, L. (1996). Foot axes and angles. *The British Journal of Radiology*, 69(826), 968-974 https://doi.org/10.1259/0007-1285-69-826-968.

Gupta, U., Sharma, A., Rizvi, M. R., Alqahtani, M. M., Ahmad, F., Kashoo, F. Z., . . . Ahamed, W. M. (2023). Instrument-assisted soft tissue mobilization technique versus static stretching in patients with pronated dominant foot: a comparison in effectiveness on flexibility, foot posture, foot function index, and dynamic balance. *Healthcare* https://doi.org/10.3390/healthcare11060785.

Gülçimen, B. & Ülkü, S. (2008). The Investigation of human foot biomechanics. *Uludağ University Journal of the Faculty of Engineering*, 13(2).

Haun, C., Brown, C. N., Hannigan, K. & Johnson, S. T. (2020). The effects of the short foot exercise on navicular drop: a critically appraised topic. *Journal of Sport Rehabilitation*, 30(1), 152-157. https://doi.org/10.1123/jsr.2019-0437.

Kızılcı, H. & Erbahçeci, F. (2016). Assessment of physical fitness in men with and without pes planus. *Turkish Journal of Physiotherapy and Rehabilitation*, 27(2), 25-33 https://doi.org/10.21653/tfrd.272249

Komisak, L. (2021). *A Comparison of Drop Vertical Jump Biomechanics Symmetry Indices in Healthy Females (Thesis)*. University of Hawai'i at Manoa.

Kothari, A., Dixon, P., Stebbins, J., Zavatsky, A. & Theologis, T. (2015). The relationship between quality of life and foot function in children with flexible flatfeet. *Gait & Posture,* 41(3), 786-790 https://doi.org/10.1016/j.gaitpost.2015.02.012.

Lopez, N., Alburquerque, F., Santos, M., Sánchez, M. & Domínguez, R. (2005). Evaluation and analysis of the footprint of young individuals. A comparative study between football players and non-players. *European Journal of Anatomy*, 9(3), 13.

Menz, H. B., Jordan, K. P., Roddy, E. & Croft, P. R. (2010). Characteristics of primary care consultations for musculoskeletal foot and ankle problems in the UK. *Rheumatology*, 49(7), 1391-1398 https://doi.org/10.1093/rheumatology/keq092.

Morrison, S., Durward, B., Watt, G. & Donaldson, M. (2005). The intra-rater reliability of anthropometric data collection conducted on the peripubescent foot: A pilot study. *The foot*, 15(4), 180-184 https://doi.org/10.1016/j.foot.2005.07.003.

Mulligan, E. P. & Cook, P. G. (2013). Effect of plantar intrinsic muscle training on medial longitudinal arch morphology and dynamic function. *Manual Therapy*, 18(5), 425-430 https://doi.org/10.1016/j.math.2013.02.007.

Nix, S., Russell, T., Vicenzino, B. & Smith, M. (2012). Validity and reliability of hallux valgus angle measured on digital photographs. *Journal Of Orthopaedic & Sports Physical Therapy*, 42(7), 642-648 https://doi.org/10.2519/jospt.2012.3841.

Nielsen, R. G., Rathleff, M. S., Simonsen, O. H. & Langberg, H. (2009). Determination of normal values for navicular drop during walking: a new model correcting for foot length and gender. *Journal of foot and ankle research*, *2*, 1-7. https://doi.org/10.1186/1757-1146-2-12

Okamura, K., Fukuda, K., Oki, S., Ono, T., Tanaka, S. & Kanai, S. (2020). Effects of plantar intrinsic foot muscle strengthening exercise on static and dynamic foot kinematics: A pilot randomized controlled single-blind trial in individuals with pes planus. *Gait & Posture*, 75, 40-45 https://doi.org/10.1016/j.gaitpost.2019.09.030.

Oskouei, S. T., Malliaras, P., Hill, K. D., Clark, R. & Perraton, L. (2022). Evaluating daily physical activity and biomechanical measures using wearable technology in people with achilles tendinopathy: a descriptive exploratory study. *Musculoskeletal Science and Practice*, 58, 102534 https://doi.org/10.1016/j.msksp.2022.102534.

Park, J. H., Moon, J. H., Kim, H. J., Kong, M. H. & Oh, Y. H. (2020). Sedentary lifestyle: overview of updated evidence of potential health risks. *Korean Journal of Family Medicine*, 41(6), 365 https://doi.org/10.4082/kjfm.20.0165.

Perera, A., Mason, L. & Stephens, M. (2011). The pathogenesis of hallux valgus. *The Journal of Bone and Joint Surgery*, 93(17), 1650-1661 https://doi.org/10.2106/JBJS.H.01630.

Sahan, T. Y., Kuz, B., Gul, G., Aksu, B., Ozcan, M. N. & Gumus, O. (2022). Comparison of subtalar angle, Q angle, trunk endurance and physical performance in individuals with pes planus and controls. *Journal of Social and Analytical Health*, 2(3), 299-305 https://doi.org/10.5281/zenodo.7197473.

Sarı, Z., Otman, A. S. & Akman, M. N. (1995). Correlation of foot deformities with heredity in children. *Journal of Turgut Ozal Medical Center*, 2(2).

Sirgo Rodríguez, G. & Aguado Jodar, X. (1991). Estudio del comportamiento de la huella plantar en jugadores de voleivol después del esfuerzo considerando su composición corporal y su somatotipo (con protocolo monopodal estático en apoyo). *Apunts Sports Medicine*, 28(109), 207-212.

Şahin, F. N., Ceylan, L., Küçük, H., Ceylan, T., Arıkan, G., Yiğit, S., . . . Güler, Ö. (2022). Examining the relationship between pes planus degree, balance and jump performances in athletes. *International Journal of Environmental Research and Public Health*, 19(18), 11602 https://doi.org/10.3390/ijerph191811602.

Tutuş, E., Polat, S. Ö., Işık, E. İ. & Göker, P. (2024). Investigation of the relationship between hallux valgus, quadriceps angle, and body image perception in young adults. *Cukurova Medical Journal*, 49(3), 673-687 https://doi.org/10.17826/cumj.1487103.

Yagci, G., Erel, S. & Okunakol, V. (2020). Validation of the Turkish version of the Revised Foot Function Index for patients with foot and ankle disorders. *Foot and Ankle Surgery*, 26(6), 624-629 https://doi.org/10.1016/j.fas.2019.08.002.

Yaliman, A., Şen, E. İ., Eskiyurt, N. & Budiman-Mak, E. (2014). Turkish Translation and Adaptation of Foot Function Index in Patients with Plantar Fasciitis. *Turkish Journal of Physical Medicine & Rehabilitation*, 60(3) https://doi.org/10.5152/tftrd.2014.26086.