International Journal of
Disabilities Sports and Health Sciences

e-ISSN: 2645-9094

RESEARCH ARTICLE

Examining the Relationship between Foot Medial Arch Height and Short and Medium Distance Running Performances and Some Variables in Athletes

H. Bayram TEMUR *[1], Hüseyin ESEN[2], O. Bilge İNCİ[3] and Hüseyin KARADAĞ[4]

[1]Bayburt University Faculty of Sports Sciences, Bayburt / Türkiye
[2]Youth Sports Provincial Directorate, Van /Türkiye
[3]Provincial Directorate of National Education, Van / Türkiye
[4]Türkiye Istanbul Gelişim University Faculty of Dentistry, İstanbul / Türkiye
*Corresponding author: temurbay@hotmail.com

Abstract

In this study, the relationship between foot medial arch height, age, height, body weight, body mass index (BMI), calf and thigh thickness and 100-meter and 3000-meter running performances in athletes was investigated. 28 athletes competing in national competitions, with an average age of 18.29±5.68 years, were included in the study on a voluntary basis. The right foot medial arch heights, heights, body weights, calf and thigh thicknesses of the participants were determined. BMI's were calculated. Also, 100 m and 3000 m. running times were determined. Data analyzes were performed using descriptive statistics and correlation tests. As a result of the analysis, 100 m running performance had a negative relationship with the values of height (r= -.377), body weight (r= -.466), BMI (r= -.428) and thigh circumference (r= -.433). It was observed that there was a relationship with the calf circumference measurement value (-.496) at the p<0.01 level. On the other hand, it was determined that the relationship between foot medial arch height (r= -.178) was not significant (p>0.05). On the other hand, 3000 m running performance was negatively affected by height (r= -.493), body weight (r= -.641), BMI (r= -.625) and calf girth thickness (r= -.623). It was determined that it showed significance at the p<0.01 level. It was also determined that there was a significant relationship with medial arch height in a negative direction (r = -.404) and at p < 0.05. As a result, it can be said that foot medial arch height, height, body weight, BMI, thigh and calf circumference thickness values are effective on short and medium distance running performances.

Keywords
Running Performance, Foot Medial Arch Height, BMI, Calf, Thigh

INTRODUCTION

Flat and high feet are serious health problems that can lead to gait irregularities and postural disorders in all age groups (Mickle et al., 2006). These deformities, in addition to disrupting walking patterns, can also cause foot, leg and waist pain. This can affect daily activities such as playing sports, standing for long periods of time, and walking. In a strong foot, muscle activity that allows the foot to adjust when it encounters unevensurfaces during movement plays a role in balance. Foot posture may vary between runners as well as between healthy individuals (Morris, 1977). The foot is divided into the following three categories based on arch height. Pes planus (PP), normal and pes cavus (PC) foot types. PP, also known as flat feet, where excessive pronation causes the ankle to be unable to stabilize the body, reducing its ability to properly absorb shock, but

Received: 17 April 2024 ; **Revised** ; 04 May 2024 ; **Accepted:** 20 June 2024; **Published:** 25 July 2024

How to cite this article: Temur, H.B., Esen, H., İnci, O.B., and Karadağ, H. (2024). Examining the Relationship between Foot Medial Arch Height and Short and Medium Distance Running Performances and Some Variables in Athletes. *Int J Disabil Sports Health Sci*;7(4):816-824. https://doi.org/10.33438/ijdshs.1468002

running speed is unaffected (Franco, 1987). On the other hand, it has been reported that individuals with flat feet feel fatigue in their feet more easily (Ledoux & Hillstrom, 2002).

The medial longitudinal arch (MLA) of the foot is involved in shock absorption and force transmission in the standing position and during gait (Fiolkowski et al., 2003). Changes in height can alter plantar pressure distributions (Jonely et al., 2011), and affect force absorption (Subotnick, 1985), muscle activity (Denyer et al., 2013; Murley et al., 2009), stability and gait (Cote et al., 2005). Foot morphology; It is closely related to many functions such as balance, walking, standing on one or two legs, jumping, and squatting (Jankowicz-Szymanska et al., 2015). The arch of the foot is the area between the heel and the heel on the bottom of the foot. The arch consists of three separate arches forming a triangle. Two are longitudinal (medial and lateral) arches and one is transversely arched. These arches are formed by the tarsal and metatarsal bones and are supported by the ligaments and tendons in the foot. The arch shape is designed to resemble a bow; It bears the weight of the body and absorbs the shock of movement. The flexibility of the foot provided by the arches is a feature that facilitates daily locomotor functions such as walking and sprinting

The foot, which carries the entire body weight and undertakes the task of adapting to the ground structure, has 3 contact points with the ground, the first metatarsal, the fifth metatarsal and the calcaneus, and among these contact points there are 3 arches: transverse, lateral longitudinal and medial longitudinal (Ledoux & Hillstrom, 2002). In vertical standing position, body weight is distributed equally on both feet. 60% of the weight on the foot is carried by the heel and 40% by the metatarsal heads. 1/3 of the weight carried in front is taken by the 1st metatarsal head, and 2/3 is distributed among the other metatarsal heads. The medial longitudinal arch is more flexible and higher. Its height from the ground is 15-18 mm (Mann, 1991).

The main arch that affects the foot structure is the medial longitudinal arch (MLA). This provides an elastic connection between the forefoot and hindfoot. This ensures that most of the plantar forces occurring during load bearing are dissipated before they reach the femur and leg bones. Problems and alignment disorders that arise specifically from the MLA, such as pes cavus and pes planus, ultimately affect the function of the lower extremity muscles and joints (Franco, 1987; Torun & Çay, 2018).

Arch structure is affected by various factors. Based on age and gender, it has been reported that older adults tend to have a stiffer arch than middle-aged and younger individuals, and women are more likely to have feet with lower arches compared to men (Zhao et al., 2020). It has also been suggested that there is a relationship between body mass index (BMI) and belt structure. In a comparative study, it was noted that the values of the height and width parameters of the belt in overweight and obese individuals are greater than in those with normal body weight. Additionally, other factors such as sports training, shoes, and bilateral asymmetry have been shown to affect foot structure and function (Obrien & Tyndyk, 2014). Various anthropometric and training characteristics have been identified as variables predicting race performance in endurance and ultra-endurance athletes. Various anthropometric characteristics (e.g. body mass, body fat, skinfold thicknesses, height, limb length and girth), training characteristics (e.g. speed during training units, duration of training units, training volume) and physiological variables in endurance and ultra-endurance athletes (i.e. maximum oxygen uptake, anaerobic threshold, lactate threshold, respiratory threshold) have been stated to be important determining variables for race performance (Knechtle, 2014). Here, ultra-endurance performance is defined as activity exceeding six hours (Zaryski & Smith, 2005). The arch of the foot plays an important role in supporting body weight, absorbing ground reaction forces, and maintaining balance during weight-lifting activities or sports. Changes in arch structure inevitably have a profound impact on physical activity and sports (Obrien & Tyndyk, 2014).

Since running is a linear movement of the whole body, the horizontal component of dynamic balance momentum is much more important than the vertical component for speed performance. After preparation for ground contact, the emphasis is shifted to vertical propulsion for sprinting at maximum speed (Lundberg et al., 1989). Although sprinting is a combination of pushing and pulling, focusing on vertical pushes will enable the athlete to actively accelerate his/her thigh towards the ground during the flight phase and increase leg stiffness after the contact time with the ground is achieved. This will reduce ground contact time, recovery mechanics and increase step frequency and length (Morris, 1977).

In effective running, the foot must hit the ground as close to gravity as possible. If the foot strikes ahead of the line of gravity, the reaction force to this forward and downward thrust will be a backward and upward force that acts to retard forward and backward motion (Kitaoka et al., 1997). The more precisely the horizontal force is directed backwards, the greater its effect. But sprinting consists of a series of ballistic steps in which the body is thrown forward repeatedly like a projectile. These forces are largely absorbed by the arches of the foot (Thordarson et al., 1995).

It is a very important issue to investigate the direction and level of the relationship between variables such as foot medial arch height, age, height, body weight, BMI, calf and thigh circumference thickness values, and 100-meter and 3000-meter running performances. This research is of great importance to understand the factors affecting sports performance and to help athletes train more effectively.

MATERIALS AND METHODS

Participant

The study was conducted with 28 volunteer athletics athletes. Chronological ages, sports ages, heights, body weights, thigh and calf thicknesses, and medial longitudinal arch heights were determined. Additionally, body mass index (BMI) values were calculated and participants' 100-meter and 3000-meter running times were determined. Approval for this study was received from the Bayburt University Rectorate Ethics Committee with the letter dated 01.04.2024-196963 (decision number:72). Participants were informed about the study risks, benefits, confidentiality, and participant rights through the volunteer form covering the research, and their consent was given. The research strictly adhered to the ethical principles of the Declaration of Helsinki, prioritizing participant's rights and well-being in design, procedures, and confidentiality measures.

Data Collection Techniques

To date, no consensus has been reached regarding the measurement of the foot arch. There is no single, globally accepted and agreed-upon method for measuring medial arch height clinically or radiologically. Clinical examination depends on the examiner and is not objective. Many methods for objective measurement of the medial longitudinal arch (MLA) have been described in the literatüre (Forriol & Pascual, 1990; Staheli et al., 1987). These can be roughly divided into direct and indirect methods. Direct methods include anthropometric measurements and radiological evaluations (Staheli et al., 1987; Viladot, 1992). Indirect measurements are footprints and photographic analyzes (Saltzman et al., 1995; Volpon, 1994). Significant debates regarding the validity of these measurement methods still continue (Razeghi & Batt, 2002).

Medial Arch Height Measurement

Participants were asked to sit on a bench with their feet bare. While the legs were extended straight and the feet were in their natural position, a non-flexible plate was extended between the starting point of the thumb metatersal and the lowest part of the calcaneus bone, so as not to create any pressure on the feet. It was then determined by measuring the area between the navicula bone and the plate (the highest area). This method was not used in medial arch height measurements made while standing, as increasing body weight may affect the arch height due to the pressure created. With increasing BMI, pressure on the sole of the foot increases, causing collapse or disappearance of the medial longitudinal arch when standing (Mosca, 2010). During foot arch measurements, only the right foot was measured. The reason for this is that there is no significant difference between the left and right foot (Shariff et al., 2017). Therefore, the right side was used to represent the overall feet of the participants.

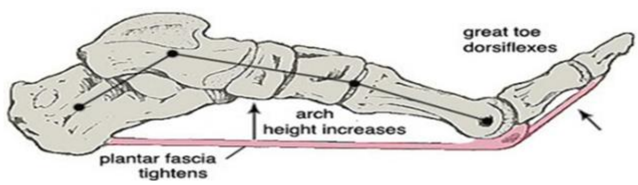

Figure 1. Foot arch height

Height

Participants' heights were measured using a meter while standing barefoot on a flat surface.

Body Weight

Body weight was measured using an electronic precision scale while the athletes were wearing shorts and barefoot.

Thigh Circumference

The individual was asked to open his feet shoulder-width apart (M. Quadriceps in extension). The athlete was asked not to tense both thigh muscles. Measurements were taken from the widest area close to the groin. Measurement values from both thighs were collected and averaged by dividing by two.

Calf Circumference

Measurements were made at the widest point of the calf, with the subject standing and upright, with the legs slightly open and the body weight distributed equally on both feet. Measurement values of both calves were collected and averaged by dividing by two.

BMI

BMI values of the participants were calculated by dividing body weight (kg) / height in meters squared (m2).

Running Times

Both the 100 m and 3000 m running times of the participants were determined using a stopwatch.

Statistical Analysis

SPSS (Version 26.0) package program was used to analyze the data obtained as a result of measurements and calculations. It was determined whether the data were normally distributed or not by the Shapiro–Wilk test. Tabachnick and Fidell (Tabachnick et al., 2013) reported that in the normality test, skewness and kurtosis values being between +1-5 and -1.5 indicate that the data is normally distributed. The skewness and kurtosis values of the study data being between +1.5 and -1.5 were considered as an indication that the data were normally distributed. Pearson Correlation Test was applied to analyze normally distributed data. The significance level was determined as p<0.05. In relationships that provide a p<0.05 value in the correlation test, if the correlation (r) value is below 0.30, it is interpreted as low, if it is between 0.30-0.70, it is interpreted as a medium relationship, and if it is between 0.70-1.00, it is interpreted as a high relationship (Büyüköztürk et al., 2016).

RESULTS

Table 1. Descriptive information about the variables included in the study

Variables	**n**	**Minimum**	**Maximum**	**Average**	**Standard deviation**
Height (cm)	28	145	185	167,29	9,63
Body weight (kg)	28	30	75	51,25	12,56
BMI (kg/m^2)	28	11,02	23,53	18,12	3,14
Calf (cm)	28	27,0	44,0	33,62	5,08
Thigh (cm)	28	34	62	47,07	8,27
Medial arch height (cm)	28	1,5	3,0	2,25	,60
100 m running time (sec)	28	11,23	17,21	13,89	1,74
3000 m running time (min)	28	9,00	16,02	12,26	2,12

When Table 2 is examined, it can be seen that the age variable has a positive relationship with body weight, height, BMI, thigh and calf circumference thickness, medial foot arch height at the level of p < 0.01, and a negative relationship with the 3000 m running time at the level of p < 0.01. detected. It was revealed that body weight had a negative relationship with 100 m running time at p<0.05, 3000 m running time with p<0.01, and a positive relationship with all other variables at p<0.01. When the height values of the participants were considered, it was determined that there was a positive relationship between them at the level of p < 0.01 with BMI, thigh circumference, calf circumference and medial arch height of the foot. On the other hand, it was determined that there was a negative relationship with the 100 m running time at the level of p<0.05 and with the 3000 m running time at the level of p<0.01. In BMI values, there is a positive relationship between thigh and calf circumference thicknesses and foot medial arch height at the level of p<0.01, a negative relationship with the 100 m running time at the level of p<0.05 and the 3000 m running time at the level of p<0.01. It was seen to be. It was revealed that the perimeter thickness of the femur (thigh) region had a positive and significant (p<0.01) relationship with the calf circumference and medial arch height of the foot. In addition, it was determined that the relationship between 100 m and 3000 m running times was negative and the significance levels were p<0.05 and p<0.01, respectively. It was revealed that calf circumference had a positive and significant relationship with the medial arch height of the foot (p<0.05), and a negative and significant relationship with 100 m and 3000 m running distances (p<0.01). On the other hand, it was determined that the relationship between foot medial arch height and 100 m running time was negative but not significant (p>0.05), and it was also negative but significant (p<0.05) with 3000 m running time. Finally, the relationship between 100 m time and 3000 m running time was found to be positive and significant (p<0.01).

Table 2. Correlation of some variables of the participants with each other (n=28)

Variable		Age (years)	Body weight (kg)	Height (cm)	BMI (kg/m^2)	Thigh circumfer en ce (cm)	Calf circumfe rence (cm)	Foot arch (mm))	100 m time (sec)
Body weight (kg)	r	,810**							
	p	,000							
Height length (cm)	r	,621**	,749**						
	p	,000	,000						
BMI (kg/m2)	r	,726**	,899**	,387*					
	p	,000	,000	,042					
Thigh circumference (cm)	r	,861**	,936**	,733**	,829**				
	p	,000	,000	,000	,000				
Calf circumference (cm)	r	,804**	,864**	,691**	,745**	,927**			
	p	,000	,000	,000	,000	,000			
Foot arch (mm)	r	,515**	,485**	,544**	,347	,499**	,405*		
	p	,005	,009	,003	,071	,007	,032		
100 m running time (sec)	r	-,286	-,428*	-,385*	-,334	-,433*	-,496**	-,178	
	p	,140	,023	,043	,083	,021	,007	,366	
3000 m running time (min)	r	-,540**	-,625**	-,497**	-,549**	-,605**	-,623**	-,404*	,803**
	p	,003	,000	,007	,002	,001	,000	,033	,000

*P<0,05; ** p<0,01

DISCUSSION

The average age of the participants included in the study was 17.29 ± 5.68 years. It was observed that the age values of the participants had a significant positive (r = .810) relationship with their body weight values, at the p = .000 level. It was revealed that the age variable showed a positive (r = .621) and significant (p = .000) relationship with height. Another feature that shows a positive (r = .726) and significant (p = .000) relationship with the age variable is BMI. Thigh and calf circumference thickness is another feature that increases significantly (p<0.01) as age increases. It was determined that the height of the medial arch of the foot, which was the focus of the study, increased significantly (p = .005) with increasing age (r = .515). On the other hand, one of the features that decrease as age increases is the 100 m (r = -.285) and 3000 m (r = -.540) running times. However, it was revealed that this decrease was not significant (p = .140) in the 100 m running time, but was significant (p = .003) in the 3000 m running time. Research and expert opinions on flat feet (Mickle et al., 2006; Staheli et al., 1987) do not recommend any treatment for flat feet in children. They suggest that this condition can often resolve on its own as children grow older. However, another study (Dare & Dodwell, 2014) suggests that the chance of natural recovery of flat feet decreases after the age of 10. In addition, there is also a study (Chang et al., 2010) reporting that flat feet tend to decrease with increasing age. The research results overlap with the literature data above. This can be explained by the fact that the bone structure takes its final shape with increasing age. On the other hand, the improvement in short and medium distance running performance with increasing age can be expressed by the increase in both muscle mass and step length caused by height increase with age.

The average body weight of the participants is 51.25 ± 12.56 kg. There was a positive and significant difference between body weight and height (r = .749; p = .000), with BMI (r = .899; p = .000), and with thigh circumference (r = .936; p = .000). It was revealed that there was a positive and significant relationship with calf circumference (r = .864; p = .000) and medial arch height (r = .485; p = .009). It was determined that there was a negative (r= - .428) significant relationship with the 100 m running time (p= .023), and a negative and significant relationship with the 3000 m running time (p= -.625; p= .000). A study conducted on university students (Bjelopetrovich, 2016) revealed that there is a positive relationship between foot arch index and body weight. On the contrary, there is also a study (Mickle et al., 2006) that reveals a negative relationship between the height of the medial arch and body weight. Atamtürk (Atamtürk, 2009), in his study on individuals between the ages of 18-60, reported that there was no significant relationship between flat and high feet and body weight. On the other hand, according to the study results, short and middle distance running performance decreases as body weight increases. This is as important as the amount of load the feet carry, as well as the duration of the load. As the running distance increases, the athlete's fatigue will increase accordingly. This will be reflected in your performance.

Among the variables included in the study, as height increased, BMI, thigh and calf circumference values, and medial arch height also increased. It was determined that the relationship between them was positive and significant ($p < .05$). On the other hand, there was a negative (r= -.385) and significant (p=.043) relationship with 100 m running performance and a negative (r= -.497) and significant (p=.007) relationship with 3000 m running performance. determined. In a study (Atamtürk, 2009), it was stated that there was no significant relationship between flat feet or high arches and height. In tall people, the body center of gravity is higher. This means there is less balance. In tall people, the higher medial arch height may be related to the need to bear more body weight and maintain balance. Being taller results in longer strides. Since the study group consists of athletes, the factor affecting BMI is muscle mass rather than fat. However, the increase in muscle mass affects running performance.

Another variable studied is BMI. It was determined that there was a positive (r=.829) and significant (p=.000) relationship between BMI and thigh circumference thickness. It was also determined that there was a positive (r = .745) and significant ($p < .01$) relationship with calf circumference thickness. When its relationship with medial arch height was examined, it was revealed that it was positive (r = .347) but not significant (p = .071). It was seen that there was a negative relationship between 100 m and 3000 m, respectively (r=-.334), (r=-.549). Their significance levels are p = .083 and p = .002, respectively. In a study conducted on adult individuals (Rosende-Bautista et al., 2021), it was reported that there was a positive relationship between medial arch height and BMI values in both men and women. In another study (Atamtürk, 2009) in which the relationship between flat feet (pes planus) and high arch (pes cavus) morphology and anthropometric characteristics was investigated, it was reported that flat feet or high arch status was not related to BMI. Another study (Rejeki et al., 2017), which revealed that there was no relationship between BMI and medial arch height, was conducted on 5-6 year old children. The reason for not finding a relationship between BMI and medial arch in the literature may be due to the fact that the study groups were composed of children who had not yet completed their development process, and the participants in the study were athletic athletes, whose BMI average was quite low (18.12±3.14 kg/m^2). Because it is known that BMI will not give accurate results in children, pregnant women and muscular athletes.

The participants' thigh circumference thickness had a positive (r= .927) and significant relationship with their calf circumference thickness (p= .000), and the medial arch height had a positive (r= .499) and significant relationship (p= .007). appeared. On the other hand, it was determined that there was a negative relationship with the 100 m running time at the level of p = .021, and with the 3000 m running time at the level of p = .001. The main muscle groups that make up the thigh area are quadriceps and hamstring muscle groups. Developing these muscles through training in addition to the natural growth process can positively affect both medial arch height and running performance.

The study revealed that as calf circumference thickness values increased, medial arch height also increased. It was determined that this increase was significant at the p = .032 level. However, it was revealed that there was a negative and significant ($p < .01$) relationship with 100 m and 3000 m running times. The medial longitudinal arch is an anatomical feature that aids shock absorption and terrain adaptation at heel strike and mid-stance, subsequently allowing effective driving on the toes (Windlass effect) (Madhav et al., 2018). The shape of the bones, ligaments and muscle tone in the legs play an important role in supporting the arch (Chang et al., 2010).

What is the relationship between the medial arch height of the foot, which inspired the study, and short and medium distance running performances? An attempt was made to find an answer to the question in the light of the data obtained. It was determined that medial arch height had a negative (r = -.178) relationship with 100 m running performance, but this relationship was not significant (p = .366). It was also found to have a negative relationship (r= -.404) with 3000 m running performance. However, the difference between this relationship and the previous one is that it is significant (p=.033).

In the study conducted by Usman et al. (Usman et al.) on runners, they reported that the 100 m running times of runners with high medial arch height were shorter than those with normal and low medial arch height. Another study (Scott & Winter, 1991) reported that those with high-arched feet and normal-arched foot types made forefoot contact faster than those with low-arched foot types. It has also been reported that in the high-arched foot type, hindfoot contact is rare and less time is spent on the hindfoot compared to the low-arched foot type. In their study on individuals with flat feet and normal medial arch height, Sharma and Upadhyaya (Sharma & Upadhyaya, 2016) reported that there was a significant difference in 100 m running performance in favor of participants with normal arch height. In the same study, it was stated that there was a significant difference in 12-minute running performance in favor of participants with normal arch height. It has been stated that high-arched foot type is more beneficial for short distance runners (Morris, 1977). In another study on this subject (Morita et al., 2015), it was reported that foot arch height in children was related to 50-meter sprint time. The shock level that movements create in the human body increases from head to foot. The same situation applies to the load carried by these joints. The bone and muscle structure that makes up the belt can be effective in preventing injuries and creating movements. The medial arch of the foot also ensures that body weight is evenly distributed across the calcaneus and metatarsals. Dorsiflexion of the fingers combined with planter flexion of the ankle allows the body to be moved forward. It is thought that this may positively affect running performance.

Conclusion

Depending on the study results, it can be said that medial arch height increases as age, height, body weight, thigh and calf thickness increase. It can be stated that medial arch height has a negative relationship with both 100 m and 3000 m running performance. However, it was determined that the relationship between medial arch height and 100 m running performance was not significant. Studies with larger participation are needed.

ACKNOWLEDGMENT

We thank all participants who voluntarily participated in this study.

Conflict of interest

There is no conflict of interest between the authors in this article.

Ethical statement

Before conducting this study, the necessary permissions (dated and numbered, 01.04.2024-196963 and decision number; 72) were obtained from the Bayburt University ethics committee. Participants were informed with a volunteer consent form. Additionally, all principles of the Declaration of Helsinki were complied with.

Authors Contribution

Study Design, HBT and HK; Data Collection, HBT and HE; Statistical Analysis, HBT; Data Interpretation, HBT and HK; Manuscript Preparation, HBT, HE, and OBI; Literature Search, HBT, OBI and. All authors have read and agreed to the published version of the manuscript

REFERENCES

Atamtürk, D. (2009). Relationship of flatfoot and high arch with main anthropometric variables. *Acta orthopaedica et traumatologica turcica*, *43*(3), 254-259). [CrossRef]

Bjelopetrovich, A. (2016). Effects of Body Weight Loading on Arch Height. [CrossRef]

Büyüköztürk, Ş., Çoklu, Ö., & Köklü, N. (2016). Statistics for social sciences, (18th edition) Ankara. Pegem Publications.

Chang, J.-H., Wang, S.-H., Kuo, C.-L., Shen, H. C., Hong, Y.-W., & Lin, L.-C. (2010). Prevalence of flexible flatfoot in Taiwanese school-aged children in relation to obesity, +gender, and age. *European journal of pediatrics*, *169*, 447-452. [CrossRef]

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 . [PubMed]

Dare, D. M., & Dodwell, E. R. (2014). Pediatric flatfoot: cause, epidemiology, assessment, and treatment.

Current opinion in pediatrics, 26(1), 93-100. [CrossRef]
Denyer, J. R., Hewitt, N. L., & Mitchell, A. C. (2013). Foot structure and muscle reaction time to a simulated ankle sprain. *Journal of athletic training, 48*(3), 326-330. [CrossRef]
Fiolkowski, P., Brunt, D., Bishop, M., Woo, R., & Horodyski, M. (2003). Intrinsic pedal musculature support of the medial longitudinal arch: an electromyography study. *The Journal of foot and ankle surgery, 42*(6), 327-333. [CrossRef]
Forriol, F., & Pascual, J. (1990). Footprint analysis between three and seventeen years of age. *Foot & ankle, 11*(2), 101-104. [CrossRef]
Franco, A. H. (1987). Pes cavus and pes planus: analyses and treatment. *Physical therapy, 67*(5), 688-694. [CrossRef]
Jankowicz-Szymanska, A., Mikolajczyk, E., & Wardzala, R. (2015). Arch of the foot and postural balance in young judokas and peers. *Journal of Pediatric Orthopaedics B, 24*(5), 456-460. [CrossRef]
Jonely, H., Brismée, J.-M., Sizer Jr, P. S., & James, C. R. (2011). Relationships between clinical measures of static foot posture and plantar pressure during static standing and walking. *Clinical Biomechanics, 26*(8), 873-879. [CrossRef]
Kitaoka, H. B., Ahn, T.-K., Luo, Z. P., & An, K.-N. (1997). Stability of the arch of the foot. *Foot & ankle international, 18*(10), 644-648. [CrossRef]
Knechtle, B. (2014). Relationship of anthropometric and training characteristics with race performance in endurance and ultra-endurance athletes. *Asian journal of sports medicine, 5*(2), 73. [CrossRef]
Ledoux, W. R., & Hillstrom, H. J. (2002). The distributed plantar vertical force of neutrally aligned and pes planus feet. *Gait & posture, 15*(1), 1-9. [CrossRef]
Lundberg, A., Svensson, O. K., Bylund, C., Goldie, I., & Selvik, G. (1989). Kinematics of the ankle/foot complex—part 2: pronation and supination. *Foot & ankle, 9*(5), 248-253. [CrossRef]
Madhav, R., Amin, A., Eastwood, D., & Singh, D. (2018). Biomechanics and joint replacement of the foot and ankle. In *Basic Orthopaedic Sciences* (pp. 337-349). CRC Press. [CrossRef]
Mickle, K. J., Steele, J. R., & Munro, B. J. (2006). The feet of overweight and obese young children: are they flat or fat? *Obesity, 14*(11), 1949-1953. [CrossRef]
Morita, N., Yamauchi, J., Kurihara, T., Fukuoka, R., Otsuka, M., Okuda, T., Ishizawa, N., Nakajima, T., Nakamichi, R., & Matsuno, S. (2015). Toe flexor strength and foot arch height in children. *Medicine and science in sports and exercise, 47*(2), 350-356. [CrossRef]
Morris, J. M. (1977). Biomechanics of the foot and ankle. *Clinical Orthopaedics and Related Research®*(122), 10-17. [CrossRef]
Mosca, V. S. (2010). Flexible flatfoot in children and adolescents. *Journal of children's orthopaedics, 4*(2), 107-121. [CrossRef]
Murley, G. S., Menz, H. B., & Landorf, K. B. (2009). A protocol for classifying normal-and flat-arched foot posture for research studies using clinical and radiographic measurements. *Journal of foot and ankle research, 2*, 1-13. [CrossRef]
Obrien, D. L., & Tyndyk, M. (2014). Effect of arch type and Body Mass Index on plantar pressure distribution during stance phase of gait. *Acta of bioengineering and biomechanics, 16*(2). [CrossRef]
Razeghi, M., & Batt, M. E. (2002). Foot type classification: a critical review of current methods. *Gait & posture, 15*(3), 282-291. [CrossRef]
Rejeki, P. S., Irwadi, I., & Munir, M. (2017). Correlation Between Body Mass Index and Medial Longitudinal Arch of The Foot in Children Aged 5–6 Years. In: Proceedings of Surabaya International Physiology Seminar. SCITEPREES-Science and Technology Publications, Surabaya, pp. 230-233. [CrossRef]
Rosende-Bautista, C., Munuera-Martínez, P. V., Seoane-Pillado, T., Reina-Bueno, M., Alonso-Tajes, F., Pérez-García, S., & Domínguez-Maldonado, G. (2021). Relationship of body mass index and footprint morphology to the actual height of the medial longitudinal arch of the foot. *International Journal of Environmental Research and Public Health, 18*(18), 9815. [CrossRef]
Saltzman, C. L., Nawoczenski, D. A., & Talbot, K. D. (1995). Measurement of the medial longitudinal arch. *Archives of physical medicine and rehabilitation, 76*(1), 45-49. [CrossRef]
Scott, S. H., & Winter, D. A. (1991). Talocrural and talocalcaneal joint kinematics and kinetics during the stance phase of walking. *Journal of biomechanics, 24*(8), 743-752. [CrossRef]
Shariff, S. M., Manaharan, T., Shariff, A. A., & Merican, A. F. (2017). Evaluation of foot arch in adult women: Comparison between five different footprint parameters. *Sains Malaysiana, 46*(10), 1839-1848. [CrossRef]
Sharma, J., & Upadhyaya, P. (2016). Effect of flat foot on the running ability of an athlete. *Indian Journal of Orthopaedics Surgery, 2*(1), 119-123. [CrossRef]
Staheli, L. T., Chew, D. E., & Corbett, M. (1987). The longitudinal arch. *J Bone Joint Surg Am, 69*(3), 426-428. [CrossRef]
Subotnick, S. I. (1985). The biomechanics of running implications for the prevention of foot injuries. *Sports Medicine, 2*, 144-153. [CrossRef]
Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2013). *Using multivariate statistics* (Vol. 6). pearson Boston, MA. [CrossRef]
Thordarson, D. B., Schmotzer, H., Chon, J., & Peters, J. (1995). Dynamic support of the human longitudinal arch: a biomechanical evaluation. *Clinical Orthopaedics and Related Research®*(316), 165-172. [CrossRef]
Torun, B., & Çay, N. (2018). Relationship between the angle of the foot arch and the length of the foot. *Kafkas TıpBilimleri Dergisi, 8*(3), 172-177. [CrossRef]
Usman, M. A., Supriyadi, W., Zulkarnain, Z., & Thehumury, A. A. Arabian Journal of Medical Sciences. [CrossRef]
Viladot, A. (1992). Surgical treatment of the child's flatfoot. *Clinical Orthopaedics and Related Research®, 283*, 34-38. [CrossRef]

Volpon, J. B. (1994). Footprint analysis during the growth period. *Journal of pediatric orthopedics, 14*(1), 83-85. [CrossRef]

Zaryski, C., & Smith, D. J. (2005). Training principles and issues for ultra-endurance athletes. *Current sports medicine reports, 4*(3), 165-170. [CrossRef]

Zhao, X., Gu, Y., Yu, J., Ma, Y., & Zhou, Z. (2020). The influence of gender, age, and body mass index on arch height and arch stiffness. *The Journal of Foot and Ankle Surgery, 59*(2), 298-302. [CrossRef]