

Linking foot arch, oxygen uptake and injury risk: A study of Indonesian futsal athletes

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Abstract:

Foot arch functions as a natural shock absorber during athletic activities such as running, jumping, and rapid changes. Changes in foot arch morphology can affect oxygen consumption and increase the risk of injury. This study aims to identify foot arch, somatotype, maximum oxygen uptake, nutritional intake, and injury among Indonesian futsal athletes, as well as to analyze the relationship between foot arch characteristics, maximum oxygen uptake and injury incidence. A quantitative observational study with a cross-sectional design involving 73 futsal athletes in West Kalimantan province, Indonesia. Participants were divided into elite and non-elite team categories. The variables were determined using standardized instruments. Both teams had abnormal foot arch types. Forty-four athletes (60.27%) had an abnormal foot arch and 29 athletes (39.73 %) had a normal foot arch; the average somatotypes for both teams were the central type, 2.5-3.7-2.3 and 3.1-3.0-2.7, respectively. However, the elite team had more extremity injuries (57.58%, n = 19/33) than the non-elite team (40%, n = 4/40) and both had a poor daily nutritional intake (2.74%, n = 2/73). Furthermore, the maximum oxygen uptake of the elite team was higher (44.35 ± 5.41 mL/kg/minute) than the non-elite team. Kendall's Tau test with p value = 0.788 showed that there was no association between foot arch characteristic and maximum oxygen uptake, and Fisher's exact test with p value = 0.198 showed that there was no association between foot arch characteristic and the incidence of injury. A low foot arch was dominant in futsal athletes. The oxygen uptake and incidence of injury among professional futsal athletes were not solely influenced by the foot arch characteristic. However, the interplay between nutritional status, foot arch morphology, oxygen capacity, and somatotype underpins the need for a comprehensive, individualized approach to athlete preparation. A customized insole prescription can offer a solution for comfort and performance improvement.

Key Words: foot arch, futsal, somatotype, oxygen, injury

Introduction

The foot arch plays a pivotal role in supporting biomechanics, and it also influences energy efficiency and cardiovascular performance (Stearne et al., 2016; Zhang et al., 2024), including maximum oxygen uptake (Sulowska-Daszyk et al., 2024). Futsal is a popular sport that uses most the lower limbs and has a high potential for injury. The lower limbs play an important role in most physical activities and are important for maintaining posture and good movement (Hamill et al., 2013).

Normal foot arches provide the best support for certain physical activities. However, abnormal foot arches, including low and high foot arches lead to the problems of inappropriate movement, poor absorption (Hamill et al., 2013) and altered weight distribution (Chauhan & Taqi, 2023). These issues contribute to the impact of body gait and potentially lead to injuries (Chauhan & Taqi, 2023; Yunus et al., 2020). Additionally, studies indicate that the medial longitudinal arch significantly contributes to an individual's risk of injury (Williams & McClay, 2000).

The observable anatomy of futsal athlete's body is their body shape, which supports movement and performance. Somatotypes, which determine an athlete's body shape, can affect athletes' performance (Andreato et al., 2016; Hakman et al., 2020; Penichet-Tomas et al., 2022; Ryan-Stewart et al., 2018; Suhaimi et al., 2022), as do nutrition (Jeukendrup, 2017; Mielgo-Ayuso et al., 2015), and injuries (Jones & Wilson, 2019).

Athletic performance depends on the physical and physiological efficiency, which is believed to be related to the cardiovascular endurance. Cardiovascular endurance is one of the essential health conditioning components in soccer (Aksoy et al., 2022). A decline in cardiovascular, muscle strength, speed-agility and power capacities was reported in multiple studies of the last decades. Further, in support of this hypothesis, literature suggested that the increase of sedentary lifestyle and industrialization, and negatively influenced the fitness over the time in children and adolescent (Giuriato et al., 2022).

Food is one of the fundamental pillars of physical activity as it provides the necessary energy for performance in both physical activity and sports, plays a crucial role in building and repairing muscles, maintaining hormonal homeostasis and even as a prophylactic measure against injuries. The eating habits of young athletes can help education and health professionals create more stimulating learning environments that promote more active and healthy human development (Lourenço et al., 2024). A study using a 4-week electrical muscle stimulation training performed in 2 independent groups twice a week for 20 minutes at a time, in one group including eating habit modifications, confirmed the generally anticipated assumption that such physical activity performed would be beneficial in reducing the overall body weight as well as eliciting favorable changes in body composition. In case of the more complex intervention namely combining diet modification and exercise, the results are up to three times more substantial (Junger et al., 2020).

Sustaining an injury is one of the inevitable consequences of participating in athletics and are extremely complex because not only affect the individual athlete's physical and mental functioning, but also a team as a whole. Detailed information of injuries can be used to determine how to prevent injuries in the future and help athletes with the mental side of coping with recovery and possible financial costs. A study showed that the most injuries located in lower leg, more specifically strains and sprains, are in conformity with previous research findings (Lacasse & Njororai, 2021). A properly planned and performed training is essential for allowing players to meet the match requirements at the elite level. Potential relations between the external training load and rating of perceived exertion could provide practical information for coaches during session preparation when they want to avoid the effect of subjective fatigue that can lead to injury (Radzimiński, 2021).

There is insufficient evidence to describe the characteristics and problems related to foot arches in athletes participating in futsal disciplines, particularly in Asian countries with large populations such as Indonesia. There is no particular research investigating foot arch as predictor of oxygen uptake and injury risk. Hence, the aims of the work were to investigate the foot arch characteristic, somatotype, maximum oxygen uptake, nutritional intake, and rate of injury among Indonesian futsal athletes and to analyze the association between foot arch characteristic and the maximum oxygen uptake and injury rate in futsal athletes. A cross sectional observation study conducted in futsal athletes to seek the relationship between foot arch characteristic and the maximum oxygen uptake, relationship between foot arch and injury rate.

Material and methods

The participants in this study were futsal athletes and members of professional futsal teams that competed in the highest futsal competition in Indonesia. There were both elite and non-elite teams. The elite team comprised professional athletes who participated in the Indonesian Futsal League 1 competition on a national scale, while the non-elite team comprised local university futsal athletes from West Kalimantan who competed in local matches in Pontianak.

This study was a cross-sectional study using purposive sampling in which any prospective subject who met the study criteria could be a participant. The inclusion criteria for this study were: male, aged 17 years old or above, and a member of a West Kalimantan professional futsal team with minimum 2 years' experience. The exclusion criterion was having a history of lower extremity fracture(s) or surgery(ies). The study took place at the Anatomy Laboratory, Universitas Tanjungpura, Pontianak, Indonesia and at Pontianak stadiums, Indonesia from January 2023 to May 2023.

The variables were determined using various instruments as follows: the type of foot arch was determined using the wet method and the foot arch index; the somatotype was obtained using Heath-Carter measurement and somatotype formula; the 12-minute Cooper run test was employed to measure maximum oxygen uptake; nutrition was assessed used a 24-hour food recall form; and information of injuries was gathered by using an injury form.

Type of foot arch

Participant underwent foot print creation, foot area calculation, and foot arch type examination.

Foot print creation.

Prepare a flat examination area, an ink pad, blue ink, and two sheets of white paper; evenly applied ink evenly to the podograph; prepared two white papers in front of the podograph; participant was asked to clean and dry his feet and plantar; participant stand on the podograph for 10 seconds; participant carefully lifted his foot off the podograph, stepped carefully forward, and stood on the two prepared white sheets of paper, one sheet for the right foot and one sheet for the left foot; and the foot prints from the right and left foot were obtained on both sheets of white paper.

Foot Area calculation

Prepare the equipment: a ruler, writing tools, a calculator, a computer with Excel and Photoshop CS2 programs, and a scanner; measure the length of the foot print without toes using a ruler; obtained length then divided by 3 using a calculator to create horizontal lines forming three areas: top (A), middle (B), and bottom (C); prepare the scanner that is connected to the computer; scan the foot prints that have been divided into three areas; the scan results are opened in the Photoshop CS2 program; each area can be measured in pixels; record the results per area in an Excel program that has the arch index formula included; and obtain the arch index.

Foot arch type examination.

Foot arch type was determined using the arch index from the calculation:

Area B (middle area)

$\frac{\text{Area A} + \text{B} + \text{C (top area + middle area + bottom area)}}{2}$

According to the arch index, the standard types of foot arch are namely (Menz & Munteanu, 2005; Roy et al., 2012): normal foot arch with a value of 0.21-0.26, low foot arch with a value of > 0.26, and high foot arch with a value of < 0.21. The arch index data were simplified into normal foot arch (arch index value of 0.21-0.26) and abnormal foot arch (arch index value of < 0.21 and > 0.26).

Somatotype

Participant underwent anthropometric measurement, somatotype calculation, and somatotype determination.

Anthropometric measurement.

Anthropometric measurements namely body weight, stature, skinfold thickness (triceps, subscapular, supraspinale, medial calf), limb girths, and bone breadths, following standardized protocols. Four skinfold thicknesses (triceps, subscapular, supraspinal, and medial calf), two bone breadths (humerus and femur), and two calf circumferences (relaxed and contracted arm and calf) were measured following the procedures established by the International Society for Advancement of Kinanthropometry (Eston & Reilly, 2009).

Body weight and height were measured using a body weighing scale (Richter, Germany) and microtoise (GEA Medical, China) to the nearest 0.1 kg and 0.1 cm, respectively. Body mass index was calculated as body mass (kg)/squared statureheight (m²). Skinfold thicknesses were measured to the nearest 0.1 mm using a caliper (Holtan LTD, U.K), breadths were measured to the nearest 0.1 cm using a sliding caliper (Kanon, Japan) and circumferences were taken to the nearest 0.1 cm using a measuring tape (Seca, Germany) (MacLaren & Morton, 2012).

Somatotype calculation.

Endomorphy = $-0.7182 + 0.1451X - 0.00068X^2 + 0.0000014X^3$

X = ((thickness of triceps skin fold + thickness of subscapular skin fold + thickness of supraspinal skin fold) x (170.18 / height in cm))

Mesomorphy = $0.858HB + 0.601FB + 0.188CAG + 0.161CCG - 0.131H + 4.5$

HB = *Humerus Breadth*

FB = *Femur Breadth*

CAG = *Corrected Arm Girth*

= (upper arm circumference at flexion - thickness of triceps skinfold)/10

CCG = *Corrected Calf Girth*

= (maximum calf circumference - thickness of calf skinfold)/10

H = *Height*

Ectomorphy:

If HWR > 40,74 = $0.732HWR - 28.58$

If HWR 39,65-40,74 = $0.463HWR - 17.615$

If HWR < 39,65 = 0,5

HWR = *Height over cube root of Weight*

Somatotype determination.

The calculation results of the 3 somatotype components are then entered into the X and Y axis formulas in somatotype chart as follows:

X axis: ectomorphy value - endomorphy value

Y axis: 2 x mesomorphy value - (endomorphy value + ectomorphy value)

Nutritional intake

Nutritional intake was measured using a 24-hour food recall form that listed of macronutrient components (Sirajuddin et al., 2018). The participants were provided with an explanation about the 24-hour food recall method and asked to remember it in the form of detailed notes for the food and drinks consumed over the course of one day; participants filled out the Google Form of 24-hour food recall that had been provided; each component of the food and drinks consumed was calculated for its carbohydrate, fat, and protein content using the FatSecret program.

Maximum oxygen uptake

Maximum oxygen uptake was measured using the Cooper 12-minute run test. One day before the measurement, the participants were asked to maintain fitness; health assessment in the form of vital signs was conducted before the maximal oxygen uptake measurement; participants were assigned codes for identification; participants stand at the starting line of the stadium running track, and the measurer prepares the stopwatch; when the start signal is given, the stopwatch begins and the subjects start running; participants run for 12 minutes on the stadium running track; when the time reaches 12 minutes, a stop signal is given, the stopwatch stops, and the participants must stop; the measurer will approach the point where the subject stopped and measure the distance traveled by participants during the 12 minutes; and the distance traveled will be converted into maximum oxygen intake according to the age of the subject. The categories were based on the Cooper run test

results (VO₂ max estimation): very good > 46.5, good 42.5-46.4, fair 36.5-42.4, poor 33.0-36.4, and very poor < 33.0 (Suntoda, 2009).

Risk of Injury

An injury questionnaire was used to collect data on injury. The participants were interviewed about the history of injury that occurred in the year 2022, which includes the injury region, injury side, cause of injury, whether the injury is recurrent, injury therapy, and the duration of the injury experienced.

Ethical clearance

This study had received ethical clearance from the Research Ethics Committee of the Faculty of Medicine, Public Health, and Nursing Universitas Gadjah Mada (UGM) with reference number KE/FK/1583/EC/2022 on 13 December 2022.

Results

Based on Table 1, the average age of a professional athlete (elite team) was 24.51 ± 4.06 years and the average age of a non-elite athlete was 21.70 ± 1.94 years. The average somatotype for all athletes was central, both for the elite team (2.5–3.7–2.3) and the non-elite team (3.1–3.0–2.7). The most common somatotype in the athletes was endomorphic mesomorph. There was no particular somatotype for one position in team sports. Table 1 shows that elite athletes had a higher average intake of carbohydrates by 53.44 kcal compared to non-elite athletes, a higher fat intake by 23.14 kcal, and a higher protein intake by 42.09 kcal. However, the ideal nutrient intake was not met by either the elite or non-elite athletes, with the average intake shortfall reaching 10.51% for the elite team and 21.36% for the non-elite team. The average BMI for elite athletes was 22.90, with a standard deviation of 1.87, it was slightly higher than for non-elite athletes.

Table 1: Participants' characteristics

Variables	Elite team (n = 33)	Non-elite team (n = 40)	P
Age (years)	24.51 ± 4.06	21.70 ± 1.94	0.001*
Mean			
BMI (kg/m ²)	22.90 ± 1.87	21.87 ± 3.51	0.134
Mean			
Somatotype			
Endomorph	2.5 ± 0.66	3.1 ± 1.34	0.011*
Mesomorph	3.7 ± 1.25	3.0 ± 1.65	0.075
Ectomorph	2.3 ± 0.93	2.7 ± 1.60	0.236
Nutritional intake (average)			
Carbohydrate (kcal)	266.78 ± 0.00	213.34 ± 46.49	0.001*
Fat (kcal)	71.02 ± 0.00	47.88 ± 15.17	0.001*
Protein (kcal)	110.03 ± 0.00	67.94 ± 17.19	0.299
Total intake (kcal)	2077.00 ± 0.00	1663.08 ± 273.15	0.001*
Ideal intake (kcal)	2331.80 ± 0.16	1800.50 ± 0.36	
Intake obtained (%)	89.49 ± 6.25	78.64 ± 13.79	
Nutritional intake difference (%)	10.51 ± 6.25	21.36 ± 13.79	

*Significance at the level $p < .05$

Based on Table 2, forty-four athletes (60.27 %) had an abnormal foot arch and 29 athletes (39.73 %) had a normal foot arch.

Additionally, based on Table 2, the highest number of injury incidents was found in the ankle region, with a total of 10 cases (7 in the elite team and 3 in the non-elite team).

Table 2: Foot arch and injury distribution among futsal athletes

Variables	Elite team (n = 33)	Non-elite team (n = 40)	P
Foot arch (n, %)			
Normal	13 (39.39)	16 (40.00)	0.959
Abnormal	20 (60.61)	24 (60.00)	
Injuries (n, %)			0.001*
Ankle region			
Right and left metatarsal	1 (3.03)	-	
Right ankle	7 (21.21)	3 (7.50)	
Knee region			
Right ACL	2 (6.06)	-	
Right MCL	2 (6.06)	-	
Right meniscus medialis	1 (3.03)	-	
Left patella	1 (3.03)	-	
Right knee	2 (6.06)	1 (2.50)	
Left knee	1 (3.03)	-	
Right and left knee	1 (3.03)	-	
Thigh Region			
Left hamstring	1 (3.03)	-	

*Significance at the level $p < .05$

Table 3 shows that 17 elite athletes (51.52%) had good or very good maximal oxygen uptake performance, whereas 38 non-elite athletes (95.00%) demonstrated very poor performance.

Table 3: Maximum oxygen uptake among futsal athletes

Characteristic (n, %)	Elite team (n = 33)	Non-elite team (n = 40)	P
Very good	8 (24.24)	-	0.001*
Good	9 (27.28)	1 (2.50)	
Fair	13 (39.39)	-	
Poor	3 (9.09)	1 (2.50)	
Very poor	-	38 (95.00)	

*Significance at the level $p < .05$

Bivariate or inferential analysis based on Kendall's tau test showed that there was no significant association between foot arch characteristic and oxygen uptake or performance in this study ($p > 0.05$). Moreover, Fisher exact test showed that there was no significant association between foot arch characteristic and lower extremity injuries in this study ($p > 0.05$).

Discussion

Most of futsal athletes had abnormal foot arch, differ from previous studies (Wicaksono et al., 2021; Willim et al., 2016), and endomorphic mesomorph somatotype. In this study, the arch of the foot was examined with the incidence of injury. The inferential analysis showed that there is no relationship between foot arch and maximum oxygen uptake nor injury in professional futsal athlete.

Low foot arches tend to move excessively, most of the plantar surface touches the surface and weakens the medial side (Hamill et al., 2013). The medial longitudinal has important role as an adaptation to surface differences, absorbing pressure, weight gain, and as a lever mechanism for propulsion (Houglum & Bertoti, 2012), hence low foot arch can increase the risk of injury and pain in lower extremity (Guenka et al., 2021; Tong & Kong, 2013) although in this study the direct relationship was not evident. There is a debate on the potential relationship between foot type and lower extremity injuries and a study confirmed its relationship was weak (Tong & Kong, 2013).

A study found that abnormal foot arches (especially low foot arches) will increase the load received by the body (Wibowo et al., 2017) while Primal study shows that abnormal leg arches (low arches) will interfere/decrease the stability of static posture during exercise (Primal, 2018). Several other studies have shown that many lower extremity injuries are associated with abnormal foot arches. A study conducted in Italy showed high foot arches will cause a tendency to injury in running athletes (Di Caprio et al., 2010). High foot arches will cause decreased movement in the tarsometatarsalia joint and metatarsophalangeal joints thereby increasing the risk of injury (Hamill et al., 2013; Schuster et al., 2024).

Athlete's performance and movement are additionally supported by the type of somatotype. As this study found that endomorphic mesomorph somatotype was the predominant shape, some studies corroborate this finding. In the systematic review and meta-analysis conducted by Sebastia-Rico et al on professional football athletes showed a tendency for the Balanced Mesomorph type (Sebastia-Rico et al., 2023). Study on 47 soccer athletes showed Mesomorph-ectomorph type (Handjiska et al., 2015). The dominance of somatotype components affected the adaptive strategy and training performance of an athlete. The endomorphic component is considered good for training physical endurance while the mesomorphic component is suitable for strength training. The central type (no dominance) which is the average in this study will be able to adapt to any type of exercise given (Eston & Reilly, 2009; Marfell-Jones, 2000).

The dominance or somatotype of the athlete will be able to help the athlete's task according to the position on the team. However, apparently there was no particular somatotype for one position although a large number of the types of somatotype found in team sports based on position. Athletes with the central type will be able to adapt to the type of training and position given so that the team can have more flexibility in planning and providing best training routine and position that will be adjusted to the playing strategy (Eston & Reilly, 2009; Tóth et al., 2014). Cinarli's study states that to support the strength of performance requires dominance of mesomorphic and endomorphic components (Çinarli & Kafkas, 2019).

Despite no direct association of foot arch and injury in professional futsal athletes in this study, the occurrence of abnormal foot arches is common. Hence, there is a need to perform appropriate corrective exercise to prevent foot particularly forefoot overload and changes in body alignment (Woźniacka et al., 2019).

This study also measured athletes daily nutritional intake and the maximum oxygen intake. Upon analysis, most athletes did not meet their daily nutritional requirements. In both the elite and non-elite teams, only one athlete from each team met their daily nutrient intake. Despite the insufficient average nutritional intake, in this study, the average intake of carbohydrates, fats, and proteins in the elite team slightly exceeded the non-elite team. Macronutrients, which include carbohydrates, fats, and proteins, play a crucial role in various stages of an athlete's life, such as the training phase, pre-season, competition, recovery, and rehabilitation phases. A well-balanced diet also reduces the risk of injury among athletes. Study suggests that continued improvements in fat oxidation were evident even after applying a carbohydrate-loading protocol intended to restore muscle

glycogen stores. This nutritional approach indicates that initiating with a period of high fat intake followed by carbohydrate loading may create favorable conditions for skeletal muscles to increase fat oxidation while preserving adequate glycogen levels (Amawi et al., 2023). However, there is uncertainty about this strategy to improve prolonged exercise performance (Amawi et al., 2023; Stellingwerff et al., 2006).

Maximal oxygen uptake is influenced by age (Szwarc et al., 2021), sex, nutritional status (Kyrychenko et al., 2023), daily physical activity (Rezende et al., 2024), medical history, and overall health status (Martin, 2016; Potteiger, 2011). Nutritional status and daily activities play a significant role in the body's adaptation to body weight and physical exercise (Martin, 2016; Potteiger, 2011). The average difference in maximal oxygen uptake for the elite team in this study was 8.40–12.87 mL/kg/min compared to the average values reported in international studies (Da Silva et al., 2008; Gharbi et al., 2015; Kubayi et al., 2017). Theoretically, this performance gap would be evident during training and competition. The Indonesian elite team may experience faster fatigue, reduced strength, decreased focus, and a higher risk of injury compared to international teams.

Nutritional intake, foot arch morphology, maximum amount of oxygen utilized during intense exercise ($\text{VO}_{2\text{max}}$), and injury incidence are interconnected factors that influence athletic performance and their resilience. Adequate nutritional intake—especially of macronutrients like carbohydrates, proteins, and fats—is critical for optimizing energy availability, muscle repair, and $\text{VO}_{2\text{max}}$ (Amawi et al., 2023). $\text{VO}_{2\text{max}}$ reflects an athlete's aerobic capacity and is a key determinant of endurance performance (Zheng et al., 2022). Hence, to prevent athlete's $\text{VO}_{2\text{max}}$ from decreasing, for instance due to detraining, athletes should continue performing some physical exercise during the cessation of training (Zheng et al., 2022).

Foot arch morphology plays a critical role in biomechanics and load distribution. Variations such as flat feet (*pes planus*) or high arches (*pes cavus*) - both considered abnormal foot arch types - can result in inefficient movement patterns and may influence oxygen consumption during physical activity due to altered muscle activation and gait mechanics (Mo et al., 2024). Inadequate nutritional intake, including both macro- and micronutrients such as vitamin D, can compromise energy levels and tissue repair, thereby increasing fatigue and the risk of injury (Wang et al., 2024). Concurrently, abnormal foot arches may predispose athletes to overuse injuries, particularly in the lower extremities (Mo et al., 2024). Collectively, suboptimal nutrition, altered foot biomechanics, and reduced $\text{VO}_{2\text{max}}$ may elevate injury risk, decrease performance efficiency, and hinder recovery.

Conclusions

This study proves that most Indonesian professional futsal athletes exhibited abnormal foot arch morphology—predominantly low arches—and an endomorphic mesomorph somatotype. Although no statistically significant association was found between foot arch type, maximal oxygen uptake ($\text{VO}_{2\text{max}}$), and injury incidence, biomechanical implications of low arches suggest a potential predisposition to overuse injuries in the lower extremities.

The predominant somatotype observed supports strength and endurance training capacity, however, no consistent association was identified between somatotype and specific playing positions, indicating that centrally balanced somatotypes may offer greater adaptability across various training demands and tactical roles. Athlete with central somatotype may be able to adapt to any type of exercise and training.

Nutritional intake was largely inadequate among both elite and non-elite athletes, with very few meeting daily requirements. Given the importance of macronutrients in supporting energy metabolism, recovery, and aerobic capacity, such deficiencies may contribute to lower $\text{VO}_{2\text{max}}$ levels and increased fatigue. The elite team's $\text{VO}_{2\text{max}}$ values were notably lower than international benchmarks, which may impair competitive performance.

Although there is no relationship between foot arch types and injuries, nor between foot arch types and maximal oxygen uptake in this study, there is an opinion that the number of research subjects is still limited and small, and foot arch is not a single predictor for injuries or maximal oxygen uptake in athletes.

This research only assesses one endurance performance through maximum oxygen intake. It would be beneficial to evaluate other performance components such as balance and muscle strength. The maximum oxygen intake in this study uses the Cooper 12-minute run test. Ideally, the equipment used is an ergometer bike, which is the gold standard for maximum oxygen intake tests in athletes.

This research only evaluates macronutrients in athletes. It would be better to also evaluate micronutrients and fluids/ water in athletes so that the data obtained is more complete. The muscle components of athletes can be assessed using Bioelectrical Impedance Analysis (BIA) and fluid (dehydration) can be assessed using the Visual Analogue Scale (VAS) in future research. The examination of fat mass should also be conducted.

Future work promisingly such as examine foot arch on all athletes in various sports; examine foot arch on the population of toddlers, children, teenagers, and adults; examine somatotype linked to playing position and nutrition; perform balance and muscle strength training for individuals with abnormal foot arches; perform exercises suitable to foot arch type, carry out appropriate training periodization, and consume the right nutrition to enhance performance; and provide prescriptions for insoles to the athletes according to their foot arch type abnormalities.

In conclusion, the interplay between nutritional status, foot arch morphology, oxygen capacity, and somatotype underscores the need for a comprehensive, individualized approach to athlete preparation. Enhancing dietary intake, monitoring biomechanical factors, and optimizing training based on body type are essential strategies to improve performance and reduce injury risk in futsal athletes. Additionally, the prescription of customized insoles may offer a viable solution to improve comfort, enhance athlete foot alignment, and potentially support athlete performance optimization, particularly in athletes with low or abnormal foot arches.

Conflicts of interest - All authors declare no conflict of interest.

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References:

- Aksoy, Ö., Bozdoğan, T. K., Soyal, M., & Beyaz, M. M. (2022). The examination of VO2MAX and anaerobic threshold values in elite soccer players by their positions. *Journal of Physical Education and Sport*, 22(10), 2496–2503. <https://doi.org/10.7752/jpes.2022.10317>
- Amawi, A., AlKasasbeh, W., Jaradat, M., Almasri, A., Alobaidi, S., Hammad, A. A., Bishtawi, T., Fataftah, B., Turk, N., Saoud, H. Al, Jarrar, A., & Ghazzawi, H. (2023). Athletes' nutritional demands: a narrative review of nutritional requirements. *Frontiers in Nutrition*, 10(January), 1–17. <https://doi.org/10.3389/fnut.2023.1331854>
- Andreato, L. V., Santos, J. F., Esteves, J. V., Panissa, V. L., Julio, U. F., & Franchini, E. (2016). Physiological, Nutritional and Performance Profiles of Brazilian Jiu-Jitsu Athletes. *Journal of Human Kinetics*, 53(1), 261–271. <https://doi.org/10.1515/hukin-2016-0029>
- Chauhan, H. M., & Taqi, M. (2023). Anatomy, Bony Pelvis and Lower Limb: Arches of the Foot. *StatPearls*, 1–22. <http://www.ncbi.nlm.nih.gov/pubmed/0%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=P MC6442506>
- Çinarlı, F. S., & Kafkas, M. E. (2019). The effect of somatotype characters on selected physical performance parameters. *Physical Education of Students*, 23(6), 279–287. <https://doi.org/10.15561/20755279.2019.0602>
- Da Silva, C. D., Bloomfield, J., & Marins, J. C. B. (2008). A review of stature, body mass and maximal oxygen uptake profiles of U17, U20 and first division players in Brazilian soccer. *Journal of Sports Science and Medicine*, 7(3), 309–319.
- Di Caprio, F., Buda, R., Mosca, M., Calabrò, A., & Giannini, S. (2010). Foot and lower limb diseases in runners: Assessment of risk factors. *Journal of Sports Science and Medicine*, 9(4), 587–596. <http://www.jssm.org>
- Eston, R., & Reilly, T. (2009). *Kinanthropometry and Exercise Physiology Laboratory Manual* (3rd ed., Vol. 33, Issue 4). Routledge.
- Gharbi, Z., Dardouri, W., Haj-Sassi, R., Chamari, K., & Souissi, N. (2015). Aerobic and anaerobic determinants of repeated sprint ability in team sports athletes. *Biology of Sport*, 32(3), 207–212. <https://doi.org/10.5604/20831862.1150302>
- Giuriato, M., Piretti, C., Pellino, V. C., & Lovecchio, N. (2022). Regression of physical fitness in pre-adolescent: is it a real trend? *Journal of Physical Education and Sport*, 22(2), 402–407. <https://doi.org/10.7752/jpes.2022.02050>
- Guenka, L. C., Carrasco, A. C., Pelegrinelli, A. R. M., Silva, M. F., Dela Bela, L. F., Moura, F. A., & Cardoso, J. R. (2021). Influence of the medial longitudinal arch of the foot in adult women in ankle isokinetic performance: a cross-sectional study. *Journal of Foot and Ankle Research*, 14(1), 1–10. <https://doi.org/10.1186/s13047-021-00479-3>
- Hakman, A., Andrieieva, O., Bezverkhnia, H., Moskalenko, N., Tsybul'ska, V., Osadchenko, T., Savchuk, S., Myrkovalchuk, V., & Filak, Y. (2020). Dynamics of the physical fitness and circumference sizes of body parts as a motivation for self-improvement and self-control in students. *Journal of Physical Education and Sport*, 20(1), 116–122. <https://doi.org/10.7752/jpes.2020.01015>
- Hamill, J., Knutzen, K. M., & Derrick, T. R. (2013). Biomechanical Basis of Human Movement. In *Lippincott Williams & Wilkins* (4th ed.). Wolters Kluwer. <http://www.lww.com>.
- Handjiska, E., Handziski, Z., Gjorgoski, I., & Dalip, M. (2015). The relationship between somatotype and stress hormone levels in young soccer players. *Journal of Sports Medicine and Physical Fitness*, 55(2), 8.
- Houglum, P. A., & Bertoti, D. B. (2012). Brunnstrom's Clinical Kinesiology. In *Brunnstrom's Clinical Kinesiology* (6th ed.). F.A. Davis Company. www.fadavis.com

- Jeukendrup, A. E. (2017). Periodized Nutrition for Athletes. *Sports Medicine*, 47(s1), 51–63. <https://doi.org/10.1007/s40279-017-0694-2>
- Jones, G., & Wilson, E. (2019). *Everyday Sports Injuries*. DK Publishing. www.dk.com
- Junger, J., Junger, A., & Ostrowski, P. (2020). Body composition of trainees undergoing EMS training with respect to their nutrition. *Journal of Physical Education and Sport*, 20(1), 97–101. <https://doi.org/10.7752/jpes.2020.01012>
- Kubayi, A., Paul, Y., Mahlangu, P., & Toriola, A. (2017). Physical Performance and Anthropometric Characteristics of Male South African University Soccer Players. *Journal of Human Kinetics*, 60(1), 153–158. <https://doi.org/10.1515/hukin-2017-0098>
- Kyrychenko, V., Deak, G. F., Pop, N. H., & Gomboş, L. (2023). Features of physical development and physical fitness of students from the Faculty of Physical Education and Sport, Babeş-Bolyai University. *Journal of Physical Education and Sport*, 23(2), 510–516. <https://doi.org/10.7752/jpes.2023.02063>
- Lacasse, D., & Njororai, W. W. S. (2021). Season-long pattern and anatomical distribution of injuries among college soccer players. *Journal of Physical Education and Sport*, 21(2), 927–933. <https://doi.org/10.7752/jpes.2021.02115>
- Lourenço, C., Almeida, C., & Azevedo, A. (2024). Dietary Behavior of School-Aged Young Athletes. *Journal of Physical Education and Sport*, 24(10), 1413–1419. <https://doi.org/10.7752/jpes.2024.10266>
- MacLaren, D., & Morton, J. (2012). *Biochemistry for Sport and Exercise Metabolism* (1st ed.). Wiley-Blackwell.
- Marfell-Jones, M. (2000). Kinanthropometric Assessment. In *Guidelines for Athlete Assessment in New Zealand Sport* (pp. 1–30). Anthropometry Team New Zealand.
- Martin, L. (2016). *Sports Performance Measurement and Analytics*. Pearson Education. <https://doi.org/10.1007/s11587-007-0017-2>
- Menz, H. B., & Munteanu, S. E. (2005). Validity of 3 Clinical Techniques for the Measurement of Static Foot Posture in Older People. *Journal of Orthopaedic and Sports Physical Therapy*, 35(8), 479–486.
- Mielgo-Ayuso, J., Maroto-Sánchez, B., Luzardo-Socorro, R., Palacios, G., Palacios Gil-Antuñano, N., & González-Gross, M. (2015). Evaluation of Nutritional Status and Energy Expenditure in Athletes. *Nutricion Hospitalaria*, 31, 227–236. <https://doi.org/10.3305/nh.2015.31.sup3.8770>
- Mo, S., Lu, F., Li, C., & Zhao, H. (2024). Effects of 10 KM run on foot morphology and bilateral symmetry in male recreational runners. *Frontiers in Bioengineering and Biotechnology*, 12(August), 1–9. <https://doi.org/10.3389/fbioe.2024.1427418>
- Penichet-Tomas, A., Torreblanca-Martínez, V., & Torreblanca-Martínez, S. (2022). Acute effect of induced fatigue on passing ability in elite U-19 soccer players. *Journal of Physical Education and Sport*, 22(2), 355–360. <https://doi.org/10.7752/jpes.2022.02045>
- Potteiger, J. A. (2011). ACSM's Introduction to Exercise Science. In *ACSM's Introduction to Exercise Science: Second Edition* (2nd ed.). Lippincott Williams & Wilkins. <http://www.lww.com>.
- Primal, D. (2018). The Influence of Plantar Metatarsal Pes Planus on Postural Stability of Weight-bearing Athletes.[in Indonesian] *Prosiding Seminar Kesehatan Perintis*, 1(1), 7. https://scholar.google.com/citations?view_op=view_citation&hl=id&user=H7QSugwAAAAJ&citation_for_view=H7QSugwAAAAJ:d1gkVvhDpl0C
- Radzimiński, Ł. (2021). Weekly training load distribution and relationships between external and internal load indicators in professional soccer players. *Journal of Physical Education and Sport*, 21(4), 1669–1675. <https://doi.org/10.7752/jpes.2021.04211>
- Rezende, V. H. S., Ferreira Júnior, J. B., Guttierrez, A. P. M., Cerqueira, M. S., Faria, R. C. DE, Silva, C. A. D. S., Mendes, L. G. B. G., Praça, G. M., & Costa, C. M. A. (2024). Effects of consecutive futsal games on the physical performance of U-20 school athletes. *Journal of Physical Education and Sport*, 24(10), 1420–1425. <https://doi.org/10.7752/jpes.2024.10267>
- Roy, H., Bhattacharya, K., Deb, S., & Ray, K. (2012). Arch Index: An Easier Approach for Arch Height (A Regression Analysis). *Al Ameen J Med Sci*, 5(2), 10.
- Ryan-Stewart, H., Faulkner, J., & Jobson, S. (2018). The Influence of Somatotype on Anaerobic Performance. *PLOS ONE*, 13(5), 1–11. <https://doi.org/10.1371/journal.pone.0197761>
- Schuster, R. W., Cresswell, A. G., & Kelly, L. A. (2024). Human foot form and function: Variable and versatile, yet sufficiently related to predict function from form. *Biological Sciences-Proceedings B*, 291(2014). <https://doi.org/10.1098/rspb.2023.2543>
- Sebastiá-Rico, J., Soriano, J. M., González-Gálvez, N., & Martínez-Sanz, J. M. (2023). Body Composition of Male Professional Soccer Players Using Different Measurement Methods: A Systematic Review and Meta-Analysis. *Nutrients*, 15(5), 29. <https://doi.org/10.3390/nu15051160>
- Sirajuddin, Surmita, & Astuti, T. (2018). Food Consumption Survey (2018th ed.). [in Indonesian] Kementerian Kesehatan Republik Indonesia.
- Stearne, S. M., McDonald, K. A., Alderson, J. A., North, I., Oxnard, C. E., & Rubenson, J. (2016). The Foot's Arch and the Energetics of Human Locomotion. *Scientific Reports*, 6(19403), 1–10. <https://doi.org/10.1038/srep19403>

- Stellingwerff, T., Spriet, L. L., Watt, M. J., Kimber, N. E., Hargreaves, M., Hawley, J. A., & Burke, L. M. (2006). Decreased PDH activation and glycogenolysis during exercise following fat adaptation with carbohydrate restoration. *American Journal of Physiology - Endocrinology and Metabolism*, 290(2). <https://doi.org/10.1152/ajpendo.00268.2005>
- Suhaimi, N. M., Shokri, I. S. M., Illias, N. F., Adnan, R., & Ismail, H. (2022). The cardiovascular responses on difference exercise intensity and the relationship with body composition among sedentary college students. *Journal of Physical Education and Sport*, 22(10), 2340–2345. <https://doi.org/10.7752/jpes.2022.10298>
- Sulowska-Daszyk, I., Zając, B., & Mika, A. (2024). The influence of foot muscles exercises and minimalist shoes on lactate threshold velocity in long-distance amateur runners: a randomized controlled trial. *Scientific Reports*, 14(1), 1–11. <https://doi.org/10.1038/s41598-024-67525-5>
- Suntoda, A. (2009). Tests, Measurements, and Evaluation in Sports (p. 32). [in Indonesian] UPI. file:///C:/Users/Nay/Documents/skripsi baru/Pntrn_Softball.pdf
- Szwarc, A., Dolański, B., & Wasielewski, K. (2021). Relationship between psychomotor skills and game performance in youth soccer players. *Journal of Physical Education and Sport*, 21(4), 1744–1750. <https://doi.org/10.7752/jpes.2021.04221>
- Tong, J. W. K., & Kong, P. W. (2013). Association between foot type and lower extremity injuries: Systematic literature review with meta-analysis. *Journal of Orthopaedic and Sports Physical Therapy*, 43(10), 700–714. <https://doi.org/10.2519/jospt.2013.4225>
- Tóth, T., Michalíková, M., Bednarčíková, L., Živčák, J., & Kneppo, P. (2014). Somatotypes in Sport. *Acta Mechanica et Automatica*, 8(1), 27–32. <https://doi.org/10.2478/ama-2014-0005>
- Wang, M., Chee, J., Tanaka, M. J., & Lee, Y. H. D. (2024). Relative Energy Deficiency in Sport (REDs) and knee injuries: current concepts for female athletes. *Journal of ISAKOS*, 9(4), 781–787. <https://doi.org/10.1016/j.jisako.2024.05.012>
- Wibowo, D. B., Haryadi, G. D., Widodo, A., & Rahayu, S. P. (2017). Correlation of Loaded and Unloaded Foot Area With Arch Index in Younger Flatfoot. *MATEC Web of Conferences*, 135. <https://doi.org/10.1051/mateconf/201713500060>
- Wicaksono, A., Kusumaningtyas, S., & Tulaar, A. B. (2021). Foot Arch and Plantar Pressure in the Age of 17-21 Years. *Mutiara Medika: Jurnal Kedokteran Dan Kesehatan*, 21(2), 124–129. <https://doi.org/10.18196/mmjkk.v21i2.10799>
- Williams, D. S., & McClay, I. S. (2000). Measurements used to characterize the foot and the medial longitudinal arch: Reliability and validity. *Physical Therapy*, 80(9), 864–871. <https://doi.org/10.1093/ptj/80.9.864>
- Willim, H. A., Wicaksono, A., & Asroruddin, M. (2016). The relationship between Body Mass Index and Foot Arch in Medical Education students of Faculty of Medicine Universitas Tanjungpura class of 2012. [in Indonesian] *Jurnal Cerebellum*, 2(3), 562–576.
- Woźniacka, R., Oleksy, Ł., Jankowicz-Szymańska, A., Mika, A., Kielnar, R., & Stolarczyk, A. (2019). The association between high-arched feet, plantar pressure distribution and body posture in young women. *Scientific Reports*, 9(1), 1–9. <https://doi.org/10.1038/s41598-019-53459-w>
- Yunus, N. F., Zainal, N. S., & Mustafa, U. T. (2020). Impact of different foot arches on standing balance and physical performance among nursing students. *Journal of Physiotherapy Center*, 3(2), 1–6.
- Zhang, L., Zhang, Q., Zhong, Y., Hortobagyi, T., & Gu, Y. (2024). Effect of forefoot transverse arch stiffness on foot biomechanical response--based on finite element method. *Frontiers in Bioengineering and Biotechnology*, 12(July), 1–12. <https://doi.org/10.3389/fbioe.2024.1387768>
- Zheng, J., Pan, T., Jiang, Y., & Shen, Y. (2022). Effects of Short- and Long-Term Detraining on Maximal Oxygen Uptake in Athletes: A Systematic Review and Meta-Analysis. *BioMed Research International*, 2022. <https://doi.org/10.1155/2022/2130993>