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Do athletes know the morphology of their longitudinal plantar arch?

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Abstract:

The foot corresponds to the body segment that allows the exchange of forces between the support surface and the athlete's body; its morphology and function influence the quality of movement and body alignment. Moreover, the foot morphology can be modified according to the different adaptations that different sports cause, such as running, sport combat and team sports. This work aimed to define the knowledge that a sample of athletes has about their Medial Longitudinal Foot Arch (MLA). A sample of 119 athletes, separated into three groups (runners, combat athletes, and team players), were given a self-perception questionnaire of their MLA. Their responses were contrasted with the Arch Index (AI), which is a reliable objective measurement of the MLA. Just 18.5% of the sample were able to identify their MLA, as 67.2% stated they did not know, and 14.3% erred in their self-diagnosis. Combat athletes had the highest percentage who correctly identified their MLA (25%). Association was found between the knowledge demonstrated by athletes and the sport they practiced (X^2 = 9.926, df = 4, p = 0.04). The ignorance about MLA by the athletes studied is presented as a problem of which consequences are unknown; this opens future research focused on the study of injuries caused by misalignment of the foot and the need to prescribe sports shoes as orthoses.

Keywords: Arch Index; Footwear, Cavus Foot; Flat Foot; Shoes

1. Introduction

Due to the relevance of the foot in studying human posture and locomotion, its anatomy and biomechanics have been a subject of interest for almost 100 years. How the foot operates is closely related to physical activity and sports practice because it enables the body to interact with the ground, transmitting the forces responsible for walking, running, and jumping (McKeon et al., 2015)

The human foot of today is product of over 2 million years of evolution (Pontzer et al., 2009), a process that has produced important modifications in its bone, ligamentous, aponeurotic, and muscular components (Sichting et al., 2020). Among these variables, the emerging of a Medial Longitudinal Plantar Arch (MLA) stands out (Bramble & Lieberman, 2004), with two main functions that are known. One of the functions is the accumulation/delivery of energy during gait foot strike, running and jumping (Wager & Challis, 2016); the other, the ability to adapt to the ground irregularities, thus contributing to body stability and balance during movement (Goto et al., 2009).

The MLA morphological variability among subjects makes its study and classification in different populations of great interest (Choi et al., 2015; D'Août et al., 2009; Gijon-Nogueron et al., 2013; Kulthanan et al., 2004; Sánchez-Ramírez et al., 2017; Sánchez-Ramírez, 2017; Tomassoni et al., 2014). Therefore, depending on the evaluation method used, normative values that enable classifying MLA as normal, low (flat) or high (cavus), in bipedestation (Xiong et al., 2010). Due to the complex mechanics of the tarsal joints, these concepts are associated with the concepts of normal, pronated, and supinated foot, respectively (Kirby, 1979; Krähenbühl et al., 2017). One of the most widely used methods is the Arch Index (AI) due to high levels of reliability and validation in large populations. This method establishes a relationship between the midfoot area and the total area of the plantar footprint (Cavanagh et al., 1986).

Early diagnosis of MLA morphology is important. The MLA morphological constitution has been found to modify the surface of plantar force and pressure application (Buldt et al., 2014; Buldt, Forghany, et al., 2018), and consequently, to modify biomechanical variables. Evidence indicates that flat feet tend to show greater plantar support surface on the midfoot, receiving higher pressure and force peaks in this area, as well as higher integral pressure-time and integral force-time. On the other hand, cavus feet reveal higher values of these variables on the heel and lateral area of the forefoot (Buldt, Allan, et al., 2018). These biomechanical modifications have been associated with an increased risk of injuries such as medial tibial stress syndrome, patellofemoral pain, and patellofemoral tendinitis (Tong & Kong, 2013). Apparently, a low arch should be carefully considered because this condition has a greater association with exercise-related leg pain (Bennett et al., 2012). This risk increases in athletes, due to the technical and competitive nature of the sports. For example, during the seventeen days of the Rio de Janeiro 2016 Olympic Summer Games it reported 9.8 injuries per 100 athletes (Soligard et al., 2017)

Another important reason for early diagnosis relates to the use of specialized sports shoes. For example, running footwear can be manufactured with to 10 specific construction variables that have impact on the running biomechanics (Sun et al., 2020). This, in turn, results in a wide range of different brands and models offered in the market. It is common footwear for sale labelled for pronated, supinated, or neutral feet (Abián et al., 2012), with specific midsole characteristics; however, customers do not need a professional prescription to buy them. For the clients, their selection criteria is mainly based on factors such as comfort, lightness, cushioning, or durability (Burillo & Pérez González, 2016), not to aspects considering adequate biomechanical properties. Thus, clients access the model of their interest, which could be one that could make a misalignment worse, increasing the probability of suffering an injury. As this is an indirect factor, the potential effect on the risk of injury has not yet been studied.

In view of the importance of preventing or treating injuries in athletes, the present study triggered the following research question: Do athletes know the type of their feet according to their medial longitudinal plantar arch? Likewise, it is suggested that, depending on the characteristics of the different sports disciplines, there may be differences in the degree of knowledge of this subject according to the different types of sport. Therefore, the aim of this study was to investigate the knowledge that a sample of athletes from three types of sports disciplines have about the morphology of their medial longitudinal arch contrasted with the objective measure obtained from the Arch Index.

2. Materials and Methods

Subjects —The sample included 119 athletes (78 men) from 9 sports, aged 22.8 ± 4.2 years; measuring 1.71 ± 0.1 m in height; 70.6 ± 12.6 kg in body mass; 24.1 ± 3.1 in BMI, and 0.22 ± 0.06 kg/m^2 in AI. They were chosen by convenience from a population of university athletes. The size calculation was done according to the number of university athletes of the Universidad de Santiago de Chile (N = 220). Therefore, the number of subjects used in this study is equivalent to 54% of the target population.

According to a classic sports classification (Matveev, 2001), the sample was divided into three groups: Runners (Long-distance and middle-distance, n = 35), Team Players (soccer, basketball, handball, and volleyball, n = 44), and Combat Athletes (judo, karate, and taekwondo, n = 40). The data of the participants grouped by sport type is shown in Table 1.

BMI and AI values fell within the normal classification. Participants voluntarily agreed to take part in the study, accredited by signing the informed consent drawn up according to the guidelines of the Ethics Committee of the University of Santiago of Chile (Ethical Report No. 577 of 2015). As inclusion criteria, subjects had to be university-level athletes and members of the institutions representative team for a minimum of 6 months. Athletes had to train ≥ 6 hours a week. All subjects having suffered ankle and/or foot injuries in the last 6 months were excluded.

Design— This is a cross sectional study.

Methodology— Participants completed a podalic health and sports history questionnaire (Sánchez-Ramírez et al., 2017). In the questionnaire, they were literally asked: "According to your plantar arch, what type of foot does it have?" Alternative answers included: a. "Normal," b. "Flat," c. "Cavus," and d. "I don't know." After completing the form, body weight was obtained with the subjects dressed in underwear, on a digital scale (Tanita, Model HD 314). Height was recorded with a measuring tape attached to the wall. With these values the BMI was calculated. The athletes did not receive any information regarding the classification of foot types.

To prevent results alteration due to previous activities, the participants were asked to rest in supine position for 10 min (Jimenez-Ormeño et al., 2011). The plantar footprint was obtained in a standing position for one minute over a podoscopy made of metal and solid glass (without brand) through photopodoscopy (Ribeiro et al., 2006), recorded with a 14.2-megapixel digital camera (Samsung ST65, China) without zoom directly focusing on the glass, at 0.43 m. The photopodoscopy analysis was performed using AreaCalc software to calculate plantar footprint areas of Arch Index (López Elvira et al., 2008) which is showed in the Figure 1. The software was operated by a single researcher with 5 years of experience in its use. Table II shows the normative values used to classify MLA, according to a study carried out in a similar population (Sánchez-Ramírez et al., 2017).

Statistical Analysis— All analyses considered the right foot. The data analysis was performed using SPSS software (V25.0; IBM Inc., Chicago, IL, USA). Foot type (normal, high, and low), and knowledge grade (knows, does not know, wrong) were the nominal variables, which were established in frequency and percentages. The analysis of the existing relationship among the nominal variables was defined by the Chi Square test (X^2).

For continuous variables (age, height, weight, BMI and AI) the mean and standard deviation were calculated, and the Kolmogorov-Smirnov test was applied to establish the type of distribution of the sample. The differences among the groups were established by a one-way analysis of variance (ANOVA).

To define type I error, $p < 0.05$ was considered as a value of statistical significance for all analyses.

3. Results

According to foot type distribution regarding the AI in the sample, it verified that the highest percentage registered corresponds to the normal type (46.2%), followed by low (27.7%) and high (26.1%).

Table 1. Characterization variables of the sample grouped by sport type. The data is expressed in mean and standard deviation.

	Runners (n = 35)	Team Players (n = 44)	Combat Athletes (n = 40)
Age (years)	23.0 (± 3.6)	21.5 (± 3.1)	24.1 (± 5.3)
Height (m)	1.69 (± 8.4)	1.74 (± 8.2)	1.69 (± 7.4)
Weight (kg)	66.1 (± 8.9)	73.0 (± 11.0)	71.9 (± 15.8)
BMI (kg/m²)	23.0 (± 2.3)	24.1 (± 2.5)	25.1 (± 3.9)
Arch Index	0.21 (± 0.05)	0.23 (± 0.04)	0.21 (± 0.08)

BMI = body mass index.

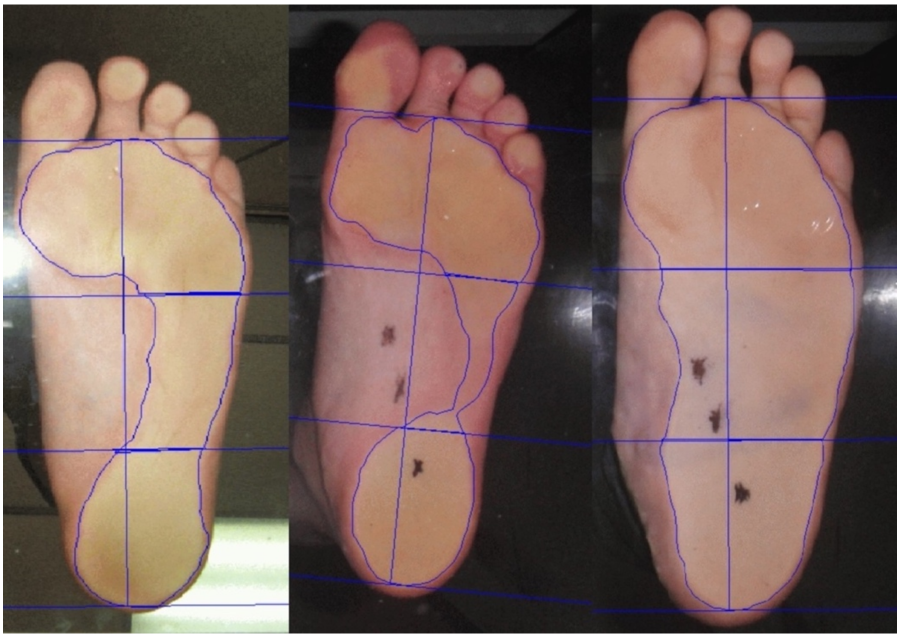

Figure 1. Examples of foot types measured with the arch index. The left image shows a normal foot, AI = 0.22. The middle image shows a cavus foot, AI = 0.12. The image on the right shows a flat foot, AI = 0.37.

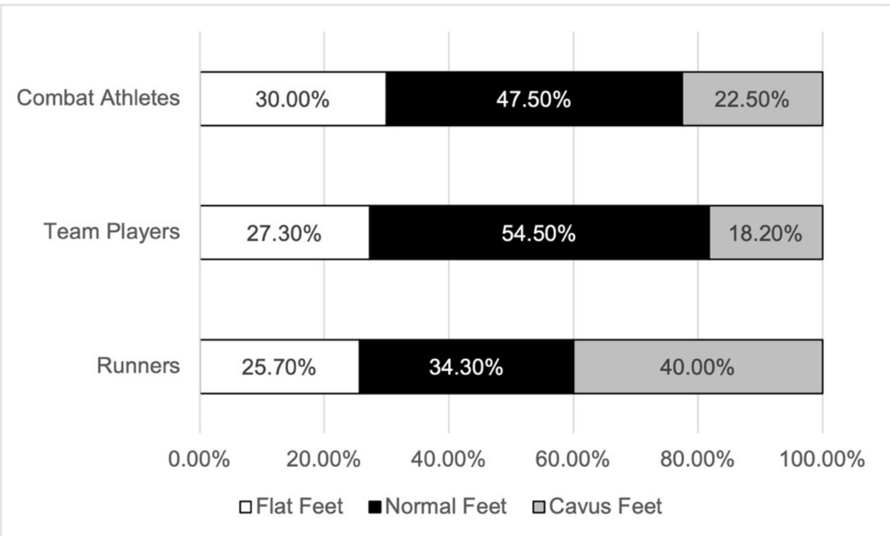

Figure 2. Percentage distribution of foot type according to Medial Longitudinal Foot Arch height in each group of athletes.

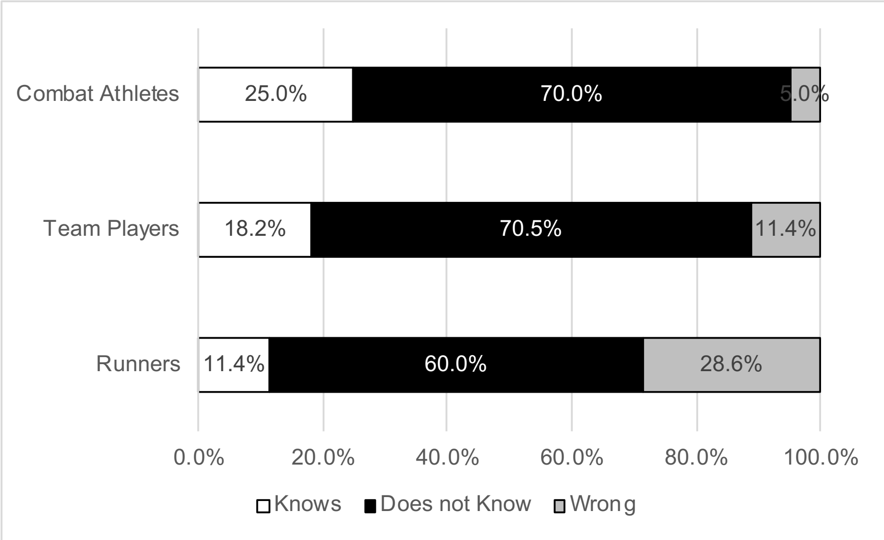

Figure 3. Knowledge of foot type level by sports group (X2 = 9.926, df = 4, p = 0.04).

Figure 2 shows the foot type frequency distribution by MLA height according to Arch Index measurement in each group of athletes, where it is noted that team sports players have the highest frequency of normal feet according to MLA, the runners have a higher frequency of subjects with high MLA, and combat athletes have the highest proportion of flat feet. However, the statistical analysis revealed that there is no association between the type in the MLA and the type of sports they practice ($X^2 = 5.735$, df = 4, p = 0.22). This result was verified with the quantitative statistical analysis of AI, where statistically significant differences among the groups could not be determined (F = 1.782, df = 2, p = 0.13).

Knowledge of the type of MLA of the participants was obtained from the frequency analysis of the responses to the questionnaire and was contrasted with the objective results obtained from the AI. This analysis showed that 80 subjects in the sample (67.2%) indicated in the questionnaire that they did not know their type of foot (Table III).

Of the 39 subjects who claimed to know their MLA type, 22 responses agreed with the results of their plantar impression analysis, equivalent to 18.5% of subjects who did indeed know their foot type. Seventeen of the 119 subjects, despite having classified their MLA in one of the typologies, erred in their self-diagnosis (14.3%). Therefore, the total number of the subjects who indicated that they did not know their MLA plus those who erred their self-diagnosis resulted was 97 subjects, equivalent to 81.5% of the sample. These figures are shown in table III.

In the analysis by type of sports discipline practiced by the study subjects, runners showed the highest percentage of ignorance regarding their MLA type, with 21 subjects who stated they did not know. In turn, 12 subjects claimed to know their foot type; however, 10 of them were mistaken, presenting the highest percentage of ignorant subjects (28.6%). Only 4 subjects knew their foot type. On the contrary, combat athletes showed the highest percentage of subjects who could correctly identify their foot type (25%), with a frequency of 10 subjects, with 2 subjects who erred in their self-diagnosis. The group of team sports players showed intermediate results between the other groups. Just 8 subjects knew their foot type (18.2%), and 36 subjects did not know or were wrong in their answer (81.9%). The statistical analysis revealed an association between the knowledge shown by the subjects and the type sports they practiced ($X^2 = 9.926$, df = 4, p = 0.04). The results are shown in figure 3.

Table 2. Arch Index values used to classify the type of medial longitudinal plantar arch (Sánchez-Ramírez et al., 2017).

Medial Longitudinal Plantar Arch Type	Arch Index Normative values for men	Arch Index Normative values for women
Normal	0.22 – 0.25	0.18 – 0.23
High (Cavus)	≤ 0.21	≤ 0.17
Low (Flat)	≤ 0.26	≤ 0.24

Table 3. Knowledge of Medial Longitudinal Foot Arch foot type in all sample subjects, expressed in frequency and percentage.

Knows	Does not Know	Wrong
22 (18.5%)	80 (67.2%)	17 (14.3%)

4. Discussion

The objective of this work was to define the knowledge that a sample of athletes has about the morphology in their MLA from the objective classification obtained from the Arch Index (AI) (Cavanagh et al., 1986). In this regard, the most interesting result was the fact that only 18.5% of the sample of athletes who competed at a university level demonstrated they knew their own MLA morphological typology. There are very few studies that have pursued this objective, and except for some that inquire into self-knowledge in patients with diabetic foot (Hämäläinen et al., 1998), the only study available is of 2012 (Hohmann et al., 2012), where a questionnaire on MLA foot type knowledge was applied to a sample of 92 recreational marathoners. The study was done in a sample of runners and revealed that 48.9% of the subjects answered correctly, a figure that contrasts with the 11.4% reported by runners in this study. However, contrasting this data with the 67.2% of the present is not possible, as the previous study's questionnaire did not include the option "I don't know" option, as an answer for those who did not know their MLA foot type. This difference may be influenced by the level of participation in the practice of sports of the sample subjects, which could be considered a reflection of their sports culture, however this is only a hypothesis.

The study by Hohmann et al. was carried out among marathon runners, a population with a recently reported incidence of injury of 66% (Messier et al., 2018). Among the subjects who suffer from injuries, 25.6% have reported foot and ankle injuries (Benca et al., 2020). This segment gets injured mainly due to high volume training, which in high-level runners it can reach 186 km per week (Enoksen et al., 2011). In a 42.195 km marathon for example, an athlete can perform 27,000-foot contacts, taking as a reference a frequency of 178.5 steps per minute (Amano et al., 2016). If the activity is performed with joint misalignment, these strides could produce overload in areas that are not adapted to such a magnitude of forces, which may result in injuries. Interestingly, in this study, it was precisely the runners that showed the lowest frequency of subjects who knew how to identify their own MLA morphology, with 11.4%, and combat athletes showed the greatest knowledge (25%). This could be due to the fact that the latter practice their sport barefoot, allowing them to have a greater visual relationship with their feet than runners.

The data presented here indicate that the three types of athletes have very low knowledge about their MLA morphology, which is worrisome. The facts are a warning of the importance of athletes being knowledgeable on the subject.

On the one hand, it is known that feet with high and low MLA are related to injuries in the lower limb (Tong & Kong, 2013), the latter being the most dangerous condition (Jungmalm et al., 2020). In addition, foot misalignment can cause postural changes in the tibia, femur, and pelvis (Khamis & Yizhar, 2007), probably due to the modification in the foot strike and the forces applied on the plantar foot (Buldt et al., 2014; Buldt, Forghany, et al., 2018). These anatomical and functional modifications are important due to the greater severity of risk in subjects who practice sports because their musculoskeletal system is subjected to greater forces than those applied to a less active subject in his/her daily life activities.

In addition, footwear providing additional foot support for low and high arch is available in the market, as an attempt to realign a misaligned foot (Abián et al., 2012). Unfortunately, it is demonstrated that sports shoe prescribing is not evidence-based (Richards et al., 2009). This opens two problems: firstly, athletes who do not know their foot type cannot decide regarding the use of one type of footwear or another, missing the opportunity to obtain any postural benefit. Secondly, specialized footwear is sold in stores without adequate labelling, allowing athletes to choose footwear based on price, appearance, and comfort (Burillo & Pérez González, 2016). In despite of the comfort could be one of the most important choosing factor to prevent injuries (Nigg et al., 2015), it is possible that a subject with low MLA could buy shoes suited for high MLA, increasing their foot imbalance and also putting the athlete at risk of suffering an injury (Wilk et al., 2000). Hence the importance of sports footwear being prescribed according to an anthropometric and biomechanical evaluation of the user.

The high level of ignorance of MLA morphology in the athletes studied is presented as a problem with an unknown scope and consequences are not known. Therefore, there is room for future lines of research in the study of injuries caused by anatomical misalignments of the foot, where physical education related to this issue may have a preponderant role. Among the limitations of this study, it is recognized that the sample size is not large enough to extrapolate the results to the entire population of athletes. Asking about the causes of the ignorance that the athletes had about their foot type would have been another interesting aspect to investigate. Additionally, it presents the need to investigate sports shoes as orthoses, which must be prescribed by competent professionals, based on a personal evaluation of the user.

5. Practical Applications.

The results of this study make visible a reality that is little known until now, which corresponds to the ignorance that athletes have on essential aspects of their sporting life.

According to this research, athletes do not know the morphology of their feet, specifically related to the medial longitudinal plantar arch. This situation can become a problem when athletes choose the type of footwear they will use during their training and competitions without considering fundamental aspects of the morphology of their feet, which can lead to mechanical misalignments and, consequently, to injuries.

This knowledge can be a valuable contribution to professionals who work with athletes since they can enhance their preventive and therapeutic skills.

Podiatrists may be aware that the footwear used by athletes may not necessarily be the best, so this point should be considered within the treatments and methodologies used with athletes of different sports. In addition, recommending a periodic evaluation of foot morphology with a podiatrist seems to be a good practice to prevent overuse injuries.

Moreover, the athletes can gain knowledge about their human body that will be useful to their wellness. This knowledge will be critical to runners, since according to these outcomes, they need this information more than players or fighters.

As conclusion, the ignorance about MLA by the athletes studied is presented as a problem of which consequences are unknown; this opens future research focused on the study of injuries caused by misalignment of the foot and the need to prescribe sports shoes as orthoses.

Supplementary Materials: The following are available online at Sanchez, Celso (2022), "The

Athletes do not know their feet morphology", Mendeley Data, V1, doi: 10.17632/x62nzc8bwb.1

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