ORIGINAL ARTICLE

Assessment of Flatfoot Index and Prevalence of Musculoskeletal Disorders of the Foot in Young Athletes: Swimming, Rowing and Weightlifting

Evaluación del Índice de Pie Plano y Prevalencia de Trastornos Músculo-esqueléticos del Pie en Deportistas Jóvenes: Natación, Remo y Levantamiento de Pesas

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Abstract

Objectives: The objective of this work was to analyze the morphology of the soles of the feet in young athletes to find the prevalence of these pathologies through the Chippaux-Smirak index.

Material and Methods: Seventy-five athletes between nine and twenty years old participated in the study (56% female and 44% male), the average mass was 62.92 ± 13.46kg and the average height was 1.67 ± 0.11m. The sports considered in the study were weightlifting, swimming, and rowing.

Results: The results clearly show that flatfeet in adolescents and young adults is a condition with a low prevalence level, 10.7% and 12% for the right and left foot, respectively. One of the most outstanding results found in the study is the high prevalence of cavus foot, where women are the most affected by this pathology. Furthermore, swimming presented the highest prevalence of cavus foot, 42.1% and 52.6% for the right and left foot, respectively.

Conclusion: In conclusion, the understanding of the morphology of the soles of the feet can help to determine the foot type in these three different sports, and therefore, it can be implemented physiotherapeutic treatments or orthotics devices for overcome the musculoskeletal disorders and prevent future injures.

Key Words: flatfoot, cavus Foot, chippaux-smirak index, foot; sport.

Resumen

Objetivos: El objetivo de este trabajo fue analizar la morfología de las plantas de los pies en jóvenes deportistas para encontrar la prevalencia de estas patologías a través del índice de Chippaux-Smirak.

Material y Métodos: Setenta y cinco atletas entre nueve y veinte años de edad participaron en el estudio (56% mujeres y 44% hombres), la masa promedio fue de 62.92 ± 13.46kg y la altura promedio fue de 1.67 ± 0.11m. Los deportes considerados en el estudio fueron levantamiento de pesas, natación y remo.

Resultados: Los resultados muestran claramente que los pies planos en adolescentes y adultos jóvenes son una condición con un nivel de prevalencia bajo, 10.7% y 12% para el pie derecho e izquierdo, respectivamente. Uno de los resultados más sobresalientes encontrados en el estudio es la alta prevalencia de pie cavo, donde las mujeres son las más afectadas por esta alteración. Además, natación presentó mayor prevalencia de pie cavo, 42.1% y 52.6% para el pie derecho e izquierdo, respectivamente.

Conclusiones: La comprensión de la morfología de las plantas de los pies puede ayudar a determinar el tipo de pie en estos tres deportes diferentes y, por lo tanto, se pueden implementar tratamientos fisioterapéuticos o dispositivos ortopédicos para superar los trastornos músculo-esqueléticos y prevenir futuras lesiones.

Palabras Clave: pie plano, pie cavo, índice de chippaux-smirak, pie, deporte;

Introduction

The foot is considered as the base of support of the locomotor system, needs to be stable and supportive, flexible, and energy efficient to be able to support the body weight and cope with irregular surfaces. The structure of the foot is subject to a wide spectrum of musculoskeletal disorders. Therefore, understanding of the structure of the foot is important to prevent and reduce the musculoskeletal disorders.[1]

It is thought that the differences in the foot structure are related to differences in foot function during movement. Moreover, many foot pathologies are related to the foot type. [2–5]

The foot structure can be classified according to the high of the medial arch or the morphology of the soles of the feet as flatfoot, rectus/normal foot and cavus foot.[2]

The flatfoot pathology is identified by the collapse of the medial arch when the person supports the body weight in standing position. The rectus/normal foot presents a correct alignment between the hindfoot and forefoot, in the literature, the normal foot is not associated to any pathology or risk of injury. The cavus foot is produced by an increase of normal concavity, where the hindfoot and forefoot regions are brought closer together. [2,3,6]

According to the clinical research published by Tahmasebi et al., individuals with flatfoot pathology are more unstable when compared with normal individuals during quiet standing [7]. In addition, Williams et al., found that runners with low-arched had more knee injuries while runners with high-arched presented more foot and ankle injuries. [4]

Adult acquired flatfoot deformity is associated mainly to a malfunction of the midfoot stabilizer described as posterior tibial tendon dysfunction, it is a known cause of pain and disability.[8] The prevalence of flatfeet in the population is around 25%, there is a higher incidence in women, in people with a higher body mass index and in individuals with larger feet.[3] Maynou et al., mentioned that the hindfoot varus increases the risk of damage to the lateral structures of the foot and ankle as well as the peroneal tendons. In addition, patients with cavus feet often have a short and tight gastrocnemius [6]. The function of the medial longitudinal arch is to absorb impacts and transmit forces both in a static position and during gait. When there is an alteration in the structure of the plantar arch, the distribution of plantar pressures is modified, the absorption of forces is affected, muscle activity is altered together with stability and gait. [9]

The analysis of the footprint has a certain advantage over other techniques as it is an objective measurement in which the patient is not exposed to ionizing radiation and is more economical than digital measurement systems. It consists in analyzing different parameters: the arch index, Staheli index, Chippaux-Smirak index and arch angle; it is done by obtaining the footprint through ink printing or digital media.[9,10] The Chippaux-Smirak index (CSI) is determined by the relationship between the minimum distance in the midfoot region and the maximum distance in the forefoot region. [10,11] Through this method it is possible to determine morphological characteristics of the foot such as anthropometric aspects, foot type, support zones, pressure zones and the presence of pathologies.

This research aims to analyze the morphology of the soles of the feet of young athletes and to find the prevalence of flatfoot, rectus/normal foot, cavus foot and extreme cavus foot through the Chippaux-Smirak index.

Material and Methods

Design

Seventy-five athletes between 9 and 20 years old participated in the study (56% women and 44% men), with an average mass of 62.92 ± 13.46kg and average height of 1.67 ± 0.11m. As an inclusion criterion, it was considered that all the participants executed their corresponding sports activities and those who presented motor problems, amputations or neuronal problems were excluded. Furthermore, this work considered athletes from three different sports, weightlifting, swimming, and rowing.

The volunteers were informed about the procedures before the tests and the informed consent of voluntary participation was obtained. The protocol was approved by the ethics committee of CIATEC A.C., with registration number CONBIOETICA11CEI00620131108.

Procedure

The protocol was explained to all the participants, and it was advised to use comfortable clothes during the trials. Then, each volunteer was instructed to stand barefoot on a PodoScan 2D to measure the footprint of the feet. Then, the flatfoot index was obtained from the footprint analysis and the athletes were classified in four different groups: Normal or rectus foot, flatfoot, cavus foot and extreme cavus.

Data processing

The digitized images of the soles of the feet were analyzed in MATLAB R2015a version 8.5.0.197613. The tools (ginput, GUI, imread) belonging to Matlab were used to locate the coordinate points in the plane of the image. The relationship B/A or Chippaux-Smirak index provided a clear evidence about the type of foot of the participants. [10]

Four categories of the soles of the feet were created, normal foot or rectus foot, flatfoot, extreme cavus and cavus foot. The CSI range for the normal/rectus foot category was $0.25 \leq CSI < 0.45$, for the flatfoot it was $CSI \geq 0.45$, for the extreme cavus it was $CSI = 0$ and for the cavus foot it was $0 < CSI < 0.25$ [9,10,12–16].

Subsequently, the soles of the feet were digitized using a 2D PodoScan (Sensormedica, Guidonia Montecelio, Roma, Italia) and the Chippaux-Smirak index was obtained, as shown in Figure 1.
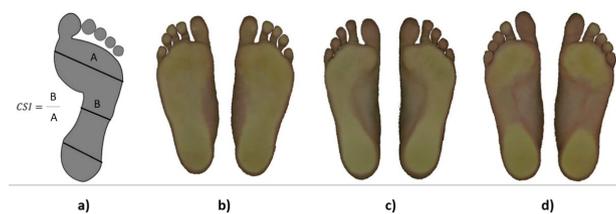
Figure 1 Morphology of the Soles of the feet: a) Chippaux – Smirak index, b) flatfeet, c) rectus or normal feet, d) cavus feet.

Results

From Table 1, it is evident that the prevalence of flatfeet in adolescents and young adults is a condition with a low level, 10.7% for the right foot and 12% for the left foot. The percentage of prevalence for the extreme cavus foot was 9.3% in the right foot and 6.7% in the left foot, for cavus foot was 26.7% in the right foot and 33.3% on the left. The feet whose CSI oscillates between 0.25 and 0.45 was considered to be a normal/rectus foot, the prevalence of this type of foot in the seventy-five athletes was 53.3% in the right foot and 48% in the left foot. It is evident from these results that there is a high prevalence of cavus feet in these athletes.

Table 1 Prevalence of feet types in seventy-five athletes.

	Right Foot (%)	Left Foot (%)
Extreme Cavus	9.3	6.7
Cavus Foot	26.7	33.3
Normal Foot	53.3	48.0
Flat Foot	10.7	12.0

Figure 2 shows the foot type of females and males of the three different sports considered in this study. It is evident the high percentage of cavus foot in women: 28.6% for the right foot and 45.2% for the left foot. Moreover, the results indicate that there is an asymmetrical morphology of the feet where the prevalence is higher in the left foot. The prevalence of flatfeet in women was low, 7.1% for both feet.


Foot Type in Athletes (Females and Males)

Foot Type	Extreme Cavus	Cavus Foot	Normal Foot	Flat Foot
Right Foot Males	6.1	24.2	54.5	15.2
Right Foot Females	11.9	28.6	52.4	7.1
Left Foot Males	6.1	18.2	57.6	18.2
Left Foot Females	7.1	45.2	40.5	7.1
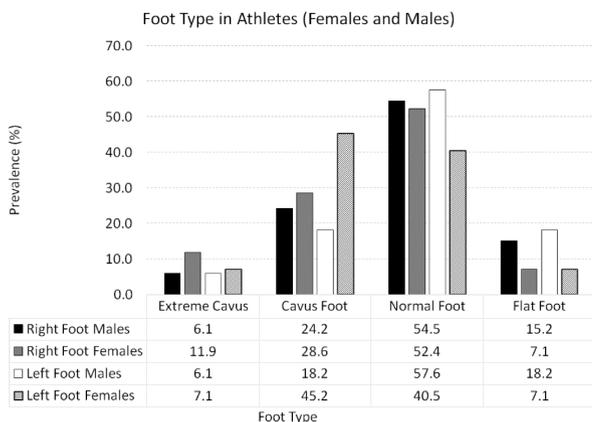
Figure 2 Prevalence of feet types by gender: Females and Males

Furthermore, Figure 2 also illustrates the prevalence of feet types of males. The prevalence of cavus foot was 24.2% for the right foot and 18.2% for the left one. The prevalence of extreme cavus was 6.1% for both feet. The prevalence of flatfoot was 15.2% for the right foot and 18.2% for the left foot. The results of the morphology of the soles of the feet indicates that males have similar structure on both feet.

The morphology of the soles of the feet was analyzed in relation to the three sports considered in this work, the results are shown in Figure 3. The sport with the highest incidence of cavus foot was swimming, with a prevalence of 42.1% for the right foot and 52.6% for the left foot. The second sport with the highest prevalence of cavus foot was weightlifting. Finally, the less percentage of prevalence of cavus foot was on rowing. The three sports considered in this study show a specific trend in relation to the foot type.


Foot Type in Athletes

Foot Type	Extreme Cavus	Cavus Foot	Normal Foot	Flat Foot
R-Foot Rowing	11.1	11.1	63.0	14.8
L-Foot Rowing	11.1	18.5	59.3	11.1
R-Foot Swimming	21.1	42.1	36.8	0.0
L-Foot Swimming	5.3	52.6	36.8	5.3
R-Foot Weightlifting	0.0	31.0	55.2	13.8
L-Foot Weightlifting	3.4	34.5	44.8	17.2
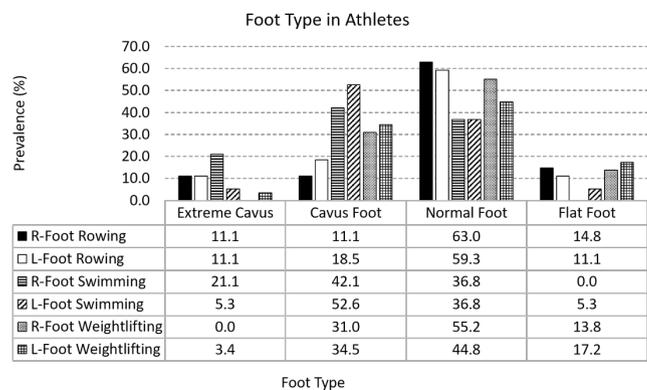
Figure 3 Prevalence of feet types by sports: Rowing, Swimming and Weightlifting. R-Right and L-Left

Discussion

The aim of this research was to characterize and understand the foot type of three different sport activities (rowing, swimming and weightlifting) with the purpose of being able to apply physiotherapeutic treatments or orthotic devices to overcome the musculoskeletal disorders. Most of the times, when changes in the structure of the foot are not treated correctly, they could represent a risk in the future. The results of the current study show that the prevalence of flatfeet is slightly higher in men than women, as indicated by other authors. [17–19]

Furthermore, the prevalence of flatfeet in adolescents and young adults is a condition with a low level as found it by other authors. [18,20]

One of the most outstanding results found in the study is the high prevalence of cavus feet in athletes, where women are the most affected by this pathology. This finding coincides with other studies that have found a tendency of the foot to increase the medial arch in the athletes and that could have an effect on the structure of the foot,[19,21] A high prevalence index of the cavus foot could be related to the mechanical demands of the foot towards the plantar flexion movement [19,21]. Furthermore, the results of the morphology of the soles of the feet in females presented a higher asymmetry than males, this could be produced due to factors such as shortening of the lower limbs or other pathologies that were not evaluated in this study.

The high prevalence of cavus foot in swimming found in the current study agrees with the research developed by Gomez Salazar et al.[21] Moreover, it is probable that the high medial arch does not allow to pass the loads correctly from the ground to the body structure, increasing the risk of suffering a musculoskeletal injury.[22]

In sports medicine, it is very important to know the foot type of the athletes as the changes in the height of the medial longitudinal arch could increase the risk of suffering injuries in the lower limbs, within these the most common are toe deformities, foot pain, ankle injuries, tibial stress syndrome, knee osteoarthritis, iliotibial band syndrome, patellofemoral syndrome and ligament injuries.[9] Furthermore, it has been found an increment of cavus foot in athletes, which could be related to the mechanical demands of the foot towards the movement of plantar flexion. [21]

The high percentage of prevalence of foot disorders found in this study suggests that some conservative treatments or orthotic devices (insoles) should be applied in the structure of the foot. Furthermore, a revision of the structure and physiology of the foot should be considered by the athletes before the structure of the foot presents an injury.

Conclusion

In conclusion, the understanding of the morphology of the soles of the feet can help to determine the foot type in these three different sports, and therefore, it can be implemented physiotherapeutic treatments or orthotics devices for overcome the musculoskeletal disorders and prevent future injuries.

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