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Analysis of Relationship Between Foot Morphology and Static Balance in Female Athletes

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Abstract

This study was conducted to investigate the relationship between the morphological structure of the foot and female athletes' static balance levels. 51 female athletes with an average age of 22.25±0.38 years participated in the research. The foot morphology was evaluated in 4 parameters. Balance scores were evaluated in 8 parameters. Spearman and Pearson correlation tests were used to determine the relationship between parameters ($p<05$). According to the results, it was observed that in the right foot there was a negative significant correlation between foot index (FI) parameter and standard deviation of forward and backward sway (FBSD), average forward backward speed (AFBS), used perimeter (P), used area (A) balance scores. In the left foot, there was a positive correlation between the FI parameter and the pressure to the average central y axis (COPY) balance score, and a negative significant relationship between the FI parameter and the FBSD and AFBS balance scores. It was determined that there was a positive significant correlation between the Chippaux Smirak index (CSI) and Staheli index (SI) parameters of both feet and the pressure to the average central x point (COPX) balance score. The results can be interpreted that the anatomical structure of the foot is important in the static balance characteristics of athletes.

Keywords: Foot Morphology, Static Balance, Female Athletes

INTRODUCTION

In today's world, the effects of morphological and anthropometric characters on achieving high sportive performance and optimum success are the issues that researchers focus on (1,2,3). The anthropometric and physical characteristics of the athletes play a decisive role as a prerequisite for performance, and it is thought that a physical structure specific to the branch should be first in order to achieve a high-impact sports efficiency. The anthropometric and physical characteristics of the athletes play a decisive role as a prerequisite for performance, and it is thought that a physical structure specific to the branch should be a priority in order to achieve a high-impact sports efficiency (4). In particular, it is emphasized that the structural changes in the anatomical components of the foot, located at the end point where all the stress applied to the body is transferred to the floor, is important for the successful execution of motor skills (5,6).

The foot is the last segment of the locomotor chain and has a complex anatomical structure. Foot and ankle biomechanics are dynamic structures that are directly related to other parts of the lower limb. While the foot works as an absorbent organ in transferring body weight to the ground in an elastic way, it also adapts to weight and ground changes and becomes a rigid lever when necessary. While the foot carries the body weight against gravity with these features, it is known that foot posture and morphology have important effects on walking, standing and balance (7,8,9,10,11,12).

Another important factor in terms of sporting performance is the ability to balance (13). Balance is the process of keeping the position of the body's center of gravity vertically (14). It is known that balance skill, which is at the center of the conditional abilities that form the basis of performance, plays an important role in successful exhibiting of many sports skills, changing direction, stopping, starting, holding, moving the object and maintaining a certain body position (15). Although the physical structure alone is not decisive in maintaining the balance, it is among the factors that create the balance (16).

Studies are continuing to determine the most ideal physical structure in order to reach high performance limits in sports. At this point, the idea that the ability to protect the body's position against gravity may be related to the structural differences in the foot constituted the subject of this research.

Many studies have emphasized the importance of foot anatomical structure and balance skills in sportive performance (17,18). However, it has been observed that there are limited number of studies on the relationship between these two factors, which are known to be important in terms of sports efficiency.

For these reasons, this study was conducted to investigate the relationship between the morphological structure of the foot and female athletes' static balance levels.

METHODS

Study Method. This research is a descriptive and analytical study to determine the relationship between foot morphology and female athletes' static balance levels.

Study Group. 51 female athletes from different branches (football n:14, volleyball n:12, basketball n:9, handball n:5, taekwondo n: 8, table tennis n:3) with a mean age of 22.25±0.38 years participated voluntarily in the study. Those with a pathological history of the foot and ankle in the last year and those with a body mass index above 30 were not included in the study. The research was carried out in accordance with the Declaration of Helsinki with the decision of Giresun University Social Sciences, Science and Engineering Research Ethics Committee dated 5/10/2022 and numbered 27/16.

Data Collection Tools

Determination of Morphological Structure of Foot. Footprint analysis method obtained from the foot plantar pressure was used to determine the foot morphology. Footprint method is a technique used in the evaluation of foot morphology and classification of foot types (19,20,21). The relevant researchers recommend that multiple parameters should be used when evaluating the foot type (22). In this study, footprint measurement was performed by footprint metric analysis method using 4 morphometric parameters in order to evaluate foot structure. The footprint method, which measures the sole pressure of the foot, is a very good way of understanding where the load is coming from and which tissues are under extreme mechanical stress (23). Chinesport brand podoscope was used for footprint measurements.

Footprint Measurement and Parameters. Foot plantar pressure images of all volunteers were taken from the podoscope by using a camera in the footprint analysis. Morphometric measurements were made on the images and cm was used as the metric unit. The application was made for both feet as right and left.

Parameters

Foot Index (FI): Obtained by dividing the transverse breadth (FB) of the foot by longitudinal length (FL) and multiplied by 100. FI=(FB/FL)*100 (24). **Chippaux-Smirak Index (CSI):** It is the ratio of the minimum width of the middle arch area of the foot (B) to the maximum width of the metatarsal region (C). CSI=(B/C)*100 (21). **Staheli Index (SI):** It is the ratio of the minimum width of the middle arch area of the foot (B) to the maximum width of the posterior region of the foot (A). SI=B/A (25). **Clark Angle (C°):** It is the angle between the line connecting the most medial metatarsal point and the most medial heel region and the line connecting the inner medial arch point (concavity of the arch) and the most medial metatarsal point (20).

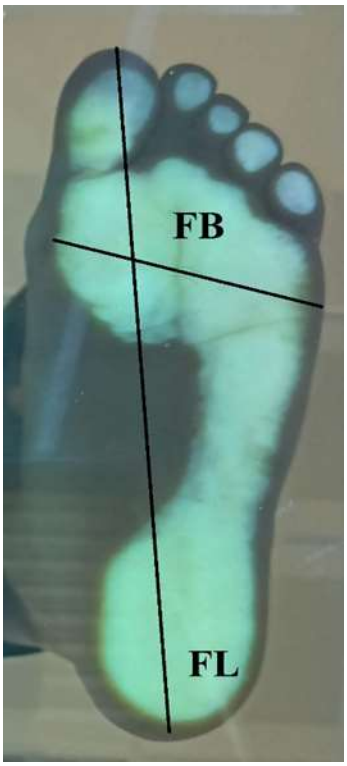

Fig 1. Foot İndex

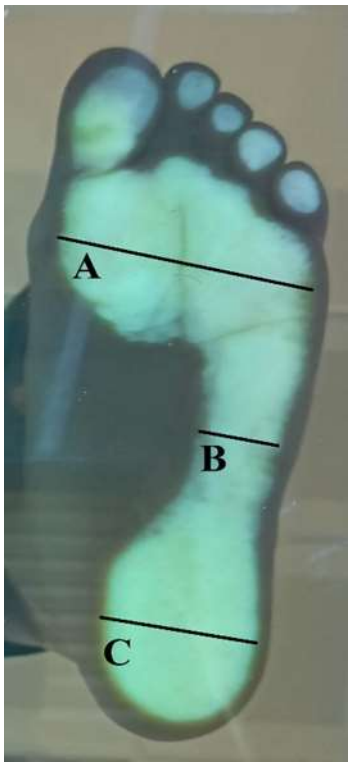

Fig 2. CSI and SI

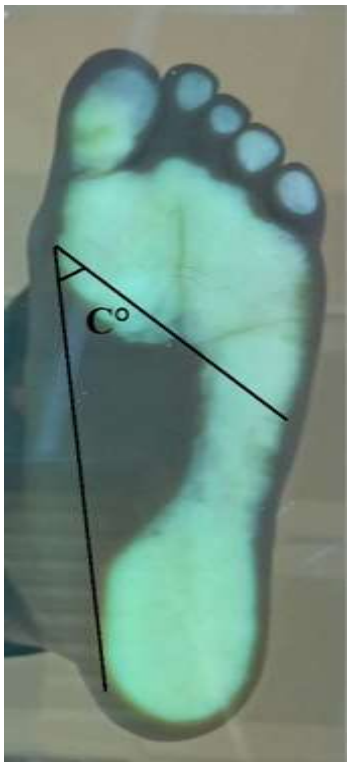

Fig 3. C°

Table 1. Foot descriptive statistics

FOOT PARAMETERS	FI		CSI		SI		C°	
	Mean	SD(±)	Mean	SD(±)	Mean	SD(±)	Mean	SD(±)
RIGHT FOOT (n:51)	37,16	2,25	30,27	0,08	0,51	0,14	56,19	5,39
LEFT FOOT (n:51)	37,16	1,95	29,76	0,11	0,50	0,18	54,49	6,35

FI: Foot index, CSI: Chippaux-Smirak index, SI: Staheli index, C°: Clarke angle

Determination of static balance levels. CSMI TecnoBody PK-252 isokinetic balance system measuring device was used to determine the balance levels of the participants. TecnoBody PK-252 device, which can measure static and dynamic balance, can objectively measure balance measurements and allows us to obtain measurable data. The data provided by the device can be monitored and recorded instantly from the screen on the device. Since this system calculates the balance score with oscillation scores relative to the central point on a certain analytical plane, the further one moves away from the centre, that is, the 0 value, the higher the score will be. Therefore, as the balance score moves away from 0, the balance of the individual is assumed to be bad, and as the score approaches 0, the balance is assumed to be good (26).

In the balance measurement, the device was first calibrated and the system was introduced to the volunteers. The "Static Stability Assessment" module of the device was selected, and the volunteers' feet were

placed on the platform with reference to the x and y lines on the platform. In the measuring position, the hands are drooping and the feet are bare. Measurements were made for 30 seconds with bipedal and eyes open. The results were evaluated in 8 parameters.

Static balance parameters

COPX: Pressure to the average central x point. **COPY:** Pressure to the average central y axis. **FBSD:** Standard deviation of forward and backward sway. **MLSD:** Standard deviation of medial-lateral sway. **AFBS:** Average forward backward speed. **AMLS:** Average medial lateral speed. **P:** Used perimeter. **A:** Used area.

Fig 4. Static Balance Measurement System

Table 2. Static balance descriptive statistics

BALANCE PARAMETERS	Mean	SD(±)
COPX	0,69	0,99
COPY	-1,04	1,79
FBSD	5,98	3,15
MLSD	2,86	1,41
AFBS	9,45	3,12
AMLS	7,41	2,67
P	287,73	218,30
A	408,61	115,26

Data analysis. SPSS package program was used in the analysis of the data. First, the detection of normality was tested with the Kolmogorov-Smirnov test. It has been determined that the Standard deviation of medial-lateral sway (MLSD) data, which is one of the balance parameters, does not show a normal distribution. Spearman correlation test was used in the analysis of the relationship between MLSD and all other parameters. Since the data of all other foot and balance parameters showed normal distribution, the relationship between them was examined by applying the Pearson correlation test. Results were evaluated at $p < 0.05$ significance level.

RESULTS

Table. 3 The relationship between foot parameters and balance levels.

		FI		CSI		SI		C°	
		RIGHT FOOT	**LEFT FOOT**	**RIGHT FOOT**	**LEFT FOOT**	**RIGHT FOOT**	**LEFT FOOT**	**RIGHT FOOT**	**LEFT FOOT**
COPX	**r**	0,033	-0,181	**0,364****	**0,306***	**0,365****	**0,280***	-0,161	-0,214
	p	0,816	0,202	**0,009**	**0,029**	**0,008**	**0,046**	0,260	0,132
COPY	**r**	0,165	**0,322***	-0,029	0,014	-0,031	0,036	0,113	0,037
	p	0,248	**0,021**	0,839	0,921	0,829	0,803	0,431	0,797
FBSD	**r**	**-0,345***	**-0,288***	-0,047	0,071	-0,123	0,034	-0,149	0,030
	p	**0,013**	**0,040**	0,745	0,619	0,391	0,814	0,296	0,840
MLSD	**r**	-0,149	-0,120	0,125	0,134	0,078	0,142	-0,052	- 0,018
	p	0,295	0,391	0,380	0,347	0,590	0,319	0,720	0,898
AFBS	**r**	**-0,372****	**-0,284***	-0,014	0,100	-0,112	0,056	-0,230	-0,032
	p	**0,007**	**0,044**	0,921	0,486	0,435	0,697	0,100	0,826
AMLS	**r**	-0,113	-0,002	0,030	0,146	-0,019	0,134	-0,143	-0,169
	p	0,431	0,990	0,833	0,307	0,894	0,347	0,316	0,236
P	**r**	**-0,300***	-0,166	-0,032	0,124	-0,119	0,107	-0,034	0,020
	p	**0,033**	0,245	0,824	0,385	0,407	0,455	0,812	0,870
A	**r**	**-0,297***	-0,178	0,009	0,141	-0,072	0,109	-0,215	-0,110
	p	**0,034**	0,211	0,948	0,323	0,615	0,446	0,129	0,450

p<05. FI: Foot index, CSI: Chippaux-Smirak index, SI: Staheli index, C°: Clark angle COPY: Pressure to the average central y axis, FBSD: Standard deviation of forward and backward sway, MLSD: Standard deviation of medial-lateral sway, AFBS: Average forward backward speed, AMLS: Average medial lateral speed, P: Used perimeter, A: Used area.

When the relationship between foot parameters and balance levels is examined in Table 3, it was observed that there was a negative significant correlation between the right foot FI parameter and FBSD, AFBS, P and A balance scores. In the left foot, there was a positive correlation between the FI parameter and the COPY balance score, and a negative significant relationship between the FI parameter and the FBSD and AFBS balance scores. In addition, it was determined that there was a positive significant correlation between the CSI and SI parameters of both feet and the COPX balance score.

DISCUSSION

As a result of developing technology and increasing financial resources, the competition in reaching sports goals is increasing day by day. In this process of elitism and professionalization in sports, the issue of maximizing sports efficiency increases the demands on scientists. For these reasons, scientists are constantly investigating the key factors and characteristics required for successful athletic performance. In line with the researches, it is seen that morphological variables are important in determining potential successful athletes (27,28,29,30). Among these morphological factors, it is important to comprehensively reveal the relationship between foot structure and sportive performance since the foot is the last point of the locomotor chain and is the structure that transfers the load of the whole body to the ground. It is thought that providing the necessary postural control in order to show the expected performance in athletes and transferring the pressure applied to the body correctly to the ground is related to the anatomical structure of the foot.

According to the results of this study, which tried to determine the relationship between some components in the foot anatomical structure and static balance performance in female athletes, a significant negative correlation was found between the right foot FI parameter and FBSD, AFBS, P and A balance scores. In the left foot, there was a positive correlation between the FI parameter and the COPY balance score, and a negative correlation between the FI parameter and the FBSD and AFBS balance scores (p<05, table 3).

In the literature review, it was seen that researchers generally focused on arch structure when examining the relationship between foot structure and sportive performance. Foot index (FI) was used in this study to indicate the importance of other components involved in foot biomechanics.

Foot index is one of the parameters that gives an idea about the foot structure and is accepted by researchers (31,32). It is calculated by dividing the width of the metatarsal region by the length of the foot (24,

Fig 1). The relationship findings between foot index and balance in this study can be interpreted that an improvement is visible in balance scores with an increase in the ratio of metatarsal width to foot length.

In this study, it was observed that there was a significant positive correlation between the CSI and SI parameters of both feet and the COPX balance score ($p<05$, table 3). CSI and SI parameters are important parameters used by many researchers to determine the height and lowness of the medial longitudinal arch of the foot. CSI and SI parameters are important parameters used by many researchers to determine the height level of the medial longitudinal arch of the foot. In CSI 1-29,9 values (33) and in SI 0,30-0,59 values (25) are accepted as normal arch. The CSI and SI findings in this study are at or close to values considered normal by the researchers (Table 1).

When the relevant literature was reviewed, in a study conducted by Harrison and Littlewood (2010) on fifteen healthy adults, it was stated that static balance levels improved as the level of flat feet decreased (34). Lin et al. (2006) also found that there was a significant relationship between footprint parameters and postural balance ability in a study on children, and that as the arc height increased, the sway field decreased (35). In addition, Kim et al. reported in one of their studies that individuals with low arc had higher COPX values than individuals with normal arc (36). It is seen that the results of previous studies regarding the relationship between arch height and postural control support our results.

As a result of the study, significant values between some foot parameters and some static balance parameters can be interpreted as the importance of the anatomical structure of the foot in the static balance characteristics of athletes.

We believe that these results will shed light on other studies to reveal the relationship between foot structure and body biomechanics.

These research results can be used in determining the ideal physical structure and criteria for athlete talent selection. In addition, these results can be taken into consideration during training processes in increasing sportive performance and determining preventive measures to protect athletes' health.

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