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Full Length Research Paper

Foot morphology of Turkish football players according to foot preference

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Football is the most popular sport in the world. Foot morphology and foot preference are important factors in football player's performance. The aim of this cross-sectional study was to evaluate the foot morphology of elite football players with different foot preferences. 407 male football players participated in this study. 328 of them preferred their right foot, while 79 of them preferred the left one. Eleven anthropometric measurements were taken from each foot with standard anthropometric methods. Foot length, T1, T2, T3, T4 and T5 lengths, foot circumference of right and left feet and right foot width of right foot preference group were higher than those of left foot preference group, which is statistically significant ($p < 0.05$). Left foot measurements of right foot preference group were interestingly higher than those of the right side. It was suggested that these data may be useful to define the foot morphology of elite football players.

Key words: Foot morphology, football, measurements.

INTRODUCTION

The human foot exhibits a wide range of structural variations than many other parts of the body. During growth, the foot changes not only its dimensions but also its shape (Kulthanan et al., 2004). The human foot, the foundation for bipedal locomotion, is a complex adaptation that evolved through extensive remodeling of the hind appendage of the human arboreal primate forebears (Fessler et al., 2005). The characteristics of foot shape are manifold, since numerous factors are associated with foot morphology. Aside from natural biological variance, distinctive age classes and population groups show prevalent qualities in foot dimensions (Krauss et al., 2010).

The foot is the base of support for the chain of motion and body posture (Mauch et al., 2008), foot length also affects dorsoventral stability (Fessler et al., 2005). When there is a unilateral overload, an athlete may exhibit an obvious discrepancy (Aydog et al., 2008). Like anatomical alignment of a joint, foot morphology has an important effect on the relationship between the ground reaction force and the axes of rotation of the ankle, knee and lower extremity as well as the corresponding forces developed on these structures (Murphy et al., 2003).

Motoric dominance, the preferential usage of an upper or lower limb based on its primacy or dominant use in motor functions in a specific situation, is a universal, uniform and unique characteristic of all humans. One of the most obvious manifestations of motoric dominance is footedness, the tendency to prefer the use of a consistent foot in performing voluntary motor acts (Grouios et al., 2004; Grouios, 2005).

Typically, footedness for a particular task is characterized by its stabilizing and mobilizing (or manipulating) features. That is, one limb is used to manipulate an object or lead out (example, kicking a ball), whereas the other foot has the role of lending postural (stabilizing) support. In such a bilateral context, which provides a relatively clear division of functional limb action, the consensus is that the mobilizing limb is the preferred (dominant) foot, whereas the foot used to support the actions of the preferred foot is defined as the non-preferred limb (Gabbard and Hart, 1996; Gabbard and Hart, 1998; Gabbard and Hart, 1997).

Footedness has been implicated as a risk factor for the development of pathology in the lower extremity

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because most individuals place a greater mechanical demand on their preferred foot during voluntary motor acts. Thus, long-term mechanical stress acting in-homogeneously on the preferred lower limb, particularly during high-demand activities, may cause injuries and hazards to that limb. However, the association between lower limb laterality and side of lower limb pathology is controversial (Grouios, 2005; Devita et al., 1991).

When the literature was investigated, there were many scientific researches related to the effects of foot morphology on foot injury, estimate of stature, body composition, age, sex and lower extremity muscle strength (Fessler et al., 2005; Mauch et al., 2008; Aydog et al., 2008; Grivas et al., 2008; Sanli et al., 2005; Ozden et al., 2005). For example, in the Sanli's study on the sample of a Turkish adult population, the correlations between stature and foot length for males were found to be statistically significant (Sanli et al., 2005).

Some of these studies have reported an association between foot morphology and injury. In contrast, several studies suggested that footedness does not appear to be an influential etiology in the formation of lower limb pathology. This discrepancy may be due in part to a lack of consistency in quantifying foot morphology. Also, these contrasting findings may have been the result of different study designs, instrumentation, sample composition and size, recruitment profiles of the preferred versus the non-preferred foot or the methods used for data collection and analysis (Gabbard and Hart, 1997). To conclusively establish the relationship between foot structure and lower extremity injury, an objective and quantifiable method must be developed and used. In addition, it is important to study contact biomechanics of the foot inside the footwear in which the athlete is likely to incur injury (Murphy et al., 2003). For this reason, foot morphology is well known and concerned with sport and athletics.

Long-term mechanical stress acting in-homogeneously on the preferred lower limb, particularly during demanding and repetitive physical activity or high-impact exercising, may contribute to the causation of corn and callus formation to that limb. Grouios study has verified this belief and he reported that footedness should contribute to the causation of corn and callus formation in lower extremities of physically active individuals (Grouios, 2005).

Football which is the most popular sports in the world needs high skilled coordination of different body parts, especially the lower extremities (Junge et al., 2004). Body proportions and size are the important factors for the sports performance. Especially, the feet of the football players are essential for their proper performances among other factors. Also, determination of foot morphology and shape will be helpful for designing footwear to enhance performance (Manna et al., 2001; Wunderlich and Cavanagh, 2001). It is likely that the functional requirements of participants' feet vary between sporting disciplines such that the optimal foot type for footballers is different from that for marathon runners. Indeed, sport-specific foot morphology of athletes engaged in various sporting disciplines has been demonstrated recently (Mauch et al., 2008).

To knowledge of this study, this is the first study evaluating foot morphology which depends on foot preference. For this purpose, the foot morphology of professional football players was investigated by taking into account their foot preference which was thought to affect the morphology with the advance of the age.

MATERIALS AND METHODS

The cross-sectional study was performed with the participation of 407 male volunteer football players, playing for the teams attending First and Second Professional Turkish Leagues. The participants were recruited from the camp before the seasons. The subjects were assessed before training, thus problems were eliminated from arising exercise, to get permission from athlete and club before beginning the study. All participants met the following inclusion criteria: (1) no history of congenital deformity in the lower extremity or foot; (2) no previous history of lower extremity or foot fractures; (3) no surgical operation on foot and lower extremity; (4) no systemic diseases that could affect lower extremity or foot posture; (5) no history of trauma or pain to either foot, lower extremity or lumbosacral region at least 12 months prior to start of the investigation.

Having reported age, height, weight, stature and foot and footwear characteristics, measurements were taken with the help of a millimetric table prepared according to Hall et al (1989) anthropometric measurement methods. The foot was put on the measurement table in a full weight bearing position, while the other rested lightly on a 25 cm raised platform. The body was in a normal, upright position. The foot was placed on the measurement table so that the medial side would be touching the long side of the platform and the most prominent part of the heel would be touching the short side of it. The length between the extreme point of heel and the extreme point of the longest toe (either first or second toe) was measured as foot length. The lengths between the most projecting part of the heel, and the tips of each toe which were defined as T1, T2, T3, T4 and T5 were measured. The length between inner side of the first metatarsal bone's caput and outer side of the fifth metatarsal bone's caput was measured as the foot width. Ball girth was measured at the level of metatarsal joint by using a tape-measure. Ankle circumference was carried out by tape-measure right above the medial and lateral malleoli. For calf circumference, a measurement was carried out by tape-measure in the widest area of lower leg. Foot height was measured by using caliper from top of navicula to floor. Stature and body weight of each individual were also measured. Measurements result of 407 subjects obtained from both feet were recorded in centimeters.

Foot preference was assessed by asking subjects which foot they would use to kick a football into a goal (Barut et al., 2007). If subjects were not sure of their preference, they were asked to simulate the action. Subjects were classified as 'right', 'left' or 'either' depending upon preference.

Size of footwear used during training, match and daily was also recorded. Statistical analyses were performed with SPSS for Windows Release 11.00. Comparison of means within two foot preference groups were performed with independent samples t-test. Comparison of means of left and right side of individuals were performed with paired samples t-test. Correlations of the parameters were evaluated with Pearson correlation analysis in both groups. Significance was set at $p < 0.05$.

Table 1. Comparison of foot parameters according to foot preference.

Parameter	Right foot preference (n = 328)		Left foot preference (n = 79)	
	Mean	SD	Mean	SD
Age *	23.64	3.05	22.70	3.00
Weight	74.12	6.18	72.99	6.03
Stature	180	5.00	178	6.00
Football Age *	13.16	2.40	12.52	2.30
Shoe size	41.80	1.29	41.75	1.38
Exercise shoe size	41.73	1.47	41.78	1.43
Match shoe size	41.64	1.55	41.68	1.65
Right foot length *	26.77	1.08	26.48	1.24
Right T1 *	26.76	1.08	26.47	1.23
Right T2 *	26.34	1.13	26.01	1.31
Right T3 *	25.26	1.16	24.94	1.32
Right T4 *	23.78	1.09	23.38	1.25
Right T5 *	21.82	.96	21.51	1.08
Right foot width *	10.14	.47	10.01	.48
Right foot circumference *	25.12	1.27	24.78	1.23
Right ankle circumference	22.97	1.18	22.76	1.17
Right leg circumference	37.13	2.05	36.70	2.13
Right foot height	6.17	.59	6.15	.61
Left foot length *	26.84	1.12	26.53	1.20
Left T1 *	26.83	1.13	26.52	1.19
Left T2 *	26.44	1.16	26.07	1.35
Left T3 *	25.41	1.18	24.93	1.34
Left T4 *	23.91	1.09	23.46	1.30
Left T5 *	21.94	.97	21.63	1.15
Left foot width	10.20	.58	10.11	.53
Left foot circumference *	25.19	1.13	24.80	1.21
Left ankle circumference	22.79	1.14	22.59	1.29
Left leg circumference	36.87	2.03	36.65	2.06
Left foot height	6.19	.64	6.10	.66

Independent samples test; * $p < 0.05$.

RESULTS AND DISCUSSION

The sample for this study consisted of 407 male football players (about 80.6% of them has right foot preference; the remaining has the left foot preference). The average ages were determined as 23.64 ± 3.05 and 22.70 ± 3.00 years for right foot preference and left foot preference, respectively.

The descriptive statistics such as the means and standard deviations are classified by foot preference and are shown in Table 1. In this table, foot length, T1, T2, T3, T4 and T5 lengths and foot circumference of right and left feet and right foot width of right foot preference group were higher than those of left foot preference group, which is statistically significant ($p < 0.05$). No significant difference was found in other measurements.

Left foot length, T2, T3, T4 and T5 lengths, and foot width were higher than right foot in right foot preference group, and the differences were statistically significant ($p < 0.05$). Right foot circumference and ankle circumference were higher than the left foot and the results were statistically significant ($p < 0.05$). Also, for all parameters, right ankle circumference was higher than the left foot which is statistically significant ($p < 0.05$) (Table 2).

When the left foot preference group was examined, it was seen that only left foot width was higher than the right foot width and this result was statistically significant ($p < 0.05$). For the rest of the parameters, the differences were not statistically significant ($p > 0.05$) (Table 3).

Most right and left foot characteristics of right foot preference group subjects were correlated with each other ($p < 0.05$). But, there was no correlation between the other parameters such as left foot height, left foot circumference and left leg circumference ($p > 0.05$) (Tables 4 and 5).

Similarly, most of the foot characteristics were correlated with each other in the left foot preference group. However, left foot height was correlated with left foot

Table 2. Comparison of dimensions of right and left foot in right foot preference group.

Parameter	Right		Left	
	Mean	SD	Mean	SD
Foot length*	26.7688	1.08172	26.8404	1.12747
T1	26.7654	1.08135	26.8303	1.12875
T2*	26.3363	1.13760	26.4351	1.15553
T3*	25.2555	1.15620	25.4064	1.18140
T4*	23.7832	1.09139	23.9134	1.09173
T5*	21.8216	.95824	21.9372	.96598
Foot width*	10.1436	.46919	10.2009	.57806
Foot circumference	25.1235	1.26864	25.1936	1.13047
Ankle circumference*	22.9713	1.18274	22.7875	1.13983
Leg circumference*	37.1250	2.05433	36.8732	2.03404
Foot height	6.1723	0.58852	6.1909	0.64289

Paired samples test. * $p < 0.05$.

Table 3. Comparison of dimensions of right and left foot in left foot preference group.

Parameter	Right		Left	
	Mean	SD	Mean	SD
Foot length	26.48	1.24	26.53	1.20
T1	26.47	1.23	26.52	1.19
T2	26.01	1.31	26.07	1.35
T3	24.94	1.32	24.93	1.34
T4	23.38	1.25	23.46	1.30
T5	21.51	1.08	21.63	1.15
Foot width*	10.01	.48	10.11	.53
Foot circumference	24.78	1.23	24.80	1.21
Ankle circumference	22.76	1.17	22.59	1.29
Leg Circumference	36.70	2.12	36.65	2.06
Foot height	6.15	0.61	6.10	0.66

Table 4. Correlation of left foot parameters in right foot preference group.

Parameter	Left foot length r(p)	Left foot width r(p)	Left foot circumference r(p)	Left ankle circumference r(p)	Left leg circumference r(p)	Left foot height r(p)
Left foot length	1	0.35(0.000)	0.44(0.000)	0.44 (0.000)	0.34(0.000)	0.14(0.01)
Left foot width	0.35(0.000)	1	0.44(0.000)	0.34(0.000)	0.27(0.000)	0.30(0.000)
Left foot circumference	0.44(0.000)	0.44(0.000)	1	0.51(0.000)	0.49(0.000)	0.05(0.37)
Left ankle circumference	0.44(0.000)	0.34(0.000)	0.51(0.000)	1	0.51(0.000)	0.14(0.01)
Left leg circumference	0.34(0.000)	0.27(0.000)	0.49(0.000)	0.51(0.000)	1	-0.05(0.37)
Left foot height	0.14(0.01)	0.30(0.000)	0.05(0.37)	0.14(0.01)	-0.05(0.37)	1

r, Pearson correlation coefficient.

Table 5. Correlation of right foot parameters in right foot preference group.

Parameter	Right foot length r(p)	Right foot width r(p)	Right foot circumference r(p)	Right ankle circumference r(p)	Right leg circumference r(p)	Right foot height r(p)
Right foot length	1	0.45(0.000)	0.44(0.000)	0.46(0.000)	0.38(0.000)	0.11(0.05)
Right foot width	0.45(0.000)	1	0.61(0.000)	0.44(0.000)	0.40(0.000)	0.22(0.000)
Right foot circumference	0.44(0.000)	0.61(0.000)	1	0.41(0.000)	0.54(0.000)	-0.01(0.90)
Right ankle circumference	0.46(0.000)	0.44(0.000)	0.41(0.000)	1	0.52(0.000)	0.17(0.002)
Right leg circumference	0.38(0.000)	0.40(0.000)	0.54(0.000)	0.52(0.000)	1	-0.07(0.22)
Right foot height	0.11(0.05)	0.22(0.000)	-0.01(0.90)	0.17(0.002)	-0.07(0.22)	1

r: Pearson correlation coefficient.

Table 6. Correlation of left foot parameters in left foot preference group.

Parameter	Left foot length r(p)	Left foot width r(p)	Left foot circumference r(p)	Left ankle circumference r(p)	Left leg circumference r(p)	Left foot height r(p)
Left foot length	1	0.49(0.000)	0.44(0.000)	0.41(0.000)	0.33(0.003)	0.23(0.04)
Left foot width	0.49(0.000)	1	0.57(0.000)	0.30(0.01)	0.28(0.01)	0.22(0.048)
Left foot circumference	0.44(0.000)	0.57(0.000)	1	0.56(0.000)	0.55(0.000)	0.11(0.34)
Left ankle circumference	0.41(0.000)	0.30(0.01)	0.56(0.000)	1	0.58(0.000)	0.17(0.15)
Left leg circumference	0.33(0.003)	0.28(0.01)	0.55(0.000)	0.58(0.000)	1	0.10(0.38)
Left foot height	0.23(0.04)	0.22(0.048)	0.11(0.34)	0.17(0.15)	0.10(0.38)	1

r: Pearson correlation coefficient.

length and left foot width, and right foot height was related. Only right foot length was different from right foot preference group (Tables 6 and 7).

Certain anthropometric features are advantageous in some sports, and repetition of certain exercises over a long time may also cause sport specific adaptations in the body (Aydog et al., 2004). It is generally believed that the function of the foot depends, to a significant extent, on the shape of the foot. Despite having many common anatomical characteristics, the shape of the foot differs greatly between individuals (Razeghi and Batt, 2002). The morphology of the foot plays a role not only in the performance of a player but also, its relationship with the shoe may play a role in lower limb injuries (Soper et al.,

Table 7. Correlation of right foot parameters in left foot preference group.

Parameter	Right foot length r(p)	Right foot Width r(p)	Right foot circumference r(p)	Right ankle circumference r(p)	Right leg circumference r(p)	Right foot height r(p)
Right foot length	1	0.61(0.000)	0.44(0.000)	0.46(0.000)	0.38(0.001)	0.27(0.02)
Right foot width	0.61(0.000)	1	0.65(0.000)	0.44(0.000)	0.37(0.001)	0.15(0.18)
Right foot circumference	0.44(0.000)	0.65(0.000)	1	0.54(0.000)	0.56(0.000)	0.01(0.95)
Right ankle circumference	0.46(0.000)	0.44(0.000)	0.54(0.000)	1	0.69(0.000)	0.15(0.19)
Right leg circumference	0.38(0.001)	0.37(0.001)	0.56(0.000)	0.69(0.000)	1	-0.03(0.78)
Right foot height	0.27(0.02)	0.15(0.18)	0.01(0.95)	0.15(0.19)	-0.03(0.78)	1

r: Pearson correlation coefficient.

2001). Thus, morphology of the foot in football players was investigated in this study with respect to foot preference.

There are several studies in the literature evaluating foot dimensions in Turkish population samples of adults (Peker et al., 1997; Anil et al., 1997) and children (Ulukent et al., 1997). Also, there are several studies in the literature regarding estimation of stature from foot dimensions, indicating foot dimensions (Grouios, 2004, 2005).

The right and left foot lengths and widths of both foot preference groups in this study were higher than those measured by Ozden et al. (2005). Football players' feet were longer and wider than the study group of Ozden et al. (2005). Left foot length and width measured by Ozaslan et al. (2005) were lower than the measurements of this study, whereas left foot height measurements were higher than these results. Left foot length, width and T1, T2, T3, T4 and T5 lengths of Hong Kong Chinese adult males were lower and their foot height was higher than Turkish football players (Goonetilleke et al., 1997). The feet of Turkish football players were longer and wider than the aforementioned studies. Stature of the study group was higher than the results of Ozaslan et al. (2003) and Goonetilleke et al. (1997). This may explain the reason for longer and wider feet of football players, as it might be expected that the taller individual will have larger feet (Goonetilleke et al., 1997).

Foot length and width of Indian males were lower than that of Turkish football players (Manna et al., 2001). Leg and ankle circumferences of American army personnel were lower than those of Turkish football players, whereas their foot length and foot width were higher, and the two groups had almost equal foot circumference values (Wunderlich and Cavanagh, 2001). Racial and socioeconomic status differences may be the reason for the differences between these studies.

In the study of Manna et al. (2001) only right foot width was significantly higher than the left and for the rest of the parameters; the differences were not statistically significant. Based on this, it could be suggested that most of the foot dimensions are symmetric in India. In this study, foot length, T2, T3, T4 and T5 lengths, and foot width of the left side were significantly higher than that of the right side in right foot preference group. Only right ankle and leg circumference values of right foot preference group were significantly higher than the left side. This represents an asymmetry favoring left side for the right foot preference group. Furthermore, left foot width was significantly higher in left foot preference group in contrast to the results of Manna et al. (2001). Hence, the feet of left foot preference group seemed to be symmetric in this study.

The correlation of foot length, foot width, ankle circumference and leg circumference of both right and left foot preference groups for both right and left feet were more prominent in this study when compared to the study of Peker et al. (1997). Based on this prominent relationship, it can be suggested that all these aforementioned parameters should be taken into account for proper shoe design in order to increase the performance of football players.

To knowledge of this study, this is the first study evaluating foot morphology depending on foot preference. The asymmetry in right foot preference group and symmetry in left foot preference group is also suggested to be important. Results of this study may bring insight to the foot morphology of Turkish football players.

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