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The Effect of Volleyball on The Sole Contact Areas and Maximal Forces of Female Volleyball Players

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Original scientific paper

Abstract
The aim of the present study was to compare the pedobarographic parameters of contact areas and maximal forces for 11 contact areas of foot-soles in professional female volleyball players and healthy people and to investigate the effect of volleyball on the foot-sole. The study consisted of 27 female Volleyball players without any foot-related complaints and, as the control group, 28 female volunteers. EMED-SF plantar pressure analysis system was used in the study. Any statistically significant difference between the averages of the study and the control groups was examined using non-parametrical Mann Whitney U test, and the extent of the linear relationship between the physical structure and the variables of the foot-sole was examined by calculating the Pearson (r) coefficient. Based on the results of the study, it was found that all results showed similarities in contact areas in comparisons between female volleyball players and the control group, and 1 parameter in each of the right and left foot maximal forces had differences. It was concluded that there was a close relationship between the type of sports done by the volleyball players and the variables relating to the foot-sole, the sports activity didn't harm the foot-sole, causing much less changes in the foot-sole as compared to basketball and, especially, wrestling, and had similarities with the results of the control group.

Key words: **Foot-Sole, Contact Area, Maximal Force, Pedobarographic**

Introduction

Volleyball is a high-tempo, dynamic physical game without a definite playing time based on agility, strength, mobility, flexibility, endurance and the action of bounding (Akalın, 1995; Erhan, 1995; Şimşek, Ertan, Göktepe, & Yazıcıoğlu, 2007). Volleyball is generally considered a competitive sports branch with a high level of injury in the musculoskeletal system. Blocking and spiking are two basic actions in volleyball and bounding and landing actions are particularly investigated in the musculoskeletal system (Salci, Kentel, Heycan, Akin, & Korkusuz, 2004). Bounding which is one of the factors having a direct effect on the performance is the type of action frequently preferred both in offence and in defence and affects the performance substantially. Such actions as spiking and blocking based on bounding form the basis of this sports branch. These actions are performed very frequently during the match at different intervals and bounding high is an important factor in success(Akalın, 1995).

Volleyball is not a particularly dangerous sports branch despite the fact that it is played in halls or on sand. Injuries seen in both male and female volleyball players share similarities and are mostly consist of excessive use, ankle sprain and deformities in the shoulder. Ankle sprains are the most common injuries that occur both before and during the game in male and female volleyball players (Bahr & Bahr, 1997; Ekinci, 2011; Kılıçoğlu, 2009; Reeser, Verhagen, Briner, Askeland, & Bahr, 2006; Stasinopoulos, 2004). Ankle injuries are more common in certain sports branches. Ankle injuries make up 45% of all injuries in basketball, 25% in volleyball and 31% in football (Kılıçoğlu, 2009). Athletes who have to bound frequently in volleyball have a higher risk of ankle sprain. In other words, 90% of ankle sprains are after the blocking action. Following the ankle sprains, the most common problem is the occurrence of functional changes in walking in 15-60% of athletes having pain and this causes different pressure spots on the foot-sole to emerge (Stasinopoulos, 2004).

Metatarsalgia is one of the main foot-sole disorders (Kang, Chen, Chen, & Hsi, 2006). Metatarsalgia is related to repetitive loadings of metatarsal heads, and is one of the most common foot disorders in the general population. The load that is borne by the metatarsal heads while walking varies from person to person. A greater part of the patients consulting the orthopedic polyclinics have complaints of metatarsalgia (Eils et al., 2002; Kılıçoğlu, 2009). Its causes include such problems as pes cavus, pes planus (flat feet), hallux valgus, capsulitis, synovitis, periostitis, stress fractures, plantar plate tears, neurinomas, callus, Freiberg's disease, fat pad athrophies, flexor tendinitis. It is known that the imbalances in the load distribution and the increase of load on metatarsal heads are the major causes of metatarsalgia (Kang et al., 2006).

Stress fractures in metatarsal bones are micro-fractures caused by the load on the physiological boundary lines to the bones. Stress fractures in the foot are more commonly seen in runners, in sports branches requiring bounding action and in dancers. Stress fractures are most commonly seen in the second metatarsal head which is the longest metatarsal head and which bears most of the load in cases of abnormal loading. The proxymal diaphysis stress fracture in the fifth metatarsal head has different characteristics to other diaphysary metatarsal fractures. It is most commonly seen in overweight athletes. It is frequently accompanied by hidden or clear pes cavus deformity (Kılıçoğlu, 2009).

In recent years, with the popularization of new methods developed for the measuring pressure on the foot-sole, it has been possible to get a quantitative measurement of the load on metatarsal heads (Aydos, 2011; Hughes, Clark, Linge, & Klenerman, 1993; Luger, Nissan, Karpf, Steinberg, & Dekel, 1999; Uzun, 2012). Determination of the amount of load and pressure distribution on each metatarsus in healthy people will help determine the diagnosis and treatment programs for metatarsalgia (Eils et al., 2002). Also, it will facilitate the defining the different walking types; the explanation of mechanisms causing their formation, understanding the foot problems we face in the clinic and determination of treatment protocols (Kanatli et al., 2008). Despite the speed at which these methods are developed, the knowledge on the pressure distribution types on metatarsal heads is still a subject of discussion (Aydos, 2011; Kanatli et al., 2008; Kang et al., 2006; Queen, Haynes, Hardaker, & Garrett, 2007; Uzun, 2012)

Diabetes Mellitus, Rheumatoid Arthritis and Leprosy are the major disorders affecting the foot and emphasizing the importance of foot pressure measurements. The measurement of foot pressure distribution, prevention, treatment and rehabilitation of deformities which such disorders would cause in the foot and the provision of suitable shoes have gained importance (Patil, Thatte, & Chaskar, 2009).

Spiking and blocking actions in volleyball which involve bounding actively and directly affect the foot and the foot-sole of the athlete. Especially in professional athletes with their physical characteristics which develop in periods of 10 to 15 years, these actions are used more frequently in training exercises and in matches everyday.

The aim of the present study is to demonstrate the factors affecting the load borne by the metatarsal heads in volleyball players and to investigate the effect of volleyball on the foot-sole by comparing the contact area and maximal forces for various regions of the foot-soles of female volleyball players and healthy individuals during walking barefoot and by examining the common disorders in the foot and the foot-sole. This study further aims to measure the load applied on metatarsal heads in volleyball players and to contribute to the studies towards the use and development of shoes specially built for volleyball players.

Methods

The present study was approved by the Local Ethics Committee of the Faculty of Medicine, T.R. Gazi University (February 25, 2008; approval number 074 for non-pharmacological clinical studies).

The study included 27 professional female volleyball players who had no feet complaints (aged 23,0 ± 2,8years) and a control group of 28 female volunteers (aged 27,5 ± 1,4 years). The average age at which the sportsmen started volleyball players was found to be 11 years. Those with a foot disorder, a neurological disease affecting the movement system, a peripheral neuropathy; those who had a previous foot or ankle surgery; and those who had a previous fracture in this area were excluded from the present study.

Pedobarographic (sole pressure measurements) measurements of the study participants were performed using an EMED-SF (Novel GmbH, Munich, Germany) plantar pressure analysis system at the Gazi University Faculty of Medicine Department of Orthopedy and Traumatology walking laboratory. The system uses a 71 Hz sampling frequency; its dimensions are 44.4 × 22.5 cm; it includes two receptors per cm^2; and it is mounted on a wooden platform of 7 × 1 m and covered by a thin layer of leather.

The respondents walked freely on a 7-meter walking band before stepping on the pedobarograph and the area where the measurement was performed is not stated The measurements were performed with naked feet and two dynamic measurements were performed for each foot. The sole was divided into 11 areas, each of which was evaluated in terms of contact area (cm^2) and maximal force (N/cm) (Figure 1).

Statistical Evaluation

The data obtained was analyzed using SPSS software (Version 18). The two measurements of the experimental and control groups were averaged and the non-parametrical Mann Whitney-U test was used to test whether there was a statistically significant difference between the related averages. The extent of the linear relationship between physical structure and the variables for each sole measurement was examined by calculating the Pearson coefficient (r). A 95% reliability interval was used and the level of significance was accepted to be $P < 0.01 – 0.05$.

Results

The difference between age, height and BMI averages of the volleyball players and of the control group was found to be significant to the level of $P<0.01$. Based on this, while the age, body weight and body mass index of volunteers in the control group were higher, their average height was lower. (Table 1).

The difference between the averages in the comparison of total right-left feet levels and 11 contact areas for the female volleyball players and the control group on all the results weren't found significant ($P < 0.01$- 0.05). (Table 2)

The difference between the averages in the comparison of total right foot levels and maximal force on 11 contact areas for the female volleyball players and the control group, and the results for 2nd metatarsal head of right and left foot were found significant (**P**< 0.01-0.05) (Table 3).

The extent of the linear relationship between continuously measured variables was examined using Pearson's correlation coefficient (r) for categorical comparisons and significant positive and negative relationships were observed (0,01 ve 0,05) in comparisons of age, height, body weight, BMI and right-left foot contact areas and maximal power comparisons.(Table 4)

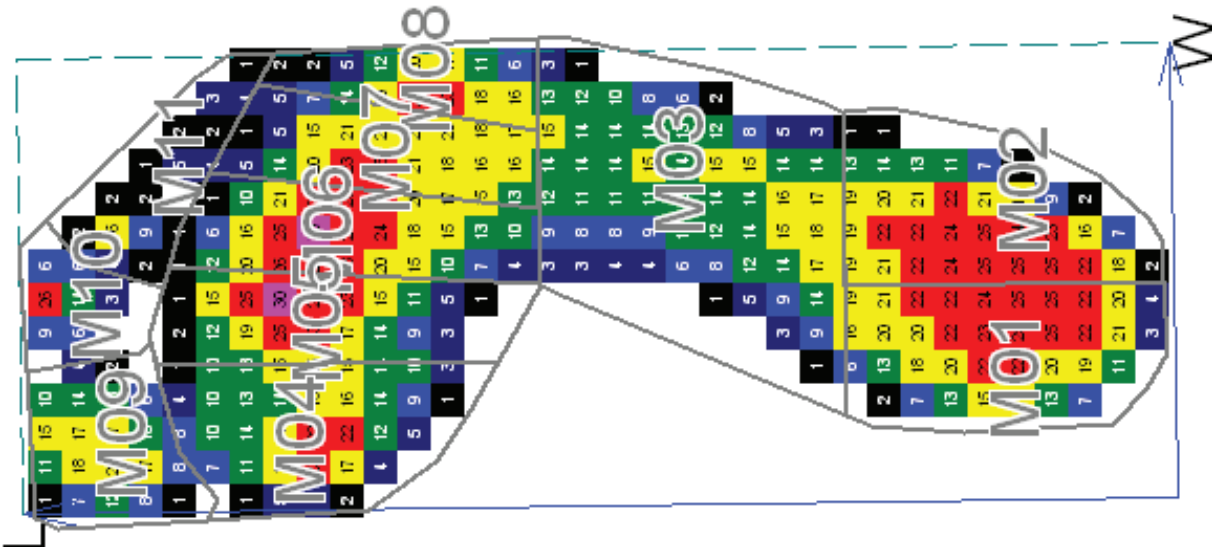

Figure 1. Mask areas in pedobaography (M01: medial of heel, M02: lateral of heel, M03: midfoot, M04: 1st metatarsal head, M05: 2nd metatarsal head, M06: 3rd metatarsal head, M07: 4th metatarsal head, M08: 5th metatarsal head, M09: pollex M10: 2nd finger, M11: 3rd 4th and fifth fingers).

Discussion

In our study, contact area and maximal forces of various foot-sole areas of the participating volleyball players were examined and compared with those of the control group consisting of healthy people. While the height and body mass index (BMI) for the participating volleyball players and the control group were found statistically significant, the difference between their body weights and ages was not found to be statistically significant. The study shows that the volleyball players are younger than the members of the control group. In consideration of the heights and body weights of the volleyball players and of the control group, the fact that the height levels of volleyball players are higher than those of the control group while their body weight levels are close to each other has caused the difference between their body mass indexes (BMI) to be statistically significant (Table 1).

Feet provide balance while standing, walking and running. Feet have five main functions. They are the basic support for the body, adaptable to flat, non-flat and rough surfaces with shock-absorbing ability while walking, and present the driving force and transverse plane leg rotation in the leverage. The loss of any of these functions is indicative of foot disorder and may be harmful for the person(Patil et al., 2009). An important aspect of the plantar pressure analysis is that it is capable of measuring the pressure distribution on various anatomical parts of the foot. During walking, high pressure takes place on the pollex, and a lower pressure takes place on the central parts of the foot(Bennett & Duplock, 1993). In studies dealing with mobility and balance parameters; it was demonstrated that the balance parameters of most people with walking dysfunctions were not normal (Cavanagh, Hewitt Jr, & Perry, 1992; Duncan, Chandler, Studenski, Hughes, & Prescott, 1993; Eils et al., 2004).

In comparison of 11 contact points of right and left soles of volleyball players and control group, difference between averages (Table 2) was in general lower in volleyball players, whereas no statistically significant difference was found.

In a study researching effect of basketball on the sole and examining ground contact areas of the foot, with respect to the differences between averages, it was reported that tip of 2nd and 3rd metatarsi of right foot, middle part of left foot, and tip of 2nd and 3rd metatarsi were smaller than in healthy subjects not doing sports, and that contact area of 2nd finger of left foot was smaller by 23.11% cm2 than in the control group (Uzun, 2013) . In a study conducted by Aydos in elite wrestlers, in comparison of 11 contact areas, he reported that the difference between averages in right heel medial, left heel lateral, tip of 3rd metatarsus of right foot was 11.18%, in tip of the 4th metatarsus was 11%, and in the tip of 5th metatarsus was 10.77% cm2 higher in the control group than in the wrestlers(Aydos, 2011).

Table 1. Physical Characteristics of Female Volleyball Players (1) and Control Group (2)

Variables	Gender	Art. Mean.	S.D	X1 - X2	Min.	Max	t.	P
Age (year)	1	23,00	2,828	4,00	19,00	27,00	122,000	**,093
	2	27,50	1,469		19,00	36,00		
Height (cm)	1	179,33	8,387	10,63	160,00	190,00	86,000	**,005
	2	168,70	2,443		157,00	187,00		
Weight (kg)	1	65,66	6,230	-1,04	57,00	78,00	166,000	,696
	2	66,70	2,075		53,00	80,00		
BMI (kg/m²)	1	20,41	1,252	3,15	18,30	22,30	76,000	**,002
	2	23,56	,819		19,73	31,25		

** P < 0.01 * P < 0.05

According to these results, it was seen that the volleyball sport did not lead to any increase or decrease in contact areas of the sole, and that foot contact areas of female volleyball players had similar values with the control group.

When compared the maximal force of the total of 11 contact areas of right and left feet in volleyball players and control group, it was found that the difference in averages for tip of 2nd metatarsus of right foot was 19.57%, and for tip of 2nd metatarsus of left foot was 5.30% higher in the control group than in volleyball players, and that the difference was statistically insignificant (Table 3).

In a study conducted on 40 healthy subjects (age 25.3, weight 70.8 and height 176.5 cm) using EMED-SF (Novel GmbH, Munich, Germany) plantar pressure analysis system, Eils et al. observed that while there was a similarity between peak pressure distribution results and those of those of the basketball players, they were lower in comparison to the results of the control group (Eils et al., 2002) . In the study researching the maximal force applied by the contact areas of foot sole in basketball players, it was reported that for tip of 1st metatarsus of right foot, it was 63.38%, for tip of 2nd metatarsus of left foot, it was 21.16%, for toe of right foot, it was 56.56% lower in basketball players than in subjects not doing sports, and for tip of 4th metatarsus of right foot, it was 29.97, for 2nd finger of left foot, it was 43.66% higher (Uzun, 2013). For wrestlers, it was found that for right foot total, it was 10.56%, for left foot total, it was 7.24%, for right heel medial, it was 30.44%, for tip of 2nd metatarsus of right foot, it was 27.75%, for tip of 2nd metatarsus of left foot, it was 19.47%, for tip of 5th metatarsus of left foot, it was 37.22% higher in the control group than in the wrestlers (Aydos, 2011).

Table 2: Comparison of Right and Left Feet Contact Areas of Female Volleyball Players (1) and Control Group (2) (cm2)

Variables	Group	Right Foot				Left Foot			
		Mean	S.D	Mann-Whitney U	P	Mean	S.D	Mann-Whitney U	P
foot- TOTAL	1	129,27	18,03	151,000	,396	135,35	21,94	148,000	,502
	2	136,3	16,96			130,62	18,54		
MO1: The medial part of heel	1	16,13	4,699	134,000	,177	17,61	2,74	164,500	,866
	2	17,97	2,452			17,55	2,480		
MO 2: The lateral part of heel	1	15,97	4,710	160,000	,558	17,58	2,00	145,500	,453
	2	17,17	2,202			17,27	2,185		
MO 3: midfoot	1	23,91	7,432	144,000	,292	26,58	9,31	142,500	,402
	2	26,40	8,433			24,02	10,03		
MO 4: The 1st metatarsal head of foot	1	11,86	3,184	150,000	,378	12,264	2,55	134,000	,270
	2	12,65	3,403			13,05	1,986		
MO 5: The 2nd metatarsal head of foot	1	9,63	3,018	140,000	,239	10,23	2,64	144,000	,426
	2	10,82	1,893			10,32	1,995		
MO 6 The 3rd metatarsal head of foot	1	10,72	1,926	122,000	,088	11,52	1,85	125,500	,172
	2	11,65	1,581			10,70	1,901		
MO 7: The 4th metatarsal head of foot	1	9,25	1,507	166,500	,689	9,76	1,26	129,000	,208
	2	9,22	,880			9,25	1,642		
MO 8: The 5th metatarsal head of foot	1	6,02	2,032	140,000	,239	6,61	1,08	134,000	,265
	2	6,70	,849			6,12	,901		
MO 9: pollex	1	10,47	3,362	175,500	,895	11,58	2,06	166,500	,915
	2	11,07	1,664			11,42	1,822		
MO 10: 2nd finger of foot	1	4,22	1,437	173,500	,848	3,97	1,69	167,500	,939
	2	4,50	1,589			3,77	1,34		
MO 11 : 3.4.5. fingers of foot	1	7,38	2,464	145,000	,304	7,50	2,21	143,000	,409
	2	8,07	2,875			7,05	2,714		

** $P < 0.01$ * $P < 0.05$

It was found that there was difference between female volleyball players and control group only in the tips of 2nd metatarsi (Figure 1: M05) of right and left feet, and that there were similar results in other parameters. It was reported in the studies (Aydos, 2011; Eils et al., 2002; Uzun, 2012, 2013) that particularly in several sports branches, there was difference in tips of 2nd metatarsi in both female and male athletes and in subjects not doing sport. This may be attributed to weight exercises to the M05 (Figure 1) site on soles, overloading in matches, and strength of particularly the upper extremities in the subjects doing sport. It was determined that the volleyball sport leads to less change in maximal pressure distributions of the sole than both basketball and wrest sports. The fact that this change is higher in basketball players and wrestlers and lower in volleyball players may stem from the gender difference in the studies conducted shouldn't be ignored.

In a study conducted on 22 people using 19 shoes of different models on different pressure sensors, the effects of the distribution of regional forces on the foot-sole on shoe production was examined. All of the shoes were high quality running shoes. Mechanical characteristics of the shoe was determined using a device measuring the pressure, and the pressure distribution and data on natural walks made at a speed of 3.3 m/sn were collected. It was seen that the pressure was increased more in medial foot sides than lateral in foot strikes on 22 models. In this study, the distribution of pressure inside the show was analyzed and the statistical relationships between shoe production and shoe-related complaints were determined (Hennig & Milani, 1995).

According to the study results, a linear and positive relationship was found between age, length, body weight, body mass index (BMI) and the contact area of right-left foot and maximal forces (0.01 and 0.05). Lowness of the pedobaragraphic records in the volleyball players may be attributed to age, BMI, and lower extremities' having a strong and durable balance. Moreover, differences were found in 11 contact areas on the sole, and in maximal force on several sites of right and left feet between volleyball players and control group. The reason of this is thought to

Table 3: Comparison of Right and Left Feet Maximal Forces of Female Volleyball Players (1) and Control Group (2) [N]

Variables	Group	Right Foot				Left Foot			
		Mean	S.D	Mann-Whitney U	P	Mean	S.D	Mann-Whitney U	P
foot- TOTAL	1	891,25	105,60	166,500	,693	886,91	105,24	166,500	,693
	2	888,20	124,28			890,56	123,47		
MO1: The medial part of heel	1	297,37	54,23	153,500	,438	292,61	52,13	153,500	,438
	2	288,67	43,96			321,66	68,46		
MO 2: The lateral part of heel	1	242,98	41,27	178,500	,965	260,01	46,00	178,500	,965
	2	249,05	46,63			267,95	55,75		
MO 3: midfoot	1	158,12	99,11	172,000	,815	175,48	93,46	172,000	,815
	2	153,57	80,27			140,38	110,37		
MO 4: The 1st metatarsal head of foot	1	140,20	77,03	163,500	,630	162,38	57,94	163,500	,630
	2	130,18	79,50			151,22	64,03		
MO 5: The 2nd metatarsal head of foot	1	174,84	44,81	109,000	,038*	189,68	38,42	109,000	,038*
	2	209,07	44,68			199,75	38,49		
MO 6 The 3rd metatarsal head of foot	1	191,50	66,46	159,000	,539	181,25	33,55	159,000	,539
	2	206,55	41,09			192,26	40,48		
MO 7: The 4th metatarsal head of foot	1	129,00	63,24	162,000	,599	111,28	28,83	162,000	,599
	2	130,50	36,00			129,86	33,64		
MO 8: The 5th metatarsal head of foot	1	86,90	48,91	159,500	,549	81,83	48,65	159,500	,549
	2	74,48	25,55			63,56	22,22		
MO 9: pollex	1	155,72	77,47	156,500	,492	164,93	66,54	156,500	,492
	2	132,71	57,46			135,26	51,26		
MO 10: 2nd finger of foot	1	32,72	10,58	154,500	,456	29,55	10,45	154,500	,456
	2	33,72	20,57			25,53	16,03		
MO 11: 3.4.5. fingers of foot	1	31,94	17,44	167,500	,715	34,93	22,48	167,500	,715
	2	35,13	21,91			27,20	19,09		

** $P < 0.01$ * $P < 0.05$

Table. 4: Correlation between Physical Structure and Foot-Sole Variables of Female Volleyball Players and Control Group (2)

Variables	Age		Heıght		Body Weıght		BMI	
	1	2	1	2	1	2	1	2
Right Feet Contact Areas Total	,380	,397	,723**	,058	,504*	,349	-,350	,262
	,119	,083	,001	,807	,033	,131	,155	,264
Left Feet Contact Areas Total	,201	,357	,736**	,007	,816**	,236	,002	,204
	,440	,123	,001	,977	,000	,315	,994	,389
Right Feet Maximal Forces Total	-,156	,471*	,649**	,204	,886**	,919**	,331	,703**
	,535	,036	,004	,389	,000	,000	,180	,001
Left Feet Maximal Forces Total	-,121	,424	,665**	,205	,940**	,876**	,286	,664**
	,668	,062	,007	,387	,000	,000	,301	,001

** P < 0.01 * P < 0.05

be that the basketball players use their feet much more actively and effectively than the control group. In a study titled "The interaction between wrestling shoes and wrestling mats", Newton et al.,(2002) examined the effect of sweat on the friction produced between wrestling shoes and a wrestling mat. The study examined the factors that help friction and the vertical and linear force occurring between the tap and wrestling mat surface were measured. The study evaluated variations in friction when using 3 different types of old and new shoes and 12 positions on new /old and wet/ dry wrestling mats. The friction coefficient was found to be 36% higher in the new mat than in the old mat and was found to be 23-28% lower in old shoes than in new shoes. The highest friction coefficient for a more secure grip (thereby reducing the risk of ankle and knee injury) was found when combining a new mat and a new shoe (Newton et al., 2002).

In a study where Fong et al. (2008) had 15 people wearing cloth shoes and evaluated the time-pressure integral with 10 testing walks on a walking road on a 5 m. long wood which were dry, sandy, wet and lubricated and compared 9 parts on the foot-sole for surfaces that are oily or not, while the peak pressure increased by 30% on the pollex, time-pressure integral increased by 79% and in the lateral fingers the increase was by 34%. Peak pressure on the medial and lateral heel decreased by 20-24%. During the walk on the lubricated surface, the peak pressure increased from outside to inside, and the time-pressure integral increased from inside to outside. Based on these results, it was demonstrated that peak pressure walking surface of the time-pressure integral can be affected by other variables (age, height, body weight) (Fong, Mao, Li, & Hong, 2008).

According to the results of this study conducted on female volleyball players and control group, in comparison of the measured age, length, body weight, body mass index, maximal force and contact area of right and left feet, it was seen that foot contact areas were similar, and with respect to the pressure applied to the sole, the maximal forces in tips of 2nd metatarsi of right and left feet of volleyball players was lower than in the control group. In comparison of pedobarographic records between the two groups, when reviewed the total results, it was seen that the results of both contact area and maximal force were insignificant (0.01 - 0.05), but that the results were higher for the control group. Based on the study results, it may be concluded that the wrestling sport caused more effects on the sole due to several reasons such as anatomical structure of the feet, body weight, foot movement range, feet's being more forced in several positions (Aydos, 2011) , that the basketball sport caused less effect on the contact areas (Uzun, 2012) and that the volleyball sport caused less change on the sole.

Conclusion

According to these results, it may be concluded that there is a correlation between the sport being done by female volleyball players and the variables of the sole, that the sport they do does not harm the sole, and that particularly the shoes they use are successful in supporting and protection the sole.

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Submitted: April 18, 2012.
Accepted: May 25, 2012.

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