

Full Length Research Paper

Effect of wrestling on the foot sole of elite wrestlers

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The present study investigated changes in the foot soles of wrestlers. The study compared 11 pedobarographic parameters of the contact area of the foot sole area, maximal force, peak pressure, average maximal pressure and time pressure integral of elite wrestlers and a control group comprised of healthy individuals. An EMED-SF (Novel GmbH, Munich, Germany) plantar pressure analysis system was used in the study. The non-parametrical Mann Whitney U Test was used to identify statistically significant variations between the average data values of the experimental and control groups; the extent of the linear relationship between the physical structure and foot sole variables was examined using the Pearson coefficient (r). In these measurements, reliability interval was accepted as 95% and the level of significance was $P < 0.01$ to 0.05 . Statistically significant results were obtained for the 2nd, 3rd and 5th metatarsal heads and total results, foot sole medial and lateral. The results of the control group were higher for age, height, weight, body mass index, right and left feet contact areas, maximal force, peak pressure, average maximal pressure and time pressure integral.

Key words: Wrestling, foot sole, pedobarography.

INTRODUCTION

Wrestling is one of the oldest sports played in Turkey. It has also gained importance among other forms of competition that combine other martial arts. Many martial artists began to identify themselves with wrestling or to include wrestling in their specialisms (www.tgf.gov.tr, 2008).

The factors related to wrestling injuries include the position of the foot soles of the feet, ankle foot strengthening, warm-up, loadings necessary for wrestling, position changes and injuries related to the wrestling mat and its periphery. The number of injuries sustained in wrestling is relatively high when compared with other National Collegiate Athletic Association (NCAA) sports. The frequency of injuries during the 2003 to 2004 academic year was 5 to 7 per 1000 among all sportsmen, compared with 6 per 1000 among high school student wrestlers (Grindstaff and Potach, 2006).

Among high school and college students, many injuries occur while throwing and falling downward, while in a position facing one another (Agelet et al., 2007; Boden et al., 2002; Jarrett et al., 1998; Pasque and Hewett, 2000). It was reported that the number of injuries was relatively high among wrestlers who defend while in a position facing one another (Boden et al., 2002; Pasque and

Hewett, 2000; Wrobif et al., 1986).

The most common injuries in wrestling are ankle twisting, shoulder rotator cuff injuries, knee side ligament injuries, neck injuries and facial skin injuries (Agel et al., 2007; Jarrett et al., 1998; Pasque and Hewett, 2000). The most common injuries are twisting, sprains, a tear in the cartilage of the ear and contusion-putrefaction. Most of the injuries occur while wrestlers are in contact with or in technical holds with each other (Agel et al., 2007; Yard et al., 2008; Jarrett et al., 1998; Park et al., 2009; Pasque and Hewett, 2000)

The most important and serious injuries occur in effective loading parts and during competitions. The highest risk of injury is when lifting a rival from the wrestling mat, turning on the mat, in unbalanced positions and while both arms are stretched (Boden et al., 2002; <http://www.unc.edu/depts/exercise/FRED/Chapter3PDF.pdf>, 2010).

The general design features of sports footwear vary according to the sport for which they are designed. Four main points should be considered in selecting wrestling footwear: the harmony between the shoe and the wrestling mat, the manufacturing techniques used in sporting footwear and its parts, size and suitability for the

feet. Wrestling shoes should be light and heelless and they should extend towards and protect the upper part of the ankle. Stoppages during matches are generally related to the shoe lacing system (Bubb, 2007).

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 to 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).

Wrestlers have a high risk of being injured on a wrestling mat. When an appropriate wrestling mat is used, the associated risks can be reduced (www.resilite.com 2010). The prevalence of ankle twists, first foot toe joint injuries and injuries resulting from repeated hypertension are similar to the levels reported in football (Hewett et al., 2005).

Metatarsalgia is related to repetitive loadings of metatarsal heads and is one of the most common foot disorders, both in the general population and in sport. The load that is borne by the metatarsal heads while walking varies from person to person (Kanatli et al., 2008). The causes of metatarsalgia can be listed as pes cavus, pes planus, hallux valgus, capsulitis, synovitis, periostitis, stress fractures, plantar plaque ruptures, neurinomas, callus, Freiberg disease, fat pad atrophy and flexor tendinitis. It is known that metatarsalgia is most frequently related to imbalances in load distribution and a load increase in metatarsal heads (Kang et al., 2006; Stokes et al., 1979).

Knowing the applied load per metatarsal head and the pressure distribution in healthy individuals helps the diagnosis and treatment of metatarsalgia. In addition, the identification of different walking styles helps explain the mechanisms resulting in these walking styles, understand the feet problems encountered in clinics and determine an appropriate treatment protocol (Kanatli et al., 2008).

Recently, developed methods of measuring foot sole pressure now allow quantitative measurement of the load per metatarsal head (Hughes et al., 1993; Luger et al., 1999). Foot pressure measurement is of great importance in terms of diabetes mellitus, rheumatoid arthritis and leprosy, which are the most common diseases that affect the feet. The measurement of feet pressure distribution and the use of appropriate shoes are important in the prevention, treatment and rehabilitation

of such disorders (Patil et al. 2009). Despite the rapid increase in the development of such devices, the data on the types of pressure distribution in metatarsal heads are still incomplete (Kanatli et al., 2008).

The present study examined the ways in which the feet of elite wrestlers differed from those of a healthy control group. The study used the following pedobarographic parameters: contact area of the foot sole area 11 maximal force, peak pressure, average maximal pressure and time pressure integral. The present study contributes to future studies on this subject, to the diagnosis and prevention of foot sole disorders and to the use of appropriate shoes in wrestling.

MATERIALS AND 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 national wrestlers who had no feet complaints (aged 21.90 ± 3.68 years) and a control group of 25 male volunteers (aged 26.10 ± 2.40 years). The average age at which the sportsmen started wrestling was found to be 12 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; those who had a previous fracture in this area were excluded from the present study.

Pedobarographic (foot 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 ; 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-m 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 foot 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 15). 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 foot 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 $P < 0.01$ and 0.05 .

RESULTS

The difference between the age and height averages of the wrestlers and the individuals in the control group was

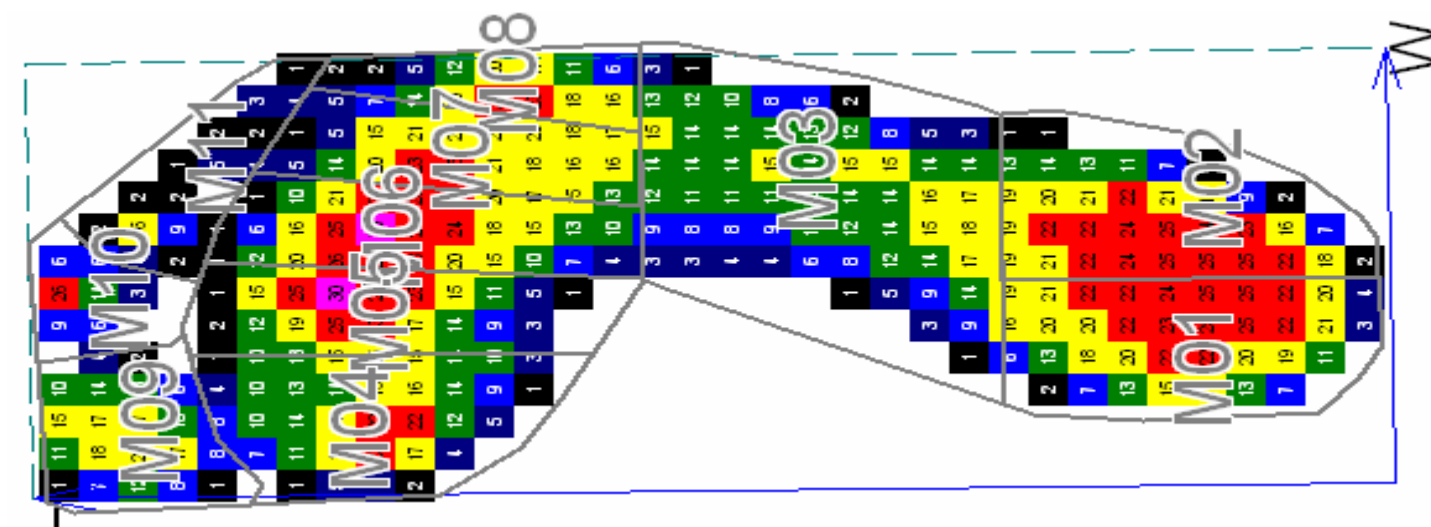


Figure 1. Mask areas in pedobaography (M01: medial of heel, M02: lateral of heel, M03: midfoot, M04: 1st metatarsal head, M05: 2nd metatarsal head, M06: 3rd metatarsal head, M07: 4th metatarsal head, M08: 5th metatarsal head, M09: pollex M10: 2nd finger, M11: 3rd 4th and fifth fingers).

Table 1. Physical characteristics of male wrestlers (1) and control group (2).

Variables	Gender	Art. mean.	S.D	X1 - X2	Min.	Max	t.	P
Age (year)	1	21.90	3.683	-4.20	18.00	31.00	60.000	0.000**
	2	26.10	2.403					
Height(cm)	1	175.10	7.447	-7.20	162.00	192.00	96.000	0.005**
	2	182.33	8.547					
Weight (kg)	1	81.10	14.02	-6.90	60.00	110.00	144.000	0.129
	2	88.00	14.05					
BMI (kg/m ²)	1	26.28	3.085	-0.309	19.11	32.28	172.00	0.448
	2	26.59	3.375					

**P < 0.01; * P < 0.05.

found to be statistically significant at the level of P < 0.01 (Table 1).

Accordingly, the age, height, weight and body mass index of the volunteers in the control group were higher. There was a statistically significant difference between the wrestlers and the control group when comparing average data values for the right and left feet total and 11 contact areas, the results related to the right foot heel medial and lateral and right foot 3rd, 4th and 5th metatarsal heads (P < 0.01 to 0.05) (Table 2).

There was a statistically significant difference between the wrestlers and the control group when comparing average data values for the right foot total and maximal

force of the 11 contact areas, right foot total, right heel medial, right and left feet 2nd metatarsal head, left foot 5th metatarsal head (P < 0.01 to 0.05) (Table 3).

A statistically significant difference between the wrestlers and the control group was noticed when comparing average data values for the right and left feet total and 11 contact areas peak pressure and the results of left foot total, right and left heel medial and heel lateral, right and left feet 2nd, 3rd and 5th metatarsal heads (P < 0.01 to 0.05) (Table 4).

Furthermore, a statistically significant difference between the wrestlers and the control group when comparing average data values for the right and left feet

Table 2. Comparison of right and left feet contact areas of wrestlers (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	159.56	16.64	237.000	0.212	158.53	17.93	230.500	0.226
	2	164.35	16.85			160.35	16.73		
MO1: the medial part of heel	1	20.10	2.114	204.500	0.057*	20.77	2.684	227.500	0.201
	2	21.10	2.204			21.10	1.895		
MO 2: the lateral part of heel	1	19.80	2.354	197.000	0.041*	20.01	2.677	197.000	0.058
	2	20.92	2.369			21.17	2.312		
MO 3: mid foot	1	34.51	5.725	274.500	0.613	33.24	4.575	288.500	0.976
	2	32.25	8.346			32.17	8.352		
MO 4: the 1st metatarsal head of foot	1	15.65	2.519	277.500	0.655	15.12	2.214	249.000	0.402
	2	15.77	2.478			15.65	1.828		
MO 5: the 2nd metatarsal head of foot	1	12.21	1.730	228.000	0.151	12.39	2.127	276.000	0.775
	2	12.95	1.700			12.17	1.914		
MO 6 the 3rd metatarsal head of foot	1	12.70	2.023	141.000	0.002**	13.13	2.243	229.500	0.215
	2	14.12	1.467			13.67	1.515		
MO 7: the 4th metatarsal head of foot	1	10.53	1.467	155.000	0.004**	11.08	1.793	236.500	0.271
	2	11.70	.879			11.35	.727		
MO 8: the 5th metatarsal head of foot	1	7.33	1.061	166.000	0.007**	7.32	1.465	224.500	0.179
	2	8.12	.723			7.87	.958		
MO 9: pollex	1	12.41	2.349	234.000	0.190	12.63	2.298	211.500	0.109
	2	13.57	2.838			13.45	2.181		
MO 10: 2nd finger of foot	1	4.63	1.265	281.000	0.704	4.68	1.012	236.000	0.265
	2	4.75	1.261			4.32	.949		
MO 11 : 3.4.5. fingers of foot	1	8.95	2.408	262.000	0.451	8.03	2.478	251.500	0.432
	2	9.05	4.189			7.37	3.516		

** P < 0.01; * P < 0.05.

total and 11 contact areas, average maximal pressure of the wrestlers and the control group and the results of right and left feet total, right and left heel medial and 2nd, 3rd and 5th metatarsal heads (P < 0.01 to 0.05) (Table 5).

The differences between the average data values for the right and left feet total and 11

contact areas, time pressure integral of the wrestlers and the control group and the results of right foot heel medial and 2nd and 3rd metatarsal heads and left foot 5th metatarsal head were found to be statistically significant (P < 0.01 to 0.05) (Table 6).

The extent of the linear relationship among the

continuously measured variables was examined by calculating Pearson's correlation coefficient (r) for categorical comparisons; statistically significant and positive relationships were found at the level of 0.01 and 0.05 when comparing age, height, weight, BMI and right and left feet contact areas, maximal force, peak pressure, average

Table 3. Comparison of right and left feet maximal forces of wrestlers (1) and control group (2).

Variables	Group	Right foot				Left foot			
		Mean	S.D	Mann-Whitney U	P	Mean	S.D	Mann-Whitney U	P
Foot- total	1	1040.84	149.7	203.000	0.050*	1091.5	154.6	226.000	0.193
	2	1150.83	179.6			1170.0	176.2		
MO1: The medial part of heel	1	328.80	69.51	124.000	0.000**	360.21	97.65	200.000	0.067
	2	428.90	97.55			431.86	120.2		
MO2: The lateral part of heel	1	298.56	47.80	221.000	0.118	318.87	60.90	277.000	0.791
	2	336.77	77.50			328.80	71.72		
MO 3: mid foot	1	216.42	63.89	231.000	0.172	210.15	72.3	243.000	0.339
	2	180.67	68.59			185.48	75.06		
MO4: The 1st metatarsal head of foot	1	179.25	75.59	236.000	0.205	185.06	78.55	272.000	0.714
	2	213.23	84.63			194.73	69.48		
MO5: The 2nd metatarsal head of foot	1	203.49	49.00	130.000	0.001**	211.48	42.05	175.000	0.019*
	2	259.96	54.69			252.66	64.21		
MO6: The 3rd metatarsal head of foot	1	232.83	45.61	229.500	0.163	242.54	50.34	207.000	0.091
	2	251.36	57.72			270.46	64.14		
MO7: The 4th metatarsal head of foot	1	159.01	48.07	288.000	0.812	169.77	59.39	282.000	0.871*
	2	157.65	40.41			166.91	47.33		
MO8: The 5th metatarsal head of foot	1	78.23	39.29	240.500	0.239	76.57	36.15	191.500	0.045
	2	84.90	27.96			105.07	48.30		
MO 9: pollex	1	174.72	54.67	297.500	0.961	182.64	71.69	264.500	0.604
	2	185.81	91.35			197.21	85.40		
MO 10: 2nd finger of foot	1	34.96	17.17	275.000	0.620	36.46	15.68	223.000	0.173
	2	39.01	21.93			29.50	13.05		
MO 11 : 3.4.5. fingers of foot	1	41.67	27.68	268.500	0.533	37.56	25.62	216.500	0.135
	2	49.40	36.48			28.20	22.55		

** P < 0.01; * P < 0.05.

Table 4. Comparison of right and left feet peak pressure of wrestlers (1) and control group (2).

Variables	Group	Right foot (N/cm ²)				Left foot (N/cm ²)																																																																																																																																																																			
		Mean	S.D	Mann-Whitney U	P	Mean	S.D	Mann-Whitney U	P																																																																																																																																																																
Foot- total	1	60.61	22.73	232.000	0.178	59.67	23.56	184.500	0.032*																																																																																																																																																																
	2	70.52	26.29			76.35	25.77			MO1: The medial part of heel	1	34.18	5.973	117.000	0.000**	35.31	6.606	151.500	0.005**	2	46.37	13.96	46.40	16.59	MO 2: The lateral part of heel	1	33.91	6.679	143.000	0.002**	34.24	5.728	185.500	0.033*	2	41.87	10.00	39.20	7.836	MO 3: mid foot	1	15.83	4.558	282.500	0.729	15.32	4.007	288.500	0.976	2	15.02	4.697	15.05	4.260	MO4: The 1st metatarsal head of foot	1	31.00	15.72	279.500	0.685	30.43	17.47	269.500	0.676	2	35.25	22.91	29.72	13.91	MO5: The 2nd metatarsal head of foot	1	37.28	8.73	87.000	0.000**	36.98	7.253	143.500	0.003**	2	65.25	27.53	60.35	29.45	MO6: The 3rd metatarsal head of foot	1	39.23	8.442	162.000	0.006**	39.74	6.543	157.500	0.007**	2	49.00	13.23	55.60	21.42	MO7: The 4th metatarsal head of foot	1	31.06	10.09	265.000	0.488	31.70	9.542	290.000	10.000**	2	28.67	5.624	32.82	10.43	MO8: The 5th metatarsal head of foot	1	24.93	20.09	194.000	0.036*	22.31	11.95	130.000	0.001	2	28.50	10.36	40.85	25.30	MO 9: pollex	1	49.83	26.78	240.000	0.235	46.82	28.70	257.500	0.508	2	41.67	21.33	48.55	24.02	MO 10: 2nd finger of foot	1	20.46	12.01	292.000	0.874	19.06	8.407	274.000	0.745	2	21.12	12.98	18.27	8.836	MO 11 : 3.4.5. fingers of foot	1	12.38	7.135	280.500	0.699	12.96	7.986	225.000	0.186
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** P < 0.01; * P < 0.05.

Table 5. Comparison of right and left feet average maximal pressure of wrestlers (1) and control group (2).

Variables	Group	Right foot				Left foot			
		Mean	S.D	Mann-Whitney U	P	Mean	S.D	Mann-Whitney U	P
Foot- total	1	15.59	2.340	176.000	0.020*	15.99	2.906	176.000	0.020*
	2	17.22	2.905			17.69	3.112		
MO1:The medial part of heel	1	19.41	2.703	188.000	0.038*	20.74	4.039	188.000	0.038*
	2	23.97	4.335			23.97	5.665		
MO2: The lateral part of heel	1	17.90	2.357	275.000	0.760	19.19	3.090	275.000	0.760
	2	19.94	3.745			19.19	3.434		
MO 3: midfoot	1	6.90	1.714	244.000	0.349	6.84	2.101	244.000	0.349
	2	6.05	1.522			6.07	1.640		
MO4:The 1st metatarsal head of foot	1	13.44	5.072	258.500	0.522	13.93	4.993	258.500	0.522
	2	15.88	6.619			14.56	4.396		
MO5:The 2nd metatarsal head of foot	1	20.83	4.813	144.000	**0.003	21.28	4.095	144.000	0.003**
	2	28.64	7.638			28.78	9.509		
MO6:The 3rd metatarsal head of foot	1	21.35	2.978	164.000	**0.010	22.05	3.879	164.000	0.010**
	2	23.15	4.255			26.65	7.704		
MO7: The 4th metatarsal head of foot	1	15.39	3.896	278.000	0.807	15.79	4.538	278.000	0.807
	2	14.64	2.893			16.15	4.693		
MO8: The 5th metatarsal head of foot	1	11.41	5.830	178.000	0.023*	10.91	4.251	178.000	0.023*
	2	11.38	3.170			14.83	6.432		
MO 9: pollex	1	15.84	4.215	281.000	0.855	16.12	5.160	281.000	0.855
	2	14.91	4.740			16.34	4.766		
MO10: 2nd finger of foot	1	8.29	3.074	241.000	0.319	8.77	2.987	241.000	0.319
	2	9.44	3.764			7.74	2.898		
MO11:3.4.5. fingers of foot	1	5.11	2.457	231.000	0.230	5.11	2.749	231.000	0.230
	2	5.54	2.970			4.18	1.951		

** P < 0.01; * P < 0.05.

Table 6. Comparison of right and left feet time pressure integral of wrestlers (1) and control group (2).

Variables	Group	Right foot				Left foot			
		Mean	S.D	Mann-Whitney U	P	Mean	S.D	Mann-Whitney U	P
Foot- total	1	23.84	9.879	207.000	0.066	24.80	8.486	215.000	0.127
	2	27.22	8.740			27.70	8.469		
MO1: The medial part of heel	1	8.84	1.464	197.000	0.041*	9.53	1.953	272.500	0.722
	2	10.69	3.304			10.54	5.226		
MO 2: The lateral part of heel	1	8.88	1.880	223.500	0.130	9.31	1.716	212.000	0.113
	2	9.86	2.474			9.05	3.071		
MO 3: mid foot	1	5.34	1.977	261.500	0.446	5.33	1.572	225.000	0.186
	2	4.78	1.755			4.51	1.597		
MO4: The 1st metatarsal head of foot	1	8.82	5.192	246.000	0.285	8.62	3.953	287.500	0.959
	2	10.08	5.804			8.43	3.387		
MO5: The 2nd metatarsal head of foot	1	11.57	2.584	151.000	0.003**	10.98	2.334	162.500	0.009*
	2	16.42	5.834			15.93	6.309		
MO6: The 3rd metatarsal head of foot	1	12.27	2.287	184.500	0.022*	12.00	2.212	169.000	0.014*
	2	14.46	3.957			15.76	5.548		
MO7: The 4th metatarsal head of foot	1	9.61	2.334	244.500	0.272	9.37	2.425	264.500	0.604
	2	9.09	2.564			10.25	3.445		
MO8: The 5th metatarsal head of foot	1	7.66	3.924	276.500	0.642	6.80	2.895	163.000	0.010**
	2	7.82	2.804			10.29	5.769		
MO 9: pollex	1	11.8	12.26	277.500	0.656	12.90	11.63	247.000	0.382
	2	11.0	7.306			11.55	5.220		
MO10: 2nd finger of foot	1	4.33	2.101	291.500	0.866	4.41	2.745	280.000	0.839
	2	4.94	3.711			4.02	2.164		
MO11: 3.4.5. fingers of foot	1	3.25	1.915	293.000	0.890	3.61	4.085	241.500	0.324
	2	3.42	2.612			2.45	1.788		

** P < 0.01; * P < 0.05.

maximal pressure and time pressure integral (Table 7).

DISCUSSION

The present study analyzed the contact areas of various parts in the foot sole of the foot, maximal force, peak pressure, average maximal force and time pressure integral parameters, and compared the findings in elite wrestlers to those of a healthy control group of non-wrestlers.

The feet enable balance during standing, walking and running and have 5 main functions: they support the body; they accommodate to smooth and rough ground; they serve the body as a shock absorber during walking; they prevent propellant power and transverse leg rotation in crank. The loss of one of these functions might be an indicator of a disorder originating in the feet and might be dangerous for the person (Patil et al., 2009).

While the difference between the age and height of the wrestlers included in the study was found to be statistically significant, the difference between their body weights and body mass indexes was not found to be statistically significant. The wrestlers included in the study from the national under-19 team and they are younger than participants in the control group. When the height and body weights of the wrestlers and the control group were analyzed, it was seen that the height and weight increase were in direct proportion. Since the height and weight of the wrestlers and the control group are similar to each other, there is no difference in their body mass indexes.

Statistically significant variations were found between the wrestlers and the control group in terms of the average right and left feet 11 contact areas and the difference between right foot heel medial and lateral and right foot 3rd, 4th and 5th metatarsal heads. It was seen that in the control group, right heel medial was 4.74% higher than the wrestler group, while left heel lateral was 5.35% higher. The right foot 3rd metatarsal head of the control group was found to be 11.18% higher, the 4th metatarsal head of the right foot was found to be 11.00% higher and the 5th metatarsal head of the right foot was found to be 10.77% higher when compared with those of the wrestlers.

It can be suggested that this is because the age average of the control group was higher than that of the wrestlers and their body weights were 7.95% higher than the wrestlers (Birtane and Tuna, 2004). It can be suggested that a larger contact area of the metatarsal heads is an indicator of a collapse in the lateral longitudinal arch.

The difference between the average data values between the right foot total and 11 contact areas maximal forces of the wrestlers and the control group was found to be 10.56% higher in right foot total, 7.24% higher in left

foot total, 30.44% higher in right heel medial, 27.75% higher in the right foot 2nd metatarsal head, 19.47% higher in the left foot 2nd metatarsal head and 37.22% higher in the left foot 5th metatarsal head when compared with the wrestlers.

In previous studies on mobility and balance parameters, it was found that many balance parameters differ from normal values in individuals whose walking functions are defective (Duncan et al., 1993).

The difference between the average data values for the right and left feet total and 11 contact areas peak pressure of the wrestlers and the control group was found to be 27.95% higher in left foot total, 35.66% higher in right foot medial, 31.40% higher in left foot heel medial, 75.00% higher in the right foot 2nd metatarsal head, 63.19% higher in the left foot 2nd metatarsal head, 24.90% higher in the right foot 3rd metatarsal head, 39.90% higher in left foot 3rd metatarsal head, 14.32% higher in right foot 5th metatarsal head and 83.10% in left foot 5th metatarsal head compared to the wrestlers. Eils et al. (2002) reported a similarity between the distribution results of the wrestlers and the peak pressure distribution results in a study using an EMED-SF plantar pressure analysis system with 40 healthy people (aged 25.3 ± 3.3 years; weight 70.8 ± 10.6 kg and height 176.5 ± 7.8 cm), while the results of the experimental group were found to be lower when compared with those of the control group (Eils et al., 2002).

There is a high statistical difference between the peak pressure values of the wrestlers and the control group. The distribution of pressure across the foot sole of the foot can be affected by various factors such as the anatomical structure of the feet, body weight, sex and feet movement width. Very young children may have different pressure-related characteristics, as they have different muscle and skeletal structures. The age difference between the wrestlers in the present study and the control group may be one of the causes of this variation (Bennett and Duplock, 1993).

The difference between the average data values for the right and left feet total and 11 contact areas average maximal pressure of the wrestlers and the control group was found to be 10.45% higher in right foot total, 10.63% higher in left foot total, 23.49% higher in right foot heel medial, 15.57% higher in left foot heel medial, 37.49% higher in right foot 2nd metatarsal head, 35.24% higher in left foot 2nd metatarsal head, 8.43% higher in right foot 3rd metatarsal head, 20.86% higher in left foot 3rd metatarsal head and 35.93% higher in left foot 5th metatarsal head when compared with the wrestlers.

An important purpose of a plantar pressure analysis is determining the distribution of pressure on various anatomical parts of the foot. While walking, high pressure occurs in toes and lower pressure occurs in the middle parts of the foot (Bennett and Duplock, 1993). In previous studies of adults, this pattern of pressure distribution was

Table 7. Correlation between physical structure and foot-sole variables of wrestlers (1) and control group (2).

Variables	Age		Height		Body weight		BMI	
	1	2	1	2	1	2	1	2
Right feet contact areas toplami	0.788** 0.000	-0.208 0.379	0.666** 0.001	0.603** 0.005	0.788** 0.000	0.374 0.105	0.666** 0.001	-0.028 0.906
Left feet contact areas total	0.848** 0.000	-0.204 0.389	0.558* 0.013	0.626** 0.003	0.848** 0.000	0.393 0.086	0.558* 0.013	-0.022 0.928
Right feet maximal forces total	0.460(*) 0.041	0.468* 0.037	0.872** 0.000	0.476* 0.034	0.460* 0.041	0.920** 0.000	0.872** 0.000	0.747** 0.000
Left feet maximal forces total	0.255 0.291	0.393 0.086	0.698** 0.001	0.413 0.070	0.255 0.291	0.931** 0.000	0.698** 0.001	0.814** 0.000
Right feet peak pressure total	-0.299 0.200	0.006 0.981	0.013 0.958	0.387 0.091	-0.299 0.200	0.639** 0.002	0.013 0.958	0.484* 0.031
Left feet peak pressure total	-0.085 0.730	0.176 0.457	0.393 0.096	0.426 0.061	-0.085 0.730	0.675** 0.001	0.393 0.096	0.555* 0.011
Right feet average maximal pressure	-0.514* 0.020	0.484* 0.031	0.145 0.543	-0.094 0.694	-0.514* 0.020	0.499* 0.025	0.145 0.543	0.678** 0.001
Left feet average maximal pressure	-0.396 0.093	0.160 0.501	0.122 0.618	0.102 0.670	-0.396 0.093	0.559* 0.010	0.122 0.618	0.637** 0.003
Right feet time pressure integra	0.106 0.656	0.105 0.660	0.322 0.166	0.370 0.108	0.106 0.656	0.686** 0.001	0.322 0.166	0.560* 0.010
Left feet time pressure integra	-0.117 0.634	0.287 0.220	0.305 0.203	0.446* 0.049	-0.117 0.634	0.801** 0.000	0.305 0.203	0.659** 0.002

** P < 0.01; *P < 0.05.

reported to be quite similar (Cavanagh et al., 1992). This was also observed in the results of the present research. There is a strong statistical relationship between maximal pressure increase on the foot sole of the foot and too much body swing, poor balance, weakening and deformation in the sensual functions of lower members and old age (Lord et al., 1992; Sorock and Labiner, 1992). From this perspective, it is probable that the average maximal pressure values of the control group members are higher when compared with those of national wrestlers.

Feet pressures and changes in pressure areas, which are caused by the unbalanced anatomical positions, are among the reasons of the physiological disorders developing in human body and muscle and joint system. Spinal disorders are directly related to these continuously

repeating abnormal effects and a direct relationship was found between an increased level of scoliosis and an increase in pressure on various parts the foot sole (Park et al., 2009).

Within the control group, the difference between the average data values for the right and left feet total and time pressure integral of the 11 contact areas was found to be 20.92% higher in right foot heel medial, 41.91% higher in right foot 2nd metatarsal head, 45.08% higher in left foot 2nd metatarsal head, 17.84% higher in right foot 3rd metatarsal head, 31.33% higher in left foot 3rd metatarsal head and 51.32% higher in left foot 5th metatarsal head when compared with the wrestlers. Fonga et al. (2008) evaluated pressure time integral for 15 persons wearing cloth shoe in four contaminated conditions (dry, sand, water and oil). Each participant

undertook 10 trial walks on a 5-m long surface. The results were compared with 9 areas of a foot sole when walking on slippery (oil) and non-slippery (dry, sandy, wet) surfaces. They found that peak pressure increased 30% in the toes, while pressure time integral increased 79% and 34% in lateral fingers on oil surface. The peak pressure in medial and lateral heel decreased by 20 to 24%, while walking on an oily surface, peak pressure increased from outer parts to inner parts while pressure time integral increased from inner parts to outer parts. These results and the results of the present study show that the peak pressure walking surface of pressure time integral can be affected by other variables (such as age, height and weight) (Fonga et al., 2008).

According to the results of the present study, a linear and positive relationship was found in the comparisons made between age, height, weight, body mass index and right and left feet contact areas, maximal force, peak pressure, average maximal pressure and time pressure integral ($P < 0.01$ and 0.05). The results of the present study showed that there is a statistically significant relationship between right foot and left foot total contact areas and physical characteristics of wrestlers, while it showed that there is a statistically significant relationship between the control group and their physical characteristics in other parameters.

Birtane and Tuna (2004), conducted research on obese and non-obese adults using a pedobarographic method and found a positive statistical relationship between body mass index and total plantar force ($r = 0.50$, $P = 0.000$) and total contact area ($r = 0.33$, $P = 0.019$). These results are similar to the results of the present study.

Conclusion

According to the results of the present study on wrestlers and a healthy control group, the control group values are higher than those of the experimental group in terms of age, height, body weight, body mass index, right and left feet contact areas, maximal force, peak pressure, average maximal pressure and time pressure integral. Statistically significant differences were found in the pedobarographic records of both groups between total results, foot sole medial and lateral and 2nd, 3rd and 5th metatarsal heads ($P < 0.01$ to 0.05).

The reason why the pedobarographic data values are lower in wrestlers is that their ages, weights and the rate of body swinging are lower; their sub members are powerful; their sensory functions are good and they have good balance.

According to these results, it can be said that the elite wrestlers included in the present study do not show significant differences or abnormalities in the foot sole and the experimental group is healthier and in a better condition than the control group.

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