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Examination of the Correlation Between Foot Biomechanics, Plantar Pressure and Balance in Adolescent Volleyball Players

Adölesan Voleybol Oyuncularında Ayak Biyomekaniği ve Plantar Basınç ile Denge Arasındaki İlişkinin İncelenmesi

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ABSTRACT

Objective: To investigate the relationship between foot biomechanics and pedobarographic evaluation with balance in adolescent male volleyball players.

Method: Total of 36 male athletes of adolescent age (average 16.16±1.52 years) who played volleyball in the youth team of the Halkbank Sports Club were included in the study. Demographic information and physical characteristics (age, height, weight and sports age) of the athletes were recorded. The foot biomechanical evaluation of the athletes was recorded with the navicular drop test, metatarsal width, subtalar joint angle and hallux valgus angle. Balance values were recorded using the Biodex Balance Stability System (Biodex Medical Systems, Shirley, NY, USA). Anterior / Posterior Balance Index, Total Balance Index and Medial / Lateral Balance Index values were recorded. In the evaluation of plantar pressure errors and surface contact errors during walking were recorded using freemed® (Sensor Medica Inc., Rome, Italy) pedobarographic device. The data were evaluated using the SPSS 22.0 package program. The relationship between independent variables with each other was analyzed by Spearman Correlation Analysis. The statistical significance level was accepted as $p < 0.05$.

Results: As a result of our study, it was found that there was no relationship between foot biomechanical values and balance ($p > 0.05$). When the relationship between the athletes' plantar pressure distribution values and their balance measures was investigated, it was discovered that some pressure distribution values and balance values were related. ($p < 0.05$).

Conclusions: According to the results obtained from the study, it was seen that the plantar pressure was related with balance. We think that it is important to perform foot plantar pressure distribution analysis in terms of both improving the balance performance of athletes and preventing foot injuries. We believe that the training programs to be organized with the applications for the changes in the plantar pressure distribution can be more effective for the athletes.

Keywords: Foot Biomechanics, Adolescent, Postural Control, Volleyball

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ÖZET

Amaç: Erkek adölesan voleybol oyuncularında ayak biyomekaniği ve plantar basınç dağılımı ile denge arasındaki ilişkinin incelenmesidir.

Materyal-Metod: Çalışmamıza Halkbank Spor Kulübü alt yapılarında voleybol oynayan, adölesan yaşta (ortalama 16,16±1,52 yıl) olan 36 erkek sporcu dahil edildi. Sporcuların demografik bilgileri ve fiziksel özellikleri (yaş, boy, kilo ve spor yaşı) kaydedildi. Sporcuların ayak biyomekaniği değerlendirmesinde navikular düşme miktarı, metatars genişliği, subtalar eklem açısı ve halluks valgus açısı kaydedildi. Denge değerlendirmesinde Biodex Denge Stabilite Sistemi (Biodex Medical Systems, Shirley, NY, USA) kullanıldı. Anterior/Posterior Denge indeksi, Toplam Denge indeksi ve Medial/Lateral Denge indeksi değerleri kaydedildi. Plantar basınç dağılımı değerlendirmesinde, yürüyüş sırasında gerçekleştirilen ağırlık dağılım hataları ve yüzeysel dağılım hataları freemed® (Sensor Medica Inc., Rome, Italy) pedobarografi cihazı kullanılarak kaydedildi. Veriler SPSS 22.0 paket programı ile bağımsız değişkenlerin birbiri ile ilişkisi Spearman Korelasyon Analizi ile değerlendirildi. İstatistiksel anlamlılık düzeyi $p<0,05$ kabul edildi.

Bulgular: Çalışmamız sonucunda ayak biyomekanik değerleri ile denge arasında ilişki olmadığı tespit edildi ($p>0,05$). Sporcuların plantar basınç dağılımı değerleriyle denge ölçümleri arasındaki ilişki incelendiğinde, bazı basınç dağılım değerleriyle denge değerleri arasında ilişki olduğu belirlendi ($p<0,05$).

Sonuç: Çalışmadan elde edilen sonuçlara göre plantar basınç dağılımının denge ile ilişkili olduğu görüldü. Sporcuların gerek denge performanslarının geliştirilmesi gerekse de ayak yaralanmaların önlenmesi açısından ayak plantar basınç dağılımı analizlerinin yapılmasının önemli olduğunu düşünmekteyiz. Ayakta meydana gelebilecek plantar basınç dağılım değişikliklerine neden olabilecek faktörlerin belirlenmesi ve bunlara yönelik uygulamalar ile düzenlenecek antrenman programlarının, sporcular açısından daha etkili olabileceği kanaatindeyiz.

Anahtar Kelimeler: Ayak Biyomekaniği, Adölesan, Postüral Kontrol, Voleybol

1. Introduction

Volleyball is a sport played as a team, where explosive force is needed, sudden and repeated jumps, spikes and blocking are made. In addition, in counter-team attacks, rapid movements are applied in the short area for effective defense [1]. For these reasons, it is a discipline of sports in which strength, anaerobic strength, agility, speed, balance and proper ground contact should be provided from the sportive performance values of the athletes. Although there is a net between the teams, repetitive jumping activities, impact with a teammate, stepping on the feet of the opposing team athlete, biomechanical disorders and repetitive movements lead to acute and chronic injuries [2-3]. Insufficient sense of foot balance and biomechanical disorders cause athletes to have acute ankle injuries and injuries to the knee, hip and waist regions together with kinetic chain force transfer [3]. For this reason, it is extremely important to have the correct biomechanical alignment of the foot in terms of preventing injuries [3-5].

Ankle and foot joints play an active role during the transportation of body weight and maintaining dynamic and static balance. The movements of these joints in all planes must adapt to the minimal displacement of the center of gravity. This adaptation can only be achieved with normal foot structure and adequate balance [6]. Balance is formed by the smooth and coordinated work of neuromuscular structures with feedback from visual, vestibular and somatosensory structures. Balance in volleyball players has an important place for athletes' game performance and protection from injuries [7]. In terms

of somatosensory aspects, the correct obtaining of the plantar pressure sensation is extremely important for the effective functioning of the somatosensory senses [8].

Biomechanical changes in the foot can alter the plantar pressure distribution of the foot. Changes in foot plantar pressure may also cause changes in foot biomechanics [9]. In changes in foot biomechanical values such as pes planus, pes cavus, congenital deformities of the foot and other lower extremity disorders, pedobarographic measurements are used to guide the recovery of foot health. In addition to this, pedobarographic measurements are widely used to investigate normal foot mechanics [10].

To our knowledge, although biomechanical changes and plantar pressure changes have been investigated, there is no study examining the relationship between balance and plantar pressure on adolescent volleyball athletes. We conducted this study with the hypothesis that changes in foot biomechanics and foot plantar pressures may have an effect on balance. The aim of our study is to examine the relationship between foot biomechanics and plantar pressure distribution with balance in male adolescent volleyball athletes.

2. Material and Method

The study was conducted with the decision of Ankara Yıldırım Beyazıt University Ethics Committee numbered 73 and dated 27.12.2019. The research was carried out according to the Helsinki Declaration. The study was conducted in Halkbank Sports Club training hall.

Participants

Forty-two male athletes aged between 14-18 years who play volleyball in the young team of the professional volleyball team and volunteered for all evaluations were screened for eligibility for the study. Athletes with a history of foot and ankle injuries and any foot deformities in the last six months were not included in the study. In addition, athletes who wanted to quit the study at any point in the evaluations were excluded from the study. Verbal and written information was given to all athletes and their families prior to the evaluations and written and verbal consents of both the athletes and their families were obtained.

Evaluation

Demographic information and physical characteristics; age (years), height (cm), weight (kg), age (years), dominant extremity, history of injuries and existing injuries and surgical operations of athletes were recorded. All the following assessments were performed barefoot.

Foot Biomechanical Evaluation

Hallux Valgus Angle: The angle between the proximal phalanx and the long axes of the 1st metatarsal was measured from the upper dorsal part of the foot with a goniometer and recorded in degrees. The pivot point of the goniometer was placed in the 1st metatarsophalangeal joint; one arm was placed parallel to the 1st metatarsal bone and the other arm was parallel to the proximal phalanx, and the measurement was performed [11].

Navicular Drop Test: The value obtained by subtracting the navicular height measured by weight on the foot while standing from the navicular height measured without weight on the foot in the sitting position was recorded. The navicular tubercle, which was felt by palpation about 2 cm in front of and below the medial malleolus, was marked on their feet while the individuals were sitting in a chair with bare feet, and the distance between them and the floor was recorded. After that, the individual was asked to stand up and the distance between the floor and the navicular tubercle was measured again during weight transfer. The difference between the two measurements was recorded as the amount of navicular drop in centimeter [12].

Metatarsal Width Measurement: The largest distance between the medial and lateral concavities at the metatarsal level was measured with a caliper while the individuals were in an upright position and the values obtained were recorded [13].

Subtalar Joint Angle: Measurement of the subtalar joint angle, the angle between the longitudinal axis of the calcaneus and the vertical midline of the distal 1/3 of the lower leg was measured with a goniometer while the athlete was standing upright. Valgus direction values as a (-) and varus direction values as a (+) were recorded in degrees [14].

Pedobarographic Assessment

Measurement of the foot plantar pressure of the athletes was made with a freemed brand (Sensor Medica Inc., Rome, Italy) pedobarographic device. Static (standing) and dynamic (walking) footpad pressures were measured with this system. The pressure measurement platform of the device includes a sensor area within the general frame of 500x600x20 mm. The device frequency is 400 Hz, pressure range is 0-150 N/cm², connection power is 220/110 volts. Static evaluation was performed by asking not to direct their body weight to a certain side on the platform and to look at a fixed point so that the athletes could focus. The athletes were evaluated while standing on the platform. Dynamic evaluation was measured by walking on the platform. The athletes started walking 5 meters before the platform so that they could walk with normal stepping. The test was repeated when the athletes were standing still on the platform or stepping on the platform incorrectly. Measurements were made three times for both feet. In the dynamic measurement, error rates on the foot plantar pressure and surface area were evaluated. In the static measurement, error rates on anterior-posterior and medial-lateral static stance were assessed [15,16].

Figure 1: Pedobarographic assessment of the foot

Balance Assessment

Test measurements were made with Biodex Balance Systems SD (Biodex Medical Systems, Shirley, NY, 11967-0702, USA) device. Athletic Single Leg protocol was applied to the athletes in both ankles. Before the test, the platform stability of the device was adjusted. Data were recorded while the athletes tried to maintain balance for 20 seconds on one leg, with hands crossed at chest level. Total Balance Index (TSI), Medial-Lateral Balance Index (ML) and Anterior-Posterior Balance Index (AP) scores were recorded. This process was repeated 3 times with 10 seconds rest periods. The test was repeated if they were out of balance and touched the bars on the sides [17].

Figure 2: Balance assessment test

Statistical Analysis

All data were analyzed using The Statistical Package for Social Sciences (SPSS) version 22.0 (SPSS Inc., Chicago, IL, USA) package program. To define the tests to be performed on the data obtained in the study, the Kolmogorov-Smirnov and Shapiro-Wilk normality tests were used. The data did not show normal distribution. The relationship of independent variables with each other was evaluated using Spearman Correlation Analysis. Statistical significance was taken as $p<0.05$.

The post-hoc power analysis was performed with the G-power (G * Power, Ver. 3.0.10, Universität Kiel, Germany) program. A total of 36 individuals was determined be adequate to detect statistically significant correlation with the power of over 93.2% ($\alpha=0.05$, Spearman rho=0.532).

3. Results

Six of the 42 players in total were excluded from the study because they suffered an ankle injury within the previous six months (n=4) or requested to quit the study (n=2). The study was completed with 36 players. The mean of age, sports age, body height, weight and body mass index (BIM) of the players were 16.16±1.52 years, 4.53±1.23 years, 183.00±10.27 cm, 67.05±12.13 kg and 19.90±2.42 kg/m^2, respectively. The evaluation results are presented in Table 1.

Table 1. The evaluation results of athletes (n=36)

		Median (IQR)	Minimum	Maximum
Demographic Features	**Age (year)**	16.00 (3.00)	14.00	19.00
	Height (cm)	182.50 (14.00)	162.00	200.00
	Weight (kg)	67.00 (21.50)	44.00	92.00
	BMI (kg/m$^{2)}$	19.96 (3.05)	12.19	24.68
	Sport Age (year)	4.00 (1.00)	2.00	7.00
Foot Biomechanical Assessment	**Navicular Drop (cm)**			
	Dominant	0.70 (0.28)	0.40	1.10
	Non-dominant	0.70 (0.20)	0.50	1.10
	Metatars Width (cm)			
	Dominant	10.30 (0.60)	9.40	11.70
	Non-dominant	10.40 (0.67)	9.50	11.70
	Hallux Valgus Angle (°)			
	Dominant	7.00 (2.00)	4.00	10.00
	Non-dominant	7.00 (2.75)	4.00	12.00
	Subtalar Angle (°)			
	Dominant	7.00 (2.00)	4.00	10.00
	Non-dominant	7.00 (2.00)	5.00	10.00
Pedobarographic Assessment	**Pressure Error (%)**			
	Dominant	7.80 (2.97)	4.60	18.00
	Non-dominant	8.80 (2.85)	5.50	14.10
	Surface Error (%)			
	Dominant	6.40 (2.17)	4.10	13.80
	Non-dominant	6.20 (2.80)	1.40	12.60
	Static Stance AP (%)	13.00 (11.50)	3.00	25.00
	Static Stance ML (%)	4.00 (3.00)	1.00	9.00
Balance Assessment	**Total Stability Index**			
	Dominant	2.10 (0.98)	0.50	4.10
	Non-dominant	2.15 (0.95)	1.10	3.70
	ML Stability Index			
	Dominant	1.35 (0.62)	0.40	2.30
	Non-dominant	1.35 (0.77)	0.90	2.50
	AP Stability Index			
	Dominant	1.40 (0.62)	0.30	2.90
	Non-dominant	1.35 (0.77)	0.90	2.50

IQR: Interquartile Range, BMI: Body Mass Index, AP: Anterior-Posterior, ML: Medial-Lateral

There was no statistical correlation between balance, age and body mass index ($p>0.05$) (Table 2). No significant correlation was found between navicular drop, metatarsal width, subtalar angle, hallux valgus and balance values of the athletes ($p>0.05$) (Table 2). A significant correlation was found between the pedobarographic and the balance values of the athletes; dominant extremity plantar pressure error and surface error ratios and dominant and non-dominant extremity total balance index, dominant extremity medial-lateral balance index, non-dominant extremity anterior-posterior balance index ($p<0.05$) (Table 2). In addition, there was correlation between anterior-posterior static stance value and non-dominant extremity anterior posterior stability index. There was no statistical correlation between the balance and the other pedobarographic values ($p>0.05$).

Table 2. Correlation between the evaluation parameters of the athletes (n=36)

			TSI Dominant	TSI Non-dominant	MLSI Dominant	MLSI Non-dominant	APSI Dominant	APSI Non-dominant
	Age	Spearman Rho	-0,032	-0,011	0,038	0,019	0,103	0,001
		p	0,855	0,948	0,824	0,912	0,551	0,997
	BMI	Spearman Rho	0,228	0,238	0,280	0,236	0,217	0,157
		p	0,180	0,163	0,098	0,166	0,203	0,360
Foot Biomechanical Assessment	**Navicular Drop**							
	Dominant	Spearman Rho	0,12	0,227	0,101	0,277	-0,016	-0,009
		p	0,484	0,182	0,559	0,102	0,927	0,960
	Non-dominant	Spearman Rho	0,151	0,102	0,066	0,191	0,156	-0,059
		p	0,38	0,553	0,702	0,264	0,365	0,731
	Metatars Width							
	Dominant	Spearman Rho	0,119	0,034	0,043	-0,013	0,115	-0,073
		p	0,49	0,843	0,806	0,941	0,504	0,672
	Non-dominant	Spearman Rho	0,096	0,023	0,016	-0,002	0,076	-0,100
		p	0,578	0,895	0,928	0,992	0,659	0,562
	Hallux Valgus Angle							
	Dominant	Spearman Rho	-0,108	0,069	-0,138	-0,069	-0,035	0,176
		p	0,530	0,689	0,424	0,691	0,841	0,306
	Non-dominant	Spearman Rho	-0,048	0,099	-0,095	-0,044	0,042	0,231
		p	0,779	0,568	0,583	0,797	0,809	0,176
	Subtalar Angle							
	Dominant	Spearman Rho	0,161	0,127	0,232	0,201	0,030	0,030
		p	0,347	0,459	0,173	0,239	0,864	0,861
	Non-dominant	Spearman Rho	0,153	0,181	0,141	0,239	0,043	0,05
		p	0,374	0,292	0,411	0,160	0,802	0,773
Pedobarographic Assessment	**Plantar Pressure Error**							
	Dominant	Spearman Rho	**0,512**	**0,451**	**0,374**	0,328	0,251	**0,393**
		p	**0,001**	**0,006**	**0,025**	0,051	0,14	**0,018**
	Non-dominant	Spearman Rho	0,226	0,204	0,115	0,111	0,11	0,277
		p	0,185	0,232	0,504	0,519	0,525	0,102
	Surface Area Error							
	Dominant	Spearman Rho	**0,405**	**0,345**	**0,374**	0,28	0,172	**0,39**
		p	**0,014**	**0,039**	**0,025**	0,098	0,317	**0,019**
	Non-dominant	Spearman Rho	0,053	0,015	0,004	0,083	-0,065	0,177
		p	0,757	0,932	0,980	0,706	0,706	0,302
	Static Stance AP							
		Spearman Rho	-0,236	-0,299	-0,16	-0,049	-0,261	**-0,378**
		p	0,166	0,076	0,351	0,775	0,124	**0,023**
	Static Stance ML							
		Spearman Rho	-0,058	0,128	-0,009	0,014	-0,133	0,168
		p	0,738	0,457	0,959	0,936	0,439	0,327

TSI: Total Stability Index, MLSI: Medial Lateral Stability Index, APSI: Anterior Posterior Stability Index, BMI: Body Mass Index, AP: Anterior-Posterior, ML: Medial-Lateral

4. Discussion and Conclusion

As a result of our study, which was planned to examine the relationship between foot biomechanics and plantar pressure with balance in male adolescent volleyball players, it was determined that there was no relationship between foot biomechanics and balance, and that the differences in plantar pressure distribution caused some changes in balance.

Considering the studies investigating the relationship between age of athletes; studies indicated that the balance declines with increasing age [18]. Structural and functional declines occur in somatosensory systems with increasing age. These changes are associated with postural instability and falling frequency [19]. We think that we could not observe a relationship between balance and age because we included our study with adolescent athletes. Contrasting results were observed in studies examining the relationship between BMI index and balance. Studies have shown that individuals with increased body mass require more movement to maintain postural balance and balance is adversely affected [20]. However, they could not find a relationship between BMI and balance in their research which they explained to the fact that they evaluated non-obese people [21] In our study, we think that there is no relationship between BMI and balance due to the fact that all of the athletes had improved balance due to training and their BMI values were normal.

Articles examining the relationship between balance and foot biomechanical data are quite limited in the literature. Balance, foot biomechanical values and pedobarographic values were mostly evaluated individually. Aydos et al. reported that volleyball sport did not cause any increase or decrease in the contact areas of the plantar foot. It was observed that the foot contact areas of female volleyball players had similar values with the control group [22]. In our study, it was determined that there were no deviations that would cause any pathology in the athletes' foot biomechanic measurements. Therefore, we believe that it contributes to the development of structures supporting foot biomechanics with a regular training program in athletes.

In our study, no correlation was found between all biomechanical properties of both dominant and non-dominant feet and balance. Harrison et al. showed in their studies conducted on individuals with foot biomechanical disorders have shown that balance values can be associated with biomechanical disorders of the individuals [23]. Karabacak R. evaluated the balance in individuals with and without pes planus and found that the dynamic balance was worse in individuals with pes planus [24]. According to the results of our study, we think that the lack of a correlation between foot biomechanical properties and balance may be due to the fact that the individuals included in our study did not have any foot deformities.

We also found a correlation between some pedobarographic values and balance of the athletes. Linda C. et al. was established by their study, the relationship between foot sole pressure distribution and postural stability. As a result of the study in which 20 individuals were evaluated, it was found that the asymmetry of control of postural stability increased with increasing weight-bearing asymmetry [25]. We think that the reason for this is that the pressure distribution in the plantar area and the correct ground contact may be related to the correct joint alignment and better somatosensory sensory input in the athletes, as well as the improved balance.

When looking at the studies in the literature, making the data of our study with objective evaluation tests increases the value of the study. In addition, the limited number of studies on this subject demonstrates the originality of our study. The limitations of our study are that only volleyball players were included, there were no foot biomechanical disorders and there were no different age groups. The fact that leg length and foot length measurements, which can affect balance and foot pressure, are not taken can be considered as another limitation.

There is a gap in the literature about this subject due to limited studies. The fact that researchers who conduct scientific studies do other studies on this subject will increase the accuracy of the information in the literature.

As a result of this study, we think that while sports physiotherapists and trainers prepare training programs for the team, it will be useful to consider the relationships between balance and pedobarographic values, which are among the effective parameters in improving the performance of volleyball players and protecting them from injuries.

Declaration of Ethical Code

In this study, we undertake that all the rules required to be followed within the scope of the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with, and that none of the actions stated under the heading "Actions Against Scientific Research and Publication Ethics" are not carried out.

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