INTERNATIONAL JOURNAL of IJSETS SPORT, EXERCISE & TRAINING SCIENCES

e-ISSN 2149-8229 **Volume** 10, **Issue** 4, 222–229, (2024) ***Original Article***

https://dergipark.org.tr/tr/pub/useeabd

A Morphometric Comparative Study on Static Footprints of National and Amateur Taekwondo Players*

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Abstract

Aim: The aim of this study is to comparatively examine the static foot structures of national and amateur taekwondo athletes.

Methods: This study is a cross-sectional research that comparatively examines the anatomical foot structures of amateur and national taekwondo athletes. A total of 25 male national taekwondo athletes and 25 male amateur taekwondo athletes, aged between 19 and 27, voluntarily participated in the study. Initially, participants' height and body weight measurements were taken, and their body mass index were calculated. Subsequently, the footprint analysis method was used to evaluate their foot structures. The data were assessed using five parameters: Body mass index, length, width, Chippaux-Smirak Index, and Clark angle, and the results were statistically analyzed.

Results: The study results indicated significant differences between the groups in terms of body mass index, Chippaux-Smirak Index, and Clark angle parameters ($p<0.05$), while no significant differences were found in length and width parameters ($p>0.05$).

Conclusion: There were notable differences in the arch structures between national and amateur taekwondo athletes. National taekwondo athletes exhibited normal arch levels, whereas amateur taekwondo athletes showed lower arch levels.

Keywords

Taekwondo athletes,
Foot,
Plantar arch.

Article Info

Received:12.10.2024
Accepted:09.12.2024
Online Published:31.12.2024

DOI: 10.18826/useeabd.1566039

Milli ve Amatör Tekvandocuların Statik Ayak İzleri Üzerine Karşılaştırmalı Morfometrik Çalışma

Özet

Amaç: Bu araştırmanın amacı, milli ve amatör tekvandocuların statik ayak yapılarının karşılaştırmalı olarak incelenmesidir.

Yöntem: Bu araştırma milli ve amatör tekvando sporcularının anatomik ayak yapılarını karşılaştırmalı olarak inceleyen kesitsel bir araştırmadır. Araştırmaya 19-27 yaş aralığında 25 erkek milli tekvandocu ve 25 erkek amatör tekvandocu gönüllü olarak katılmıştır. Araştırmada katılımcıların önce boy uzunluğu ve vücut ağırlığı ölçümleri yapılmış ve vücut kitle indeksleri hesaplanmıştır. Daha sonra ayakizi analiz yöntemi kullanılarak ayak yapıları belirlenmiştir. Veriler, vücut kitle indeksi, ayak uzunluğu, ayak genişliği, Chippaux-Smirak indeksi ve Clark açısı olarak beş parametrede değerlendirilmiş, sonuçlar istatistiksel olarak analiz edilmiştir.

Bulgular: Araştırma sonuçlarında vücut kitle indeksi, Chippaux-Smirak indeksi ve Clark açısı parametrelerinde gruplar arasında anlamlı farklılık olduğu ($p<0,05$), uzunluk ve genişlik parametrelerinde ise anlamlı farklılık olmadığı tespit edilmiştir ($p>0,05$).

Sonuç: Milli ve amatör tekvandocular arasında özellikle ark yapıları açısından önemli farklılıklar bulunduğu, milli tekvandocuların ark yapılarının normal ark seviyelerinde, amatör tekvandocuların ise daha düşük ark seviyelerinde olduğu görülmüştür.

Anahtar Kelimeler

Tekvando sporcuları,
Ayak,
Plantar kavis.

Yayın Bilgisi

Gönderi Tarihi: 12.10.2024
Kabul Tarihi: 09.12.2024
Online Yayın Tarihi: 31.12.2024

DOI: 10.18826/useeabd.1566039

INTRODUCTION

Taekwondo, one of the world's most popular martial arts, is an Olympic sport with Korean origins. As in many other martial arts, the importance of physical structure suitable for the sport is emphasized in achieving advanced athletic performance and elite sporting success in taekwondo (Bridge et al., 2014). Among the components of physical structure, the anatomical structure of the foot and its segmental alignment may have particular significance in taekwondo.

The foot is the final segment of the body that ensures the transmission of load to the ground during both static and dynamic conditions. The integrity and functionality of the anatomical structure of the foot and its components enable the proper and balanced transmission of pressure to the ground. The

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* This study was produced from the doctoral thesis of the first author.

bones, joints, ligaments, and muscles of the foot work in harmony to transfer the body's weight and the forces generated during movement to the ground (Kidder et al., 1996; Ledoux et al., 2003; Tsapenko et al., 2020). The proper structure of the foot arch optimizes shock absorption, while the flexibility and stability of the foot joints aid in the controlled and efficient execution of movement (Kaufman et al., 1999; Sekiguchi et al., 2020). Due to these characteristics, foot morphology affects the mobility and stabilization of all structures involved in the kinetic chain (Chun et al., 2021; Moreno-Barriga et al., 2023). Particularly in competitive sports where speed and agility are crucial, the response to dynamic loads directly impacts the demonstration of optimal athletic performance, and it is evident that the alignment of foot structure with the specific demands of the sport is one of the key factors for success (LaPlaca and Seedman, 2021; Sarıalioğlu, 2024).

Just as an ideal foot structure has positive effects on athletic performance, anomalies or disorders such as flat feet, high arches, and misaligned joints can restrict an athlete's mobility, increase the risk of injury, and impair sports performance (Ikuta et al., 2022; Şahin et al., 2022). Therefore, the evaluation and analysis of the anatomical structure of the foot in athletes is particularly crucial in disciplines that require advanced coordination skills, such as taekwondo. This is because taekwondo is a fast-paced sport that demands coordinated execution of rapid and powerful kicks as well as sudden movements (Şahin, 2000). The proper anatomical structure of the foot is believed to have significant impacts on the successful performance of the techniques required in this sport.

A review of previous studies reveals that no comprehensive research has been conducted on the anatomical structures of the feet of taekwondo athletes. Considering the gaps in the literature and the effects of foot morphology on the kinetic chain, the identification of the foot structures of taekwondo athletes and the differences between the foot structures of national and amateur taekwondo athletes underscore the significance of this study. In this context, the aim of this research is to comparatively examine the static foot structures of national and amateur taekwondo athletes.

METHOD

Design

This study is a cross-sectional research that comparatively examines the anatomical foot structures of amateur and national taekwondo athletes.

Participants

A total of 25 male national taekwondo athletes and 25 male amateur taekwondo athletes, aged between 19 and 27, voluntarily participated in the study. The national taekwondo athletes were selected from the Turkey National Taekwondo Team camp, while the amateur taekwondo athletes were chosen using a random sampling method from volunteers at various taekwondo gyms in the Giresun, Trabzon, and Ordu regions.

Taekwondo athletes who have been licensed for at least the last five years and have trained at least three times per week over the past year were included in the study, while those with any pathological or orthopedic issues related to foot health, as well as those who did not meet the inclusion criteria, were excluded. Additionally, participants in the national taekwondo group were required to have competed in at least one international competition in the senior category representing the Turkish National Taekwondo Team, while those in the amateur group were required to have no national achievements in medal-winning categories.

Procedure

The 50 taekwondo athletes who met the inclusion criteria were divided into two groups: the National Taekwondo Athletes Group (NTG, n=25) and the Amateur Taekwondo Athletes Group (ATG, n=25). First, the height and body weight of the athletes were measured, and their body mass index (BMI) were calculated. Subsequently, footprints of the athletes were taken, and metric measurements were conducted on these footprints. The results were then statistically analyzed. The results were evaluated in two ways: group comparisons of foot structures and intra-group bilateral asymmetry. Additionally, the following procedures have been implemented to prevent biases in the study:

All measurements were taken by the same researcher. If the foot print analyses were unclear, the measurement was repeated. To ensure that the acute effects of fatigue on plantar pressure distribution did not affect the data, measurements were only taken from participants who had not engaged in any strenuous physical activity for at least 12 hours. The data analysis was performed by a statistician different from the researchers.

Determination of morphological structure of foot

The two-dimensional footprint analysis method, derived from foot plantar pressure, was used to evaluate foot morphology. The footprint analysis method, a classical, widely used, and simple approach, is clinically recognized as a reliable method for assessing foot structure, classifying foot types, and identifying certain pathological conditions (Gijon-Nogueron et al., 2020; Razeghi and Batt, 2002; Stavlas et al., 2005). The footprint analysis method reflects the distribution on the foot's plantar surface onto the ground during a static standing position or, in some cases, under load, as the pressure applied to the body is transferred to the ground (Bek, 2018; Domjanic et al., 2013).

Footprint method

In the study, a rubber roller was used to apply ink to the bare soles (plantar surfaces) of each participant's feet. For accurate assessment, participants were asked to look at a fixed point ahead, and then, while in a static position, they stepped onto white cardboard sheets placed on a flat platform measuring 50x50 cm at 10 cm intervals. This procedure was carried out for both feet of each participant. After completing the application for all participants, the necessary morphometric measurements of each footprint were precisely taken using transparent rulers for both the right and left feet. The "Pocket Atlas of Human Anatomy, Based on the International Nomenclature" was used as a reference for anatomical terminology (Feneis and Dauber, 2000).

Length (L): The distance between the most posterior point of the calcaneus and the anterior point of the most distal phalanx (see Figure 1).

Width (W): The maximum width of the metatarsal region (see Figure 1).

Chippaux-Smirak Index (CSI): It is the value obtained by multiplying by 100 the ratio of the narrowest part of the medial longitudinal arch in the two-dimensional image obtained from the footprint analysis to the widest part of the metatarsal region. CSI=(B/A)x100 (Stavlas et al., 2005) (see Figure 2).

Clark Angle (C°): It is the angle between a tangent line drawn from the medial edge of the foot, connecting the most medial parts of the heel and the first metatarsal, and a tangent line drawn from the most medial part of the first metatarsal to the most concave part of the medial longitudinal arch (Chen et al., 2011) (see Figure 3).

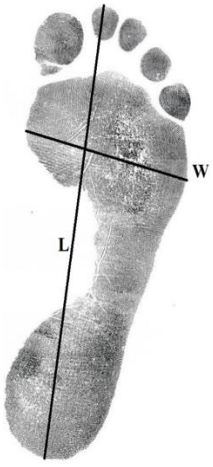

Figure 1. Length (L) and Widt (W)

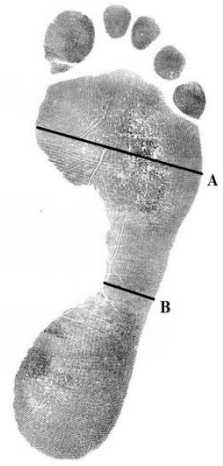

Figure 2. CSI

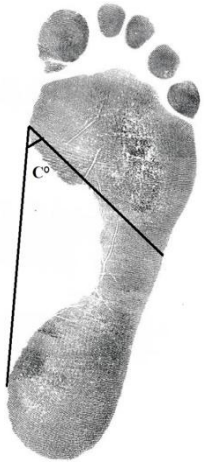

Figure 3. Clarke angle (C°)

Statistical analysis

The data obtained from the metric analyses of the footprints were first subjected to the Shapiro-Wilk normality test, which indicated that the data followed a normal distribution. Subsequently, an independent samples t-test was utilized to identify differences between groups and intra-group bilateral asymmetry. The results were analyzed at a significance level of $p<0.05$.

FINDINGS

Table 1. Comparison of BMI and foot analyses between amateur and national athletes

Parameters		Groups	$\bar{x} \pm sd$	t	p
BMI		ATG	23.20±1.98	2.26	0.03*
		NTG	21.70± 2.66		
L (cm)	RF	ATG	25.47±1.12	0.54	0.50
		NTG	25.32±0,.8		
	LF	ATG	25.46±1.10	0.55	0.58
		NTG	25.30±1.00		
W (cm)	RF	ATG	9.99±0.61	0.95	0.30
		NTG	9.83±0.58		
	LF	ATG	9.95±0.57	1.12	0.27
		NTG	9.78±0.56		
CSI (%)	RF	ATG	41±12	3.48	0.00**
		NTG	30±11		
	LF	ATG	39±11	3.19	0.00*
		NTG	29±11		
C^o	RF	ATG	36.28±11.75	-5.696	0.00**
		NTG	51.52±6.39		
	LF	ATG	39.24±12.50	-5.11	0.00**
		NTG	53.72±6.69		

Abbreviations: $\bar{x}$, mean; sd, standard deviation; BMI, body mass index; cm, centimeters; CSI, Chippaux-Smirak Index; C^o, Clarke angle; L, length; W, width; RF, Right foot; LF, Left foot; ATG, amateur taekwondo athletes group; NTG, national taekwondo players group, p<0.05; p<0,01** was considered statistically significant. P-values are from independent t-test.*

In Table 1, when comparing the foot analyses of amateur and national male athletes, it was found that there were significant differences in the BMI ($t=2.26$, $p=0.029$), CSI (RF, $t=3.48$, $p=0.001$; LF, $t=3.19$, $p=0.002$) and C^o (RF, $t=-5.696$, $p=0.001$; LF, $t=-5.110$, $p=0.001$) parameters in both feet ($p<0.05$), while there were no significant differences in the L and W parameters in either foot ($p>0.05$).

Table 2. Examination of bilateral asymmetric differences in foot structures

Groups	Parameters		$\bar{x} \pm sd$	t	p
ATG	L (cm)	RF	25.47±1.12	0.03	0.98
		LF	25.46±1.10		
	W (cm)	RF	9.99±0.61	0.24	0.81
		LF	9.95±0.57		
	CSI (%)	RF	41±11	0.79	0.43
		LF	39±10		
	C^o	RF	36.28±11.75	-0.86	0.39
		LF	36.24±12.49		
NTG	L (cm)	RF	25.32±0.98	0.11	0.91
		LF	25.30±1.00		
	W (cm)	RF	9.83±0.58	0.37	0.71
		LF	9.78±0.56		
	CSI (%)	RF	30±11	0.27	0.78
		LF	29±11		
	C^o	RF	51.52±6.39	-1.19	0.24
		LF	53.72±6.68		

Abbreviations: $\bar{x}$, mean; sd, standard deviation; L, length; W, width; CSI, Chippaux-Smirak Index; C^o, Clarke angle. ATG, amateur taekwondo athletes group; NTG, national taekwondo players group; RF, Right foot; LF, Left foot, p<0.05 was considered statistically significant. P-values are from independent t-test.*

In Table 2, when the bilateral asymmetry of foot structures was examined, no significant differences were found in any of the parameters ($p>0.05$).

DISCUSSION

Certain metric and angular parameters of footprints can provide valuable information for evaluating foot structure. Researchers emphasize that understanding foot structure across different sports disciplines can significantly contribute to athletic performance, overall abilities, and musculoskeletal injury prevention (Lopezosa-Reca et al., 2020; Mathieson et al., 1999; Monteleone et al., 2023). For this reason, this study aimed to comparatively examine certain morphometric parameters in the foot anatomy of amateur and national taekwondo athletes. Differences between groups were evaluated to reveal the foot structure of the athletes.

The first finding of the research results is that significant differences were found in the CSI and C° parameters in the comparisons between the groups while no differences were found between the groups in the L and W parameters (see Table 1). When examining the results in terms of the CSI parameter, the average CSI values were found to be 30±11 for the right foot and 29±11 for the left foot in the National Taekwondo Group (NTG). For the Amateur Taekwondo Group (ATG), the average CSI values were 41±11 for the right foot and 39±10 for the left foot. The CSI is an objective method used to assess the medial longitudinal arch. In this parameter, values between 1 and 29.9 are considered normal arches, values between 30 and 39.9 are classified as intermediate arches, and values between 40 and 44.9 are categorized as fallen medial longitudinal arches (Echarri and Forriol, 2003). In the study, it was observed that the CSI values of the Amateur Taekwondo Group (ATG) were at lower arch levels, while the CSI values of the National Taekwondo Group (NTG) were at normal arch levels. Zhang et al. (2020) conducted research that found a positive relationship between the height of the longitudinal arch and performance in athletes. Williams et al. (2001) identified significant relationships indicating that athletes with high arches moved their feet more rapidly compared to those with low arches. Caravaggi et al., (2010) found that the longitudinal arch is a crucial structure influencing performance in fast walking. The results of our study suggest that CSI values deemed normal might be important for physical fitness parameters in taekwondo.

When examining the results in terms of the C° parameter, the average C° values were found to be 51.52±6.39 for the right foot and 53.72±6.68 for the left foot in the National Taekwondo Group (NTG). For the Amateur Taekwondo Group (ATG), the average C° values were 36.28±11.75 for the right foot and 36.24±12.49 for the left foot (see Table 1). The Clarke angle provides valuable insights for researchers evaluating sport-specific foot morphology, foot deformities, and the relationship between foot structure and physical performance in competitive sports. In the literature, a flat foot is defined as below 30°, a mild flat foot as 31-40°, a normal foot as 41-50°, and a high arch foot as above 51° (Andrzejewska et al., 2019). Juniartha et al., (2023) indicated that the C° parameter might influence balance strategies in wushu athletes. Another study by Jankowicz-Szymanska et al., (2015) reported average C° values of 55.64±10.32 for judo practitioners and 47.38±7.51 for non-judo practitioners, with a positive correlation between static balance and C° in judokas. These studies support the results of the current research.

The second finding of the research is the absence of bilateral asymmetry between the right and left foot structures in both groups (see Table 2). Bilateral asymmetry refers to the presence of structural, functional, or performance-related differences or imbalances between the right and left sides of the body (Maloney, 2019). Previous research has indicated that increased bilateral asymmetry in various parameters, particularly in intensive and competitive sports, can negatively impact physical performance (Helme et al., 2021; Kalata et al., 2020; Sarabon et al., 2020). Due to the negative relationship between bilateral differences in physical structures and athletic performance, our hypothesis in this research was that there may be bilateral differences in the foot structures of the ATG group. However, the absence of bilateral asymmetry in the parameters might be attributed to the number of participants and the fact that taekwondo involves extensive use of both feet.

The third finding of the study is that there is a significant difference between the groups in terms of BMI values (see Table 1). The results of the study showed that the average BMI values of the NTG (21.70±2.66) were significantly lower than those of the ATG (23.20±1.98). In a study by Heller et al., (1998) on Czech national male and female taekwondo athletes, a BMI value of 22.00 was reported for males. Similarities were observed between the BMI values of Czech national taekwondo athletes and the Turkish national taekwondo athletes in the current study. Kazemi et al., (2009) examined the BMI values of winning and losing male and female athletes at the 2004 Olympics. It was found that the BMI

values for winning female and male athletes were 20.4 and 22.4, respectively, while the BMI values for losing female and male athletes were 21.1 and 22.5. The BMI values of winning athletes were observed to be lower than those of losing athletes. In the current study, the BMI values of national athletes were found to be significantly lower than those of amateur athletes, and this finding is supported by relevant literature. This suggests that BMI may be a determining factor for performance in taekwondo.

The Body Mass Index (BMI), which reflects an individual's weight and height, is considered an important physical factor that affects foot structure. This is because BMI can lead to changes in the loads applied to the foot structure (Rosende-Bautista et al., 2023). In individuals with a particularly high BMI, negative effects such as flattening of the medial longitudinal arch, increased plantar pressure, and foot deformities can be observed. However, in this study, despite significant differences in BMI between the groups, both groups fall within the normal weight range (18.5-24.9), which helps to minimize potential deviations in foot structure that may arise from excessive BMI and reduces the likelihood that the morphometric results are influenced by BMI factors.

Limitations

The major limitation of this study is that due to age groups, sample size, and the specific characteristics of the sport of taekwondo, there is insufficient evidence regarding the generalizability of the results to other taekwondo athletes and other sports disciplines. Participants are athletes in the senior category. Therefore, the changes in foot structure resulting from years of intensive training are not well understood. While foot structure can affect athletic performance, it can also lead to changes in foot structure due to intense training or repetitive trauma, depending on the specific characteristics of the sport being practiced. For these reasons, prospective studies involving different age groups and larger sample sizes are needed to draw definitive conclusions about the generalizability of the results.

CONCLUSION

In conclusion, significant differences were observed between national and amateur taekwondo athletes, particularly regarding arch structures. The arch structures of national taekwondo athletes were found to be at normal arch levels, while amateur taekwondo athletes exhibited lower arch levels.

SUGGESTIONS

These results may provide important insights into the physical fitness parameters used in identifying potential taekwondo candidates, as well as the individual differences that are necessary when developing training programs.

Ethical Approval Permission Information

Ethics Committee: Selçuk University, Meram Faculty of Medicine Dean's Office, Clinical Research
Division / Protocol No: 2011/045

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