Int J Clin Exp Med 2021;14(4):1784-1790
www.ijcem.com /ISSN:1940-5901/IJCEM0111685

Original Article

Spine morphology and elite taekwondo athletes' career phases

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Received March 31, 2020; Accepted December 26, 2020; Epub April 15, 2021; Published April 30, 2021

Abstract: The purpose of this study was to determine the morphological characteristics of taekwondo athletes according to their career phases. Forty taekwondo athletes and 10 non-athletes (20 males and 30 females) with a mean age of 18.2 years (range 15-23), a mean height of 173.4 cm, and a mean bodyweight of 64.8 kg were studied. Six spine variables were measured using the DIERS formetric 4D posture analysis system (DIERS Medical Systems, Chicago, IL, USA). The female athletes had greater kyphotic angles than the male athletes. Their lordotic angles were also greater than the male athletes' lordotic angles, and the high school female athletes (HFAs) were similar to the general females (GFs). The kyphotic apexes in the high school male athletes (HMAs) were higher than they were in the university male athletes (UMAs), and the kyphotic apexes in the HFAs were higher than they were in the university female athletes (UFAs). In both sexes, the kyphotic apexes were higher in the high school athletes than in the university athletes. The lordotic apexes were higher in the UMAs than in the HMAs. However, among the female athletes, their lordotic apexes were higher in the HFAs than in the UFAs. It is hoped that the findings from this morphological study of the spine according to the athletes' career phases will be useful in clinical practice.

Keywords: Taekwondo, spine, career, morphology

Introduction

Each athlete engaging in various sports may exhibit unique physical traits which differ from those of a non-athlete [1-7]. Previous studies reported the differences in body composition among soccer players [1, 8-11]. The differences in body composition affect an athlete's performance, but the association between physical traits and athletic performance is unknown [7, 12, 13]. However, elite athletes' anthropologic data are crucial for coaches or teachers as a reference for planning a personalized training program [5, 7, 14].

Taekwondo competitors also display moderate-to-high maximum dynamic strength characteristics of the lower and upper extremities and moderate endurance properties of the trunk and hip flexor muscles [15]. We believe that taekwondo athletes' physical data is crucial for the development of appropriate physical abilities, including improving performance and preventing injury.

Scientific studies investigating the factors related to the performance of taekwondo athletes have been conducted [2, 16, 17]. However, it was difficult to find a study that examined the bone mineral density (BMD) of each body by dividing the bones in detail, and it was difficult to find a study that analyzed the spine in detail according to the career phase. The purpose of this study was to study the morphological characteristics of taekwondo athletes according to their career phases.

Materials and methods

For the purpose of this study, a stratified sampling method was applied considering gender (male, female) and affiliation (high school, university, general). Injured subjects (surgery, orthopedic) and subjects who refused to be measured were excluded from the study.

Table 1. Variables measured in this study

Variables	Unit	Definition
Trunk length	mm	The distance from the VP to the center point between the DL and DM.
Trunk inclination	mm	The distance from the line connecting the VP with the DM to the gravity centerline.
Kyphotic angle	°	The angle between the surface tangents from the ICT and the ITL.
Lordotic angle	°	The angle between the surface tangents from the ITL and the ILS.
Kyphotic apex	mm	The location of the posterior apex of the sagittal profile.
Lordotic apex	mm	The location of the frontal apex of the sagittal profile in the lower region.

Abbreviations: VP: vertebral prominence; DL: sacral dimple left; DM: dimple middle; ICT: inflection point of cervicothoracic spine; ITL: inflection point of the thoracolumbar spine; ILS: lumbosacral transition point.

Table 2. General information of the participants (Mean ± SD)

	Stature (cm)	Bodyweight (kg)	Age
HMA	178.9±7.94	69.3±9.56	16.3±0.75
HFA	172.1±4.53	62.9±8.05	16.3±0.79
UMA	185.3±7.27	80.0±9.49	20.1±1.21
UFA	172.0±5.68	59.4±7.68	19.2±1.45
GF	160.3±5.05	55.0±4.36	20.1±1.45

HMA: high school male athletes; HFA: high school female athletes; UMA: university male athletes; UFA: university female athletes; FG: general female.

Forty taekwondo athletes and 10 non-athletes (20 males and 30 females) with a mean age of 18.2 years (range 15-23), a mean height of 173.4 cm, and a mean bodyweight of 64.8 kg were studied. The characteristics of the specific subjects are shown in **Table 2**. Before the research began, the participants were informed of the contents of the study and the consent forms were signed.

The participants' BMD was measured using dual-energy X-ray absorptiometry (DXA, Hologic ZDR 4500, USA) (**Figure 1**). The other six variables were measured using the DIERS formetric 4D posture analysis system (DIERS Medical Systems, Chicago, IL, USA) (**Figure 2**). The six variables are explained in **Table 1**.

In this study, Microsoft Office Excel 2016 software (Microsoft Corporation, Redmond, WA, USA) was used to perform a frequency analysis to confirm the demographic characteristics. In addition, SPSS 21.0 (SPSS Science, Chicago, IL, USA) was used to verify the differences among the six variables according to gender and affiliation, and one-way ANOVA (analysis of variance) was performed for the data analysis. When a difference between groups was identified, the difference was confirmed by applying the Bonferroni method as a post-verification test. All statistical significance levels were set to 0.05. This study was approved by the Institutional Review Board (IRB) of Korea National Sport University.

Results

The male university athletes were taller than the high school athletes. However, among the female athletes, the university (UFA) and high school athletes (HFA) had similar heights. However, the differences in height between the general females (GF) and the athletes were marked. The male university athletes (UMA) were heavier than the high school athletes (HMA). However, among the females, the high school athletes were slightly heavier than the university athletes (**Table 2**).

The BMD analysis based on gender and age of the taekwondo players showed statistically significant differences in the heads ($F = 4.724$, $P = 0.003$), trunks ($F = 4.899$, $P = 0.003$), and ribs ($F = 6.528$, $P < 0.001$). Except for the heads, the BMD of the taekwondo athletes was higher than the BMD of the GFs. In the male athletes, the BMD of all the bones measured was higher than it was among the HMAs. However, in the female athletes, the BMD of the HFAs was higher than it was in the UFAs, except for the BMD of the ribs (**Table 3**).

A rotation analysis based on the sexes and ages of the taekwondo players showed statistically significant differences in trunk length ($F = 12.334$, $P < 0.001$) and trunk inclination ($F = 2.788$, $P = 0.039$). The trunk length of the UMAs was longer than it was in the HMAs. However, in the female athletes, the trunk length of the HFAs was longer than it was in the UFAs. The trunk inclination of the HMAs

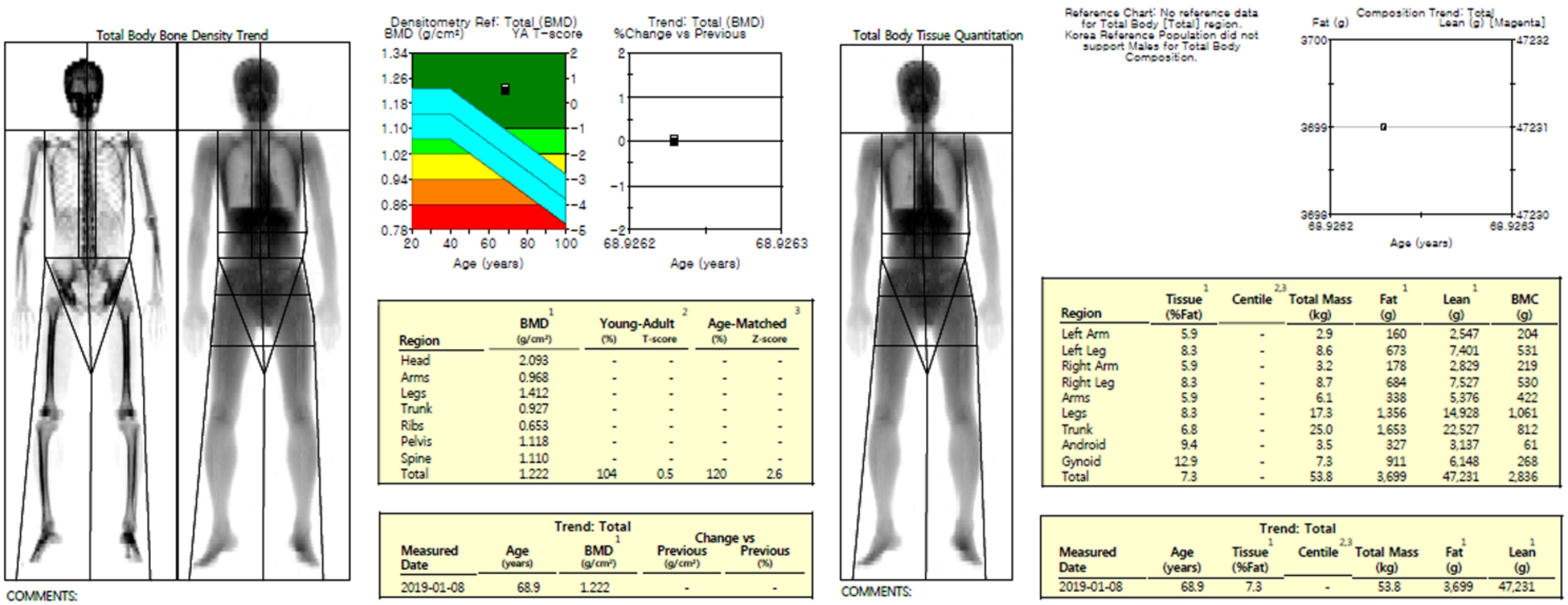

Figure 1. Example of Dual-Energy X-ray Absorptiometry (DXA) measurement.

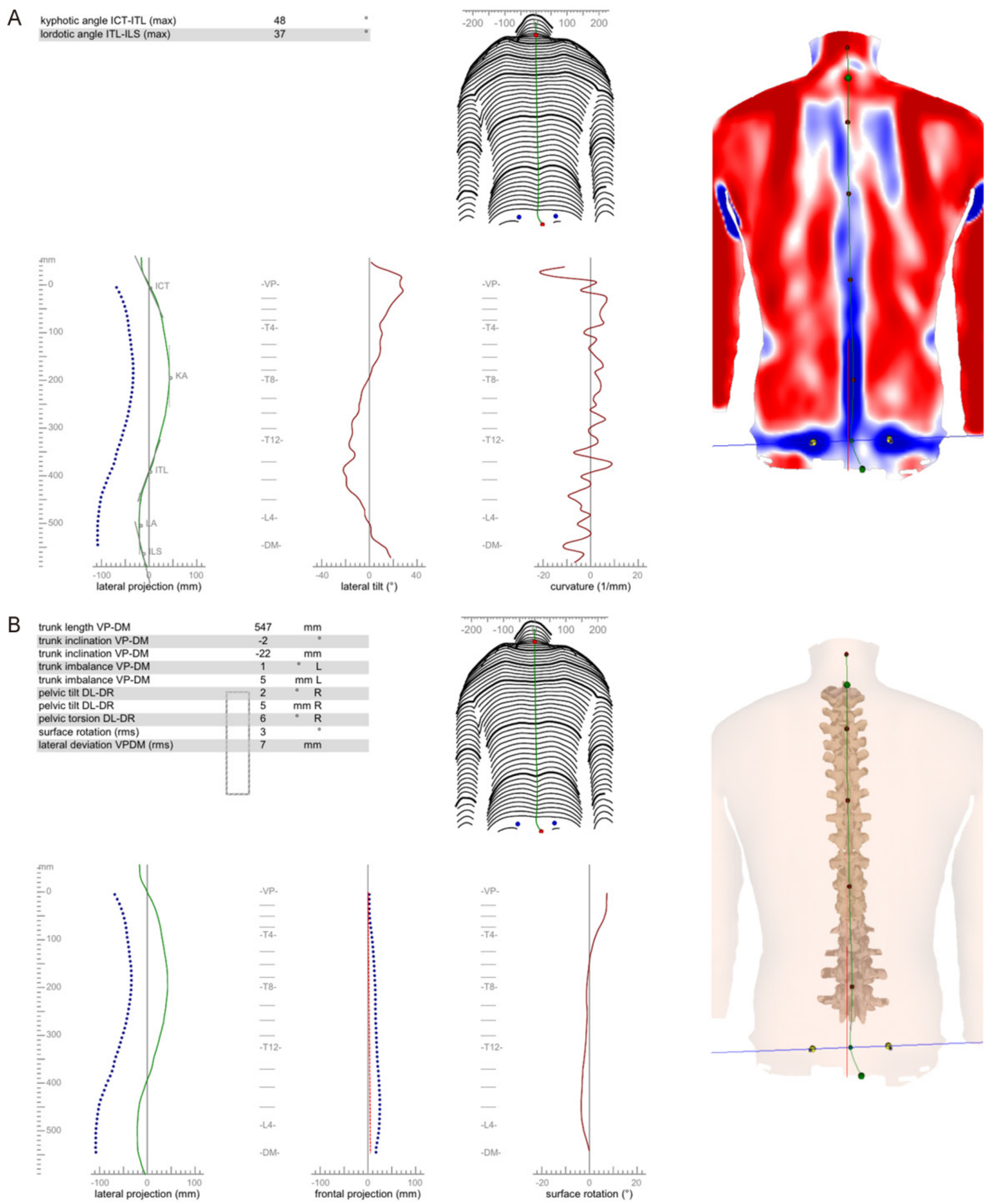

Figure 2. Examples (A and B) of formetric measurement.

was the lowest (-) among both athletes, and the value of the UFAs was the highest among the study participants (**Table 4**).

The results of the sagittal analysis based on the sexes and ages of the taekwondo players showed statistically significant differences in the lordotic angles (F = 3.160, P = 0.023). Overall, in terms of their kyphotic angles, the female athletes had greater angles than the male athletes. Their lordotic angles were also greater than the male athletes' lordotic angles, but the angles in the HFAs were similar to the lordotic angles of the GFs (**Table 5**).

Table 3. Bone mineral density (g/cm²)

Factor		M	SD	F	p	post-hot
Head	HMA	1.78	0.21	4.724	.003	HMA < HFA
	HFA	2.14	0.20			
	UMA	2.00	0.14			
	UFA	2.02	0.21			
	GF	2.04	0.21			
Trunk	HMA	1.02	0.09	4.899	.003	HMA > GF, HFA > GF UMA > GF
	HFA	1.03	0.07			
	UMA	1.07	0.07			
	UFA	1.01	0.05			
	GF	0.93	0.05			
Rib	HMA	0.72	0.06	6.528	< .001	HMA > GF, HFA < UMA UMA > GF
	HFA	0.69	0.03			
	UMA	0.76	0.06			
	UFA	0.70	0.04			
	GF	0.65	0.03			
Spine	HMA	1.10	0.12	2.075	.102	
	HFA	1.17	0.12			
	UMA	1.20	0.09			
	UFA	1.12	0.08			
	GF	1.04	0.17			

HMA: high school male athletes; HFA: high school female athletes; UMA: university male athletes; UFA: university female athletes; FG: general females.

Table 4. Rotation variables in the coronal plane (mm)

Factor		M	SD	F	p	post-hot
Trunk length	HMA	545.7	26.5	12.334	< .001	HMA > HFA, HMA > UFA, HMA > GF, HFA < UMA UMA > UFA, UMA > GF
	HFA	512.1	17.6			
	UMA	569.6	23.4			
	UFA	506.8	32.4			
	GF	488.6	31.1			
Trunk inclination	HMA	-8.0	21.5	2.788	.039	HMA > UFA
	HFA	-20.5	16.9			
	UMA	-28.1	29.2			
	UFA	-39.9	18.7			
	GF	-23.3	26.5			

HMA: high school male athletes; HFA: high school female athletes; UMA: university male athletes; UFA: university female athletes; FG: general females.

The posture analysis based on the sexes and ages of the taekwondo players showed statistically significant differences in the kyphotic apexes (F = 4.194, P = 0.006) and the lordotic apexes (F = 6.894, P < 0.001). The kyphotic apexes in the HMAs were higher than they were in the UMAs and they were higher in the HFAs than they were in the UFAs. In both sexes, the apexes in the high school athletes were higher than they were in the university athletes. The lordotic apexes in the UMAs were higher than they were in the HMAs. However, in the female athletes, the lordotic apexes were higher in the HFAs than they were in the UFAs (**Table 6**).

Discussion

Bone mineral density is the amount of bone mineral in the bone tissue. In this study, in the overall comparison between the taekwondo athletes and the non-athletes, the taekwondo athletes showed higher BMD in their trunks, ribs, and spines than in the head (**Table 2**). This may be because taekwondo athletes move their trunks more than their heads when competing or practicing. According to recent studies [7], the BMD of taekwondo athletes is slightly increased after eight weeks of training, although the value was a whole-body BMD. Another study suggested that exercising, specifically long-distance running and non-aquatic exercising, has a positive effect on BMD [15, 18].

The trunk length is well-explained in **Table 4**. The ratio of the trunk length to the whole stature for all the subjects was 30% (athletes: 30.09±1.1, general females: 30.4±1.9).

The kyphotic angles were smaller in the athletes than in the non-athletes. Similar results were found between the male and female athletes, i.e., when compared to the same-sex participants. All the participants were at good performance levels, so the kyphotic angles representing their best performances are unknown. However, too great of an angle does not permit the high-quality posture important in a match (**Table 5**).

Table 5. Kyphotic and lordotic angles (°)

Factor		*M*	*SD*	*F*	*p*	*post-hot*
Kyphotic angle	HMA	42.08	10.00	1.350	.267	
	HFA	47.00	8.72			
	UMA	42.29	10.14			
	UFA	46.67	11.82			
	GF	51.00	5.55			
Lordotic angle	HMA	31.42	8.16	3.160	.023	
	HFA	41.18	9.82			
	UMA	32.43	6.55			
	UFA	34.78	8.30			
	GF	41.50	8.04			

HMA: high school male athletes; HFA: high school female athletes; UMA: university male athletes; UFA: university female athletes; FG: general females.

Table 6. Kyphotic and lordotic apexes (mm)

Factor		*M*	*SD*	*F*	*p*	*post-hot*
Kyphotic apex	HMA	199.69	24.67	4.194	.006	HMA < UFA, HMA < GF
	HFA	166.03	38.43			
	UMA	167.03	56.32			
	UFA	138.77	56.31			
	GF	123.71	52.75			
Lordotic apex	HMA	476.40	47.09	6.894	< .001	HMA < GF, HFA > UMA UMA < UFA, UMA < GF
	HFA	436.90	29.44			
	UMA	494.11	17.09			
	UFA	432.67	43.23			
	GF	416.85	23.69			

HMA: high school male athletes; HFA: high school female athletes; UMA: university male athletes; UFA: university female athletes; FG: general females.

In the kyphotic apex variation according to sex, all the high school male and female athletes showed higher values than the university male and female athletes. However, in the kyphotic angles compared by sex, the high school and university athletes showed similar values. Even though there were some differences in certain variables of the spine, further study is needed to determine if this is related to performance. Recently, a few studies have been published comparing the differences in body composition between excellent taekwondo athletes and the general population or general level athletes. One study reported that the shear modulus of the semimembranosus in elite taekwondo athletes was in a different condition compared to the semitendinosus and biceps femoris [19]. These hamstring muscles may be affected by the pelvic movement, and pelvic impairment affects the spine [20]. So, the balance of the three hamstring muscles requires continuous care for good performance.

The athletes who participated in this study are outstanding players. The stature and body weight differences between the high school and university female athletes were not significantly large, but the university male athletes were taller and heavier than the high school athletes. Although there were these physical differences among the male athletes, it was difficult to analyze how this affected their spines and BMD. The effects of the spinal morphological differences on the performance of the spine require further analysis. In addition, we regret that the study cohort was not larger. We think these areas mentioned above are the limitations of this study.

Conclusion

The female athletes had greater kyphotic angles than the male athletes. Their lordotic angles were also greater than the male athletes' lordotic angles, and the high school female athletes (HFAs) were similar to the general females (GFs). The kyphotic apexes in the high school male athletes (HMAs) were higher than they were in the university male athletes (UMAs) and the kyphotic apexes of the HFAs were higher than they were in the university female athletes (UFAs). In both sexes, the kyphotic apexes were higher in the high school athletes than they were in the university athletes. The lordotic apexes were higher in the UMAs than they were in the HMAs. However, in the female athletes, the lordotic apexes were higher in the HFAs than they were in the UFAs.

Disclosure of conflict of interest

None.

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