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Differences in Body Composition of Upper and Lower Limbs in Elite Taekwondo Athletes

Diferencias en la Composición Corporal de los Miembros Superiores e Inferiores en Atletas de Taekwondo de Élite

MinSoo Jeon[1]; Anna Jeon[2] & Je-Hun Lee[3]

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SUMMARY: In this study, we analyzed the differences in body composition among athletes during different stages of their career Forty taekwondo athletes and 10 non-athletes (20 males and 30 females) with a mean age of 18.2 years (range, 15-23 years), a mean height of 173.4 cm, and a mean body weight of 64.8 kg were studied using dual energy X-ray absorptiometry and Biodex balance system. The bone mineral density of upper and lower limbs was higher among university athletes of both sexes than in high school athletes. The lean body mass of male athletes in the university was higher than in high school male athletes. By contrast, in case of females, the opposite results were obtained for the upper and lower limbs. Elucidation of the body composition according to career and sex of taekwondo athlete is worthwhile.

KEY WORDS: Taekwondo; Body composition; Upper limb; Lower limb.

INTRODUCTION

Each athlete engaged in various sports may exhibit unique physical traits, which differ from that of a non-athlete (Seo *et al*., 2015; Noh *et al*., 2015; Reale *et al*., 2019). Previous studies reported the differences in body composition among soccer players (Noh *et al*.). The differences in body composition affect an athlete's performance while other studies report that the association between physical traits and athletic performance is still unknown (Seo *et al*.).

In taekwondo, the ability to maintain body balance during movement is important, and is directly related to performance (Cha & Oh, 2016). Studies suggest that elite athletes carry higher lean body mass and lower fat than non-elite athletes (Seo *et al*.). In relation to physical fitness, factors such as agility, strength, endurance and flexibility are considered very important in taekwondo competition.

Motor coordination including movement, jumping and walking sideways is better among medal-winning taekwondo players than in non-medal winners (Wazir *et al*., 2019). However these results are predictable. Further information focusing on morphological parameters such as bone mineral density (BMD), spine structure and function is needed for investigation into the differences in performance of young and other athletes. Body composition information facilitates the design of training programs by coaches and indicates the performance potential of an athlete.

Comparison of the body composition between taekwondo athletes at high school and university and the general public and university students or the differences in body composition according to taekwondo career have yet to be reported. Therefore, the purpose of this study was to correlate the body composition of each athlete with performance.

MATERIAL AND METHOD

Dual-energy X-ray absorptiometry. Forty taekwondo athletes and 10 non-athletes (20 males and 30 females) with a mean age of 18.2 years (range, 15-23 years), a mean height of 173.4 cm, and a mean body weight of 64.8 kg were studied.

[1] Department of Sport Science, College of Sports Science, Korea National Sport University, Seoul, Korea.
[2] Department of Anatomy, College of Medicine, Chung-Ang University, Seoul, Korea.
[3] Anatomy laboratory, College of Sports Science, Korea National Sport University, Seoul, Korea.
Minsoo Jeon and Anna Jeon equally contributed to this research.

The body fat, bone mineral content (BMC), lean muscle mass and BMD of upper and lower limbs were calculated using dual-energy X-ray absorptiometry (DXA, Hologic ZDR 4500, USA).

Biodex balance system (Biodex medical system, Shirley, NY). Forty taekwondo athletes (20 males and 20 females) with a mean age of 19.2 years (range, 15-23 years), a mean height of 176.3 cm, and a mean body weight of 67.0 kg were studied. This study excluded non-athletes from the biodex balance system because the personal status of the general person played a strong role. Among athletes of both sexes, this study measured the stability in stage 6 including the medial-lateral stability index, anterior-posterior stability index and the overall stability index.

In this study, the SPSS 21.0 (SPSS science, Chicago, USA) statistical program was used to identify differences between 5 groups of athletes (high school males, high school females, university males, university females, and general females). Statistical methods included ANOVA, and post-hoc Bonferroni correction. The significance level was set at a P value of 0.05.

RESULTS

The results of BMD involving the lower limb based on the sex and age of taekwondo players showed statistically significant difference ($F = 20.336$, $P < .001$).

The BMD of all taekwondo athletes was higher than that of the general females (GF). Athletes at university belonging to both sexes showed a higher value than those at high school. Nonetheless, the female athletes in high school showed a higher value than that of the GF (Table I).

The body mass index (BMI) of lower limb in the specimens based on the sex and age of taekwondo players showed a statistically significant difference as follows: Left ($F =12.919$, $P < .001$), Right ($F =13.208$, $P < .001$) and Both ($F =13.446$, $P < .001$).

Table II shows the BMI of lower limb. The BMI of university male athletes (UMA) was higher than that of high school male athlete (HMA), whereas the BMI of high school female athlete (HFA) was higher than that of university

Table I. Bone mineral density (BMD) of lower limb

Factor		M	SD	F	p	post-hot
BMD	HMA	1.49	0.119	20.336	<.001	HMA>HFA, HMA>GF, UMA<HFA, UMA>GF HFA>UFA, HFA> GF, UFA>GF
	HFA	1.41	0.061			
	UMA	1.63	0.112			
	UFA	1.43	0.081			
	GF	1.23	0.070			

HMA: high school male athlete, HFA: high school female athlete, UMA: university male athlete, UFA: university female athlete, GF: general female

Table II. Body mass index of lower limb of the specimen [unit: kg/m^2]

Factor		M	SD	F	p	post-hot
Left	HMA	12.44	1.70	12.919	<.001	HMA>HFA,HMA>GF, UMA<HFA, UMA>GF, HFA>UFA, HFA>GF
	HFA	12.10	1.15			
	UMA	14.59	1.934			
	UFA	11.08	1.33			
	GF	9.72	0.76			
Right	HMA	12.37	1.64	13.208	<.001	HMA<HFA, HMA>GF, UMA<HFA, UMA>GF, HFA>UFA, HFA>GF,
	HFA	12.23	0.10			
	UMA	14.69	1.91			
	UFA	11.18	1.48			
	GF	9.67	1.01			
Both	HMA	24.81	3.33	13.446	<.001	HMA<HFA, HMA>GF, UMA<HFA,HFA>UFA, HFA>GF
	HFA	24.33	2.10			
	UMA	29.30	3.77			
	UFA	22.26	2.79			
	GF	19.37	1.75			

HMA: high school male athlete, HFA: high school female athlete, UMA: university male athlete, UFA: university female athlete, GF: general female.

female athlete (UFA). Overall, the BMI of athletes was higher than that of GF.

The results of lean body mass involving lower limb based on sex and age of taekwondo players showed statistically significant differences as follows: Left (F = 34.825, P < .001), Right (F = 31.724, P < .001), and Both (F = 33.978, P < .001).

Table III shows the lean body mass of lower limb. In the male athlete, the UMA showed a higher value compared with that of HMA. However, the HFA carried a higher value of lean body mass than the UFA. Compared with the GF, athletes also exhibited a higher lean body mass of the lower limb.

The BMC of the lower limb in the specimen based on sex and age of taekwondo players showed statistically significant difference as follows: Left (F = 24.296, P < .001), Right (F = 25.883, P < .001), and Both (F = 25.518, P < .001).

Table IV shows the BMC of lower limb. Among athletes of both sexes, the males showed a higher value than females among university and high school players. Compared with the GF, athletes also showed a higher BMC of lower limb.

Table III. Body lean of lower limb of the specimen [unit: g].

Factor		M	SD	F	p	post-hot
Left	HMA	10444.2	1286.1	34.825	<.001	HMA>UMA,HMA>UFA, HMA>GF, UMA<HFA, UMA>GF, HFA>UFA, HFA>GF
	HFA	8402.7	689.8			
	UMA	11663.0	1623.9			
	UFA	7743.9	818.9			
	GF	6458.7	431.1			
Right	HMA	10392.3	1266.1	31.724	<.001	HMA>UMA, HMA>UFA, HMA>GF, UMA<HFA, UMA>GF, HFA>UFA, HFA>GF
	HFA	8502.5	724.7			
	UMA	11756.7	1711.9			
	UFA	7806.6	931.3			
	GF	6421.4	606.6			
Both	HMA	20836.4	2535.9	33.978	<.001	HMA>UMA,HMA>UFA, HMA>GF, UMA<HFA, UMA>GF, HFA>UFA. HFA>GF
	HFA	16905.1	1377.3			
	UMA	23419.9	3300.2			
	UFA	15550.7	1735.2			
	GF	12879.7	1021.2			

HMA: high school male athlete, HFA: high school female athlete, UMA: university male athlete, UFA: university female athlete, GF: general female.

Table IV. Bone mineral content of lower limb of the specimen [unit: g]

Factor		***M***	***SD***	***F***	***p***	***post-hot***
Left	HMA	652.3	107.5	24.296	<.001	HMA<HFA, HMA>GF, UMA<HFA, UMA>GF, HFA>UFA, HFA>GF, UFA>GF
	HFA	556.9	39.4			
	UMA	788.6	125.5			
	UFA	564.5	59.8			
	GF	406.3	45.9			
Right	HMA	651.1	92.9	25.883	<.001	HMA>UMA,HMA>GF, UMA<HFA,UMA>GF, HFA>UFA,HFA>GF, UFA>GF
	HFA	565.4	30.8			
	UMA	779.9	119.9			
	UFA	570.1	75.8			
	GF	406.6	39.9			
Both	HMA	1303.5	199.9	25.518	<.001	HMA>HFA,HMA>GF, UMA<HFA,UMA>GF, HFA<UFA, HFA>GF, UFA>GF
	HFA	1122.3	67.6			
	UMA	1568.5	243.8			
	UFA	1134.7	134.1			
	GF	812.8	85.4			

HMA: high school male athlete, HFA: high school female athlete, UMA: university male athlete, UFA: university female athlete, GF: general female.

The BMD of upper limb based on the sex and age of taekwondo players showed a statistically significant difference (F = 14.365, P < .001).

The BMD of all taekwondo athletes was higher than that of GF. Among the athletes, those in university belonging to both sexes showed a slightly higher value than the high school athletes (Table V).

The BMI of upper limb based on the sex and age of taekwondo players showed a statistically significant difference as follows: Left (F = 20.190, P < .001), Right (F =19.684, P < .001), and both (F = 20.796, P < .001).

Table VI shows the body mass of upper limb. In male athlete, the UMA showed a higher body mass than the HMA, whereas the HFA carried a slightly higher level than the UFA. Overall, the female athletes scored higher in body mass than the GF.

The lean body mass of upper limb based on the sex and age of taekwondo players varied statistically significantly as follows: Left (F = 49.447, P < .001), Right (F = 42.976, P < .001) and Both (F = 49.632, P < .001).

Table VII shows the lean body mass of upper limb. Among the male athletes, the UMA scored higher in lean body mass than the HMA. However, among female athletes, the HFA scored higher than the UFA. Athletes also scored higher than the GF in lean body mass.

The BMC of the upper limb of the specimen based on the sex and age of taekwondo players showed statistically significant difference as follows: Left (F = 24.450, P < .001), Right (F = 21.959, P < .001) and Both (F = 24.297, P < .001).

Table VIII presents the BMC of upper limb. Among athletes of both sexes, the male athletes scored higher than the female athletes at university and high school players. Among both sexes, the university athletes scored higher in BMC than the high school athletes. Athletes also scored higher than the GF.

Table V. Bone mineral density (BMD) of upper limb.

Factor	***M***	***SD***	***F***	***p***	***post-hot***
HMA	0.93	0.075			
HFA	0.85	0.047			
UMA	1.01	0.062	14.365	<.001	HMA>GF,UMA<HFA, HFA>UFA, HFA>GF,
UFA	0.86	0.058			
GF	0.81	0.040			

HMA: high school male athlete, HFA: high school female athlete, UMA: university male athlete, UFA: university female athlete, GF: general female.

Table VI. Body mass index of upper limb of the specimen [unit: kg/m^2].

Factor		M	SD	F	p	post-hot
Left	HMA	3.57	0.543	20.190	<.001	HMA<HFA,HMA>UFA, HMA>GF, UMA<HFA, HFA>UFA, HFA>GF,
	HFA	2.99	0.467			
	UMA	4.40	0.605			
	UFA	2.77	0.469			
	GF	2.50	0.195			
Right	HMA	3.74	0.646	19.684	<.001	HMA>UMA,HMA<HFA, HMA>UFA, HMA>GF, UMA<HFA, HFA<UFA, HFA>GF
	HFA	3.08	0.373			
	UMA	4.46	0.594			
	UFA	2.89	0.387			
	GF	2.63	0.224			
Both	HMA	7.31	1.160	20.796	<.001	HMA>UMA,HMA>HFA, HMA>UFA, HMA>GF, UMA<HFA, HFA>UFA, HFA>GF
	HFA	6.08	0.789			
	UMA	8.84	1.187			
	UFA	5.66	0.849			
	GF	5.14	0.424			

HMA: high school male athlete, HFA: high school female athlete, UMA: university male athlete, UFA: university female athlete, GF: general female.

Table VII. Body lean of upper limb of the specimen [unit: g].

Factor		M	SD	F	p	post-hot
Left	HMA	3.57	0.543	49.447	<.001	HMA>UMA,HMA<HFA, HMA>UFA, HMA>GF, UMA<HFA, HFA>UFA, HFA>GF
	HFA	2.99	0.467			
	UMA	4.40	0.605			
	UFA	2.77	0.469			
	GF	2.50	0.195			
Right	HMA	3.74	0.646	42.976	<.001	HMA>UMA,HMA<HFA, HMA>UFA, HMA>GF, UMA<HFA, HFA>UFA, HFA>GF
	HFA	3.08	0.373			
	UMA	4.46	0.594			
	UFA	2.89	0.387			
	GF	2.63	0.224			
Both	HMA	7.31	1.160	49.632	<.001	HMA>UMA,HMA<HFA, HMA>UFA, HMA>GF, UMA<HFA, HFA<UFA, HFA>GF
	HFA	6.08	0.789			
	UMA	8.84	1.187			
	UFA	5.66	0.849			
	GF	5.14	0.424			

HMA: high school male athlete, HFA: high school female athlete, UMA: university male athlete, UFA: university female athlete, GF: general female.

Table VIII. Bone mineral content of upper limb of the specimen [unit: g].

Factor		M	SD	F	p	post-hot
Left	HMA	193.0	31.5	24.450	<.001	HMA>UMA,HMA<HFA, HMA>GF, UMA<HFA, HFA>UFA, HFA>GF, UFA>E
	HFA	155.7	16.6			
	UMA	240.0	37.7			
	UFA	159.8	22.6			
	GF	124.8	9.1			
Right	HMA	204.4	38.4	21.959	<.001	HMA>UMA,HMA<HFA, HMA>UFA, HMA>GF, UMA<HFA, HFA>UFA, HFA>GF
	HFA	160.6	15.6			
	UMA	247.9	37.2			
	UFA	162.8	19.2			
	GF	134.9	13.7			
Both	HMA	397.3	69.1	24.297	<.001	HMA>UMA,HMA<HFA, HMA>UFA, HMA>GF, UMA<HFA, HFA>UFA, HFA>GF,
	HFA	316.3	28.2			
	UMA	488.0	74.5			
	UFA	322.7	40.9			
	GF	259.6	21.1			

HMA: high school male athlete, HFA: high school female athlete, UMA: university male athlete, UFA: university female athlete, GF: general female

The analysis of right lower limb using biodex balance system of the specimen based on the sex and age of taekwondo players showed statistically significant differences as follows: Both F = 3.673, P = .022.

The values on the right side of biodex balance system in stage 6 suggest that the HMA (mean 1.54) carried a lower index value than the UMA (mean 1.89) among male athletes, whereas the UFA (mean 1.16) showed a lower index value than the HFA (mean 1.77) in terms of overall stability on the right side. The HMA (mean 1.12) and UFA (mean 0.95) showed a lower index value in the anterior-posterior stability test compared with athletes of the same sex. The HMA (mean 0.93) and UFA (mean 0.61) scored lower index values than the same-sex athletes in medial-lateral stability test (Table IX).

The results of right lower limb using biodex balance system of the specimen based on the sex and age of taekwondo players showed statistically significant

differences as follows: Left (F = 3.411, P = .028) and Both (F = 7.437, P < .001).

The value on the left side of biodex balance system in stage 6 suggest that the HMA (mean 1.55) scored lower index values than UMA (mean 2.17) among male athletes, whereas the UFA (mean 1.11) showed a lower index value than the HFA (mean 1.43) in overall stability on the right side. The HMA (mean 1.41) and UFA (mean 0.84) showed less index values than same-sex athletes in anterior-posterior stability test. The HMA (mean 0.91) and UFA (mean 0.67) exhibited reduced index values than the same-sex athletes on medial-lateral stability test (Table X).

Table IX. The results of right lower limb using biodex balance system .

Factor		*M*	*SD*	*F*	*p*	*post-hot*
Left	HMA	1.54	0.47	2.565	.072	
	HFA	1.77	0.81			
	UMA	1.89	0.83			
	UFA	1.16	0.60			
Right	HMA	2.367	.089	2.367	.089	
	HFA	1.12	0.33			
	UMA	1.68	1.03			
	UFA	1.23	0.53			
Both	HMA	0.95	0.43	3.673	.022	UMA>UFA, HFA>UFA
	HFA	3.673	.022			
	UMA	0.93	0.33			
	UFA	1.08	0.67			

HMA: high school male athlete, HFA: high school female athlete, UMA: university male athlete, UFA: university female athlete.

Table X. The results of left lower limb using boidex balance system of the specimen.

Factor		*M*	*SD*	*F*	*p*	*post-hot*
Left	HMA	1.55	0.444	3.411	.028	HFA>UFA
	HFA	1.43	0.611			
	UMA	2.17	1.188			
	UFA	1.11	0.328			
Right	HMA	1.41	1.014	.967	.419	
	HFA	1.27	1.082			
	UMA	1.58	1.042			
	UFA	0.84	0.265			
Both	HMA	0.91	0.102	7.437	.001	HMA<HFA, HFA>UFA
	HFA	0.94	0.114			
	UMA	1.23	0.440			
	UFA	0.67	0.295			

HMA: high school male athlete, HFA: high school female athlete, UMA: university male athlete, UFA: university female athlete.

DISCUSSION

This study was prompted by concerns of injury involving taekwondo athletes engaged in high kicks or performing sophisticated kicking techniques. It was also motivated by an interest in the differences in body composition according to the career and sex of taekwondo athlete. The comparison of body composition between athletes and general public was investigated before. The BMD and BMC of the cyclist were lower than in control; however, the lean mass was higher than in control (Pimentel *et al*., 2019). Other research studies reported that the BMD and BMC of non-aquatic athletes such as football players were higher than those of aquatic athletes such as swimmers and both were higher than in controls (Bellver *et al*., 2019). In this study, the BMD and BMC of taekwondo athletes of both sexes were higher

than in controls; however, the differences were greater in the lower than in upper limb. Based on these results, the taekwondo athletes are more likely to use their lower limb and exhibit a greater difference in BMD and BMC compared with controls. As indicated above, the high scores of non-aquatic athletes due to terrestrial exercises appear to result in a greater effect on BMD and BMC. Despite the positive effect of exercise on BMD, it is difficult to correlate between BMD and athlete performance (Alonso *et al*., 2019).

Among the athletes, the higher body weight seems to suggest a higher BMD (Byun *et al*., 2015). The BMD among high school participants and university athletes in this study was not analyzed according to body weight. However, in both sexes, the higher BMD of the university athletes compared with the high school athletes affected BMD according to exercise levels. All the athletes who participated in this study were top-ranking players of similar age.

A previous study reported that the BMI of the athletes was lower than that of non-athletes (Pimentel *et al*.). By contrast, the present study showed that the BMI of lower and upper limbs was higher than in non-athletes. However, no study investigated the effect of BMI on athletic performance. However, a few studies focused on the differences with body weight and age (Byun *et al*.; Nikolaidis *et al*., 2016; Reale *et al*.). Overall, taekwondo athletes of both sexes tended to show an increase in BMI with age as reported previously (Nikolaidis *et al*.). This study involving female high school athletes' upper and lower limbs showed a higher BMI than in university athletes, whereas in male athletes at the university was scored than the athletes in high school (Table II and 6). These results are contrary to previous reports.

Results of lean body mass involving upper and lower limbs in this study showed that older female athletes scored lower than younger female athletes whereas the opposite was true in males (Tables III and VII). Other studies showed that lean body mass was decreased with age among runners (Alonso *et al*.); however, in this study only female athletes showed a decrease in lean body mass of upper and lower limbs.

The bilateral balance test demonstrated that male athletes in high school performed better than male athletes in university; however, female athletes at university were better than female athletes in high school. These results are too difficult to explain because all participants were high-ranking athletes.

Among male participants, 16 % of high school athletes and 85 % of university athletes were experienced, which might have influenced the balance test. However, the study limitation relates to the lack of investigation into the extent of injury and current recovery status. In addition, previous animal studies have shown that the ability for balance decreases with age (Silveira *et al*., 2019), and no such correlation was found in this study. Additional research is needed to analyze the differences between balance and performance, and age and sex in professional athletes.

The factors underlying the higher lean body mass in the UMA than in HMA, and in HFA than in UFA may be related to differences in body weight. The average weights of UMA, HMA, UFA, and HFA were 80 kg, 69 kg, 59 kg and 63 kg, respectively. Further analysis into these differences in body weight may elucidate the differences in lean body mass.

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RESUMEN: En este estudio, analizamos las diferencias de la composición corporal entre los atletas durante las diferentes etapas de su carrera. Se estudiaron cuarenta atletas de taekwondo y 10 no atletas (20 hombres y 30 mujeres) edad media de 18,2 años (rango, 15-23 años), una altura media de 173,4 cm y un peso corporal medio de 64,8 kg. Se utilizaron la absorciometría de rayos X de energía dual y el sistema de equilibrio Biodex. La densidad mineral ósea de las miembros superiores e inferiores fue mayor entre los atletas universitarios de ambos sexos, que en los atletas de educación secundaria. La masa corporal magra de los atletas varones en la universidad fue mayor que en los varones de la educación secundaria. Por el contrario, en el caso de las mujeres, se obtuvieron los resultados opuestos para las miembros superiores e inferiores. En conclusión se debe considerar un análisis de la composición corporal según la carrera y el sexo del atleta de taekwondo.

PALABRAS CLAVE: Taekwondo; Composición corporal; Miembro superior; Miembro inferior.

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Corresponding author:
Professor Je-Hun Lee
Anatomy Laboratory
College of Sports Science
Korea National Sport University
Seoul
KOREA

Email: leejehun@knsu.ac.kr

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