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The Characteristics of Skinfold Thiackness and Muscle Mass of Judo and Taekwondo Athletes

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Abstract

Background/Objectives: This study was conducted to identify the skinfold thickness and the characteristics of muscle mass of judo and taekwondo athletes by comparing the data on those athletes with the data on non-martial art athletes engaged in sporting activities. **Methods/Statistical Analysis:** For the purpose, 20 collegiate athletes were selected from collegiate judo and taekwondo athletes and handball, rugby, table tennis and badminton players of the same ages. So, a total of 120 collegiate athletes were selected as participants in this study. And we evaluated skinfold thickness and muscle mass components based on the anthropometry manual presented by International society for accreditation kinanthropometry. **Findings:** We showed that judo athletes had larger skinfold thickness and muscle mass than the mean compared with non-martial arts players; taekwondo athletes, who are martial arts athletes similar to judo athletes, had very small skinfold thickness compared with non-martial arts players and a little larger muscle mass than racket sports players such as badminton and table tennis players. Application/Improvements: It is confirmed that the formula used by this study was appropriate for determining the ranking of muscle masses of athletes by sport types and available for their comparison with the muscle masse of a corpse.

Keywords: Judo, Muscle Mass, Non-Martial Arts, Skinfold Thickness, Taekwondo

1. Introduction

It is known that the amount and percentage of skeletal muscle, body fat and adipose tissue, which are the important factors of body composition, affect health, physical fitness and exercise capacity[1,2]. Thus, different studies have been conducting regarding the estimation of amount of body fat. The studies related to body composition are mainly classified into studies using an organic approach and studies using an anatomical approach and more specifically, can be classified into 5 levels: Atom, molecule, cell, tissue and body. Studies of body composition conducted in the area of physical education are conducted at the level of tissue[3]. As stated above, a considerable number of studies have been conducted on body composition at the tissue level. However, it is not easy to find a domestic study that has focused on predicting or evaluating athletic performance based on an estimation of muscle mass, because researchers are more interested in fat distribution. Real corpses that were cut open for anatomy purposes had been previously used for studies conducted on muscle mass. However, most of the corpses used were the dead bodies of elderly people who had died from old age or young people who had died from malnutrition or lack of activity as a result of long-term imprisonment. Furthermore, since the number of samples was limited, it was inappropriate to generalize the result. As Dual Energy X-ray Absorptiometry (DXA) or Magnetic Resonance Image (MRI) have been recently applied to anthropometry with the development of different investigation instruments, it has become possible to accurately quantify human body composition. However, such investigations face problems such in terms of time and expense. To tackle these problems, methods to make anthropometric measurements easier and more cost-effective and to increase sample stability have been recently applied.

It is reported that the variables of anthropometric measurement are appropriate for a sharp analysis regarding short term changes in muscle mass and evaluation

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of athletic performance improvement[4]. In addition, it is also reported that, since such measurements can be taken using multiple cases, their external validity is relatively high. In the estimation of muscle mass using anthropometric measurement, variables should be selected that the part of the muscle mass that is measured can represent the total muscle mass.

Previous studies using corpses among the studies on muscle mass estimation were conducted targeting a total of 25 persons including 9 adult males in the 19th century[5], 4 adult males in 1945 and 1956 and 12 adult males in a Brussels cadaver study. The mean of muscle mass in the corpse studies ranged from 15.8 kg to 40.4 kg; fat mass ranged from 27.4% to 49.1% and fat-free mass ranged from 36.6% to 59.0%. 62 male athletes and 13 ordinary men were selected to study muscle mass estimation using an anthropometer[6]. The study results revealed that the mean of muscle mass ranged from 38.4 kg to 58.7 kg; fat mass percentage (%MM) ranged from 56.5% g to 65.1%. These results showed that muscle mass estimated using an anthropometer was overestimated compared with muscle mass estimated using a corpse. Under conditions where judo and taekwondo athletes' physical fitness and body composition such as subcutaneous fat and muscle mass vary according to their sport types, this study was designed to compare their characteristics with those of non-martial arts athletes. In other words, the purpose of this study is to verify whether body fat and muscle mass are valid as factors of body composition to distinguish the sport types in which athletes are involved, by comparing the data about judo and taekwondo athletes' body composition with players in ball games such as handball and rugby and racket games such as badminton and table tennis.

2. Study Method

2.1 Subject of Study

This study was conducted to identify the patterns of judo and taekwondo athletes' subcutaneous fat and muscle mass by comparing whether there is any difference between those athletes' body composition and non-martial arts athletes' body composition. As shown in Table 1, 20 collegiate athletes were selected from collegiate judo and taekwondo athletes and handball, rugby, table tennis and badminton players of the same ages in non-martial arts were also selected. So, a total of 120 collegiate athletes were selected as participants in this study .

Table 1. The number of samples by sports of study participants

	physical match game		non-physical match game			
	judo	*taekwondo*	*hand-ball*	*rugby*	*table tennis*	*badminton*
case	20	20	20	20	20	20

2.2 Measurement Method and Instrument

This study established the methods to properly evaluate skinfold thickness and muscle mass components based on the anthropometry manual presented by International Society for Accreditation Kinanthropometry (ISAK). The height and weight and the skinfold thickness and muscle mass components of the selected samples were measured using the following methods:

2.2.1 Height

A subject was made to stand upright on the foot platform of a height meter with a feet drawing and buttocks, back, heels, back of the head against the height rod and with the chin tucked in, to look straight ahead and to straighten knees and then, subject's height was measured in cm by pushing a measuring ruler down until it rests on the top of the head.

2.2.2 Weight

A subject was made to step on the scales in a swimming suit and his/her height was measured after taking a leak and a dump if possible. Weight was measured using a CAS-manufactured product having passed through the phase of calibration before measurement.

2.2.3 Measurement of Skinfold Thickness

The measurement of skinfold thickness was targeted at 4 regions including triceps, forearm lateralis, forearm volaris and mid thigh. An investigator precisely adjusted the pressure of a measurement instrument within the scope of international accreditation standards (10 g/mm) before measurement and repeatedly measured each region by 0.1 cm three times to record the measurements. Specific measurement methods by regions are as follows:

- Triceps: mm

The right elbow of a subject standing to attention was made to be bent at 90° and a region for measurement was first determined by an X marking at the mid point of the bottom end of an elbow and the shoulder acromion.

While using the thumb and index finger of the left hand, an investigator held a region about 1 m up off the region marked already for measurement and he measured that region in mm using a measurement instrument.

- Forearm lateralis: mm

The skinfold thickness of the maximal forearm region was measured in mm with the forearm lateralis in an anatomical position with the palm directed toward the front.

- Forearm volaris: mm

The skinfold thickness of the maximal forearm region was measured in mm with the forearm volaris in an anatomical position with the palm directed toward the front.

- Mid thigh: mm

While a subject was standing to attention, an investigator determined a region for measurement with an X marking at the midpoint between the boundary point of the mid patella and the inguinal crease on the central line of the anterior mid thigh.

While using the thumb and index finger of the left hand, an investigator held, by a depth of 1 cm, a region about 1 m up off the region marked already for measurement and he measured that region in mm using a measurement instrument. During the measurement, a subject kept shifting the weight to the left leg (or the right leg) and bending the right (or the left) knee a little with the right leg (or the left leg) relaxed.

2.2.4 Measurements of Body Circumference

Body circumference measurement was carried out for upper arm girth, maximal forearm girth, mid thigh girth and maximal calf girth. The mid regions of the upper arm and mid thigh were marked using a measurement instrument. The circumferences of each region were repeatedly measured by 0.1 cm three times using an iron tape measure and the measurements were recorded. Specific methods by regions are as follows:

- Maximal upper arm girth: cm

The right elbow of a subject standing to attention was made to be bent at 90° and a region for measurement was first determined by an X marking at the midpoint of the bottom end of an elbow and the shoulder acromion. Then, the region was measured in a direction perpendicular to the longitudinal axis from the center of the upper arm using a tape measure.

- Maximal forearm girth: cm

The maximal circumference of the proximal region of the forearm was measured. While a subject was standing to attention with the arm extended from a cross section, an investigator stood behind the arm of the human subject and selected and measured the maximal girth of a region of forearm which included its most developed muscle, in a direction perpendicular (aside) to the longitudinal axis, using a tape measure.

- Mid thigh girth: cm

A subject was made to stand to attention and to position the feet 10 cm wider apart than shoulder width so that subject's weight could be evenly distributed across the body. After an investigator sat before and on the right (or left) hand side of a human subject and an X marked the midpoint between the great trochanter of the femur and lateral tibia, the investigator measured in a direction perpendicular to the longitudinal axis using a tape measure.

- Maximal calf girth: cm

A subject was made to stand to attention and to position the feet shoulder width apart so that his weight could be evenly distributed across the body. After an investigator sat on the right hand side of the subject, the investigator selected and measured the maximal girth of a region of calf which included its most developed muscle, in a direction perpendicular to the longitudinal axis, using a tape measure.

2.2.5 Measurement of Muscle Mass

The estimation of muscle mass conducted in this study was carried out using the formula for males formulated by reference applied as the existing method of muscle mass measurement.

$$\text{KgM} = [\text{height} \cdot (0.0553\text{CTG2} + 0.0987\text{FG2} + 0.0331\text{CCG2}) - 2445] \cdot 0.001$$

$$\%\text{M} = (\text{ck}/\text{body mass}) \cdot 100$$

Wherein,

CTG (free – fat mid thigh) = mid thigh – pi (medical calf SF/10)

CCG (free – fat calf circumference) = calf circumference – pi (medical calf SF/10)

FG = forearm girth

2.3 Data Processing Method

A relational analysis among variables selected to measure subcutaneous fat and body circumference was conducted using the Pearson product-moment correlation coefficient formula. The method for analysis of variance was applied to the difference between the means of fat mass and muscle mass to identify the difference between judo and taekwondo athletes' characteristics and non-martial arts athletes'. The level of acceptance of hypothesis (α) in variance analysis was set to .05. In cases where the effects of interaction showed statistical significance between independent variables, testing simple effect using a posteriori test was carried out. These data were electronically processed using SPSS22 program for Windows.

3. Statistical Results

3.1 The Difference in Corrected Upper Arm Circumferences between Groups

Table 2 shows the average (ū) and standard deviation (s) of upper arm circumferences corrected between judo and taekwondo athlete groups and non-martial arts athlete groups. Also, Table 3 shows the results of variance analysis to test whether there was a difference between the averages of upper arm circumstances corrected between groups or not. As shown in Table 3, the average of upper arm circumstances corrected between groups was $F(5,121) = 23.71$, which means that there was a statistically significant difference at a level of $p<.001$.

According to those results, the average of corrected upper arm circumstances was highest in judo athlete group (ū = 31.41) followed by the rugby player group (ū = 30.34), handball player group (ū = 28.13), table tennis player group (ū = 27.68), badminton player group (ū = 26.24) and taekwondo athlete group (ū = 26.05). Consequently, it can be known that the level of corrected upper arm circumstances affects the identification of the characteristics of groups.

Post-hoc tests of what difference in corrected upper arm circumferences those differences made were carried out using Scheffe's method. This difference was relatively high in judo and rugby groups compared with taekwondo, badminton, table tennis and handball groups. According to these results, the corrected upper arm circumstances of the athletes in judo, which a martial arts

Table 2. The average and standard deviation of each variable among groups

	age	ht	body mass	SS	Ga	Gf	Gt	Gc	MM	%MM
type	(year)	(cm)	(kg)	(mm)	(cm)	(cm)	(cm)	(cm)	(kg)	(%)
total	20.20	176.82	76.55	30.95	28.82	27.69	54.04	37.59	48.09	62.94
	1.24	5.84	12.16	10.56	2.96	1.98	3.93	2.60	7.27	3.38
1. taekwondo	20.00	176.68	70.99	24.66	26.05	26.13	52.95	37.38	45.26	63.78
	1.33	730	9.48	790	2.05	152	295	225	6.09	2.23
2. judo	20.09	175.77	82.78	36.98	31.41	29.28	54.97	38.09	50.66	61.29
	1.10	5.51	13.37	12.30	2.39	2.38	4.16	2.65	8.03	3.75
3. hand-ball	20.29	179.13	74.26	27.09	28.13	27.58	53.39	37.70	47.80	64.34
	1.27	5.57	5.51	7.39	1.35	1.11	2.63	2.18	4.53	3.26
4. rugby	20.17	177.90	83.96	31.57	30.34	28.21	57.09	39.61	53.07	63.50
	1.20	4.85	13.85	10.92	2.51	1.46	4.37	2.18	7.32	3.72
5. badminton	20.14	175.74	70.12	30.54	26.24	26.60	52.87	36.41	44.86	63.91
	1.17	6.73	6.98	8.24	1.79	1.01	2.90	1.79	5.27	2.47
6. table tennis	20.69	175.46	67.81	30.47	27.68	26.61	50.75	34.69	41.88	61.84
	1.49	5.12	6.06	8.53	2.27	.83	2.10	1.43	3.63	2.62

sport, revealed a considerable difference from those of the athletes in different sports.

3.2 The Difference in Corrected Forearm Circumferences between Groups

Table 4 shows the results of variance analysis to test whether there was a difference between the averages of maximal forearm circumstances between groups or not. As shown in Table 4, the average of maximal forearm circumstances between groups is F(5,121) = 12.94, which means that there is a statistically significant difference at a level of p<.001.

According to these results, the average of maximal forearm circumstances was highest in judo athlete group (ū = 29.28) followed by rugby player group (ū = 28.21), handball player group (ū = 27.58), table tennis player group (ū = 26.61), badminton player group (ū = 26.61) and taekwondo athlete group (ū = 26.13). Consequently, it can be known that the level of maximal forearm circumstances affects the identification of the characteristics of groups.

Post-hoc tests of what difference in maximal forearm circumferences between groups those differences made were carried out using Scheffe's method. These results show that there was a difference between the rugby player group and taekwondo athlete group and that there was also a difference between the judo athlete group and taekwondo, badminton, table tennis and handball player groups. According to these results, taekwondo athletes revealed a difference compared to rugby players in maximal forearm circumference and judo athletes showed a difference from non-martial arts athletes in this respect also.

Table 3. An variance analysis on corrtaected upper arm circumstances

	SS	df	MS	F
between	546.30	5	109.26	23.71***
within	557.61	121	4.61	
total	1103.91	126		

Table 4. A variance analysis on corrected maximal forearm circumstances

	SS	df	MS	F
between	171.35	5	34.27	12.94***
within	320.36	121	2.65	
total	491.72	126		

3.3 The Difference in Corrected Mid Thigh Circumferences between Groups

Table 5 shows the results of variance analysis to test whether there was a difference between the averages of maximal mid thigh circumstances corrected between groups or not. As shown in Table 5, the average of maximal forearm circumstances corrected between groups is F(5,121) = 7.85, which means that there is a statistically significant difference at a level of p<.001.

According to these results, the mean of corrected mid thigh circumstances was highest in the rugby player group (ū = 57.09) followed by the judo athlete group (ū = 54.97), handball player group (ū = 53.39), taekwondo athlete group (ū = 52.95), badminton player group (ū = 52.87) and table tennis player group (ū = 50.75). Consequently, it can be known that the level of corrected mid thigh circumstances affects the identification of the characteristics of groups.

Post-hoc tests of what difference in mid thigh circumferences corrected between groups those differences made were carried out using Scheffe's method. The results show that there was a difference between the judo athlete group and table tennis player group. Also, there was a difference between the taekwondo athlete group and ruby player group. Those results show that there was a significant difference between corrected mid thigh circumferences of judo athletes and table tennis players. Also, taekwondo athletes has difference from rugby players.

3.4 The Difference in Corrected Calf Circumferences between Groups

Table 6 shows the results of variance analysis to test whether there was a difference in the averages of corrected calf circumferences between groups or not. As shown in Table 6, the average of corrected calf circumstances between groups is F(5,121) = 10.67, which means that there is a statistically significant difference at a level of p<.001.

Table 5. A variance analysis on corrected mid thigh circumstances

	SS	df	MS	F
between	475.78	5	95.16	7.85***
within	1466.20	121	12.12	
total	1941.97	126		

According to these results, the average of corrected calf circumstances was highest in the rugby player group (ū = 39.61) followed by the judo athlete group (ū = 38.09), handball player group (ū = 37.70), taekwondo athlete group (ū = 37.38), badminton player group (ū = 34.69) and table tennis player group (ū = 50.75). Consequently, it can be known that the level of corrected calf circumstances affects the identification of the characteristics of groups.

Post-hoc tests of any difference in calf circumferences were carried out using Scheffe's method. According to the results, judo and taekwondo athlete groups showed a statistically significant difference from the table tennis player group in calf circumferences. The result didn't show a difference between judo and taekwondo athletes and table tennis players revealed shorter circumferences compared with judo and taekwondo athletes.

3.5 The Difference in Muscle Mass between Groups

Table 7 shows the results of variance analysis to test whether there was a difference in the averages of muscle mass between groups or not. As shown in Table 7, the average of muscle mass between groups is $F(5,121) = 8.48$, which means that there is a statistically significant difference at a level of $p<.001$.

In comparison of the average of muscle mass, the muscle mass was highest in the rugby player group (ū = 53.07) followed by the judo athlete group (ū = 50.66), handball player group (ū = 47.80), taekwondo athlete group (ū = 45.26), badminton player group (ū = 44.86) and table tennis player group (ū = 41.88). Consequently, it can be known that the level of muscle mass affects the identification of the characteristics of groups.

Table 6. A variance analysis on corrected calf circumstances

	SS	df	MS	F
between	206.87	5	52.17	10.67***
within	591.51	121	4.89	
total	852.38	126		

Table 7. The results of variance analysis on muscle mass between groups

	SS	df	MS	F
between	1727.95	5	345.59	8.48***
within	4933.43	121	40.77	
total	6661.39	126		

Table 8. A variance analysis on the sum of skinfold thicknesses

	SS	df	MS	F
between	2281.68	5	456.34	4.69***
within	11769.47	121	97.27	
total	14051.15	126		

Meanwhile, Post-hoc tests of any difference in the averages of muscle mass between groups were carried out using Scheffe's method. According to the results, there was a difference between rugby players and taekwondo athletes and there was a difference between judo athletes, taekwondo athletes, badminton players, table tennis players and handball players.

3.6 The Difference in the Sum of Skinfold Thicknesses

Table 8 shows the results of variance analysis to test whether there was a difference in the averages of the sum of skinfold thicknesses between groups or not. As shown in Table 8, the sum of skinfold thicknesses between groups is $F(5,121) = 4.69$, which means that there is a statistically significant difference at a level of $p<.001$.

According to the average of the sum of skinfold thicknesses, the average was highest in the judo athlete group (ū = 36.94), followed by he rugby player group (ū = 31.57), badminton player group (ū = 30.54), table tennis player group (ū = 30.47), handball player group (ū = 27.09) and taekwondo athlete group (ū = 24.66). Consequently, it can be known that the level of the sum of skinfold thicknesses affects the identification of the characteristics of groups.

Post-hoc tests of any difference in the sum of skinfold thicknesses between groups were carried out using Scheffe's method. According to the results, there was a difference between judo athletes and taekwondo athletes.

4. Discussion and Conclusion

This study was conducted to compare and analyze the anthropometric characteristics of collegiate male athletes in judo and taekwondo, which are among the martial arts sports and those of collegiate male players in handball, rugby, table tennis and badminton which are among non-martial arts sports. This study used an anthropometer with relatively high external validity to overcome the difficulties that occurred when targeting corpses and when using expensive research instruments. This study was planned to identify the difference between skinfold thicknesses and muscle masses by sport types. However, there was a statistically significant difference in variables such as height and weight that affected skinfold thickness and muscle mass among athletes selected by sport types (e.g. martial arts including judo and taekwondo and non-martial arts sports such as ball games including handball and rugby and racket games including badminton and table tennis). Thus, this research adopted a method of analysis by games over by sport types. To minimize problems that previously existed in terms of experimental methods and researchers' investigation methods for the measurement of skinfold thickness and muscle mass[7–10], all subjects were measured by one investigator trained professionally about the use of measurement instruments according to the measurement guidelines of ISAK using one measurement instrument.

According to the study results, the variables of physical constitution (e.g. weight, height and body circumference of athletes) by sports affect the skinfold thickness and muscle mass of athletes by sports. Also, according to the results of variance analysis for muscle mass between groups, there is a statistically significant difference. The results of Post-hoc tests show that, since the measurement variables for judo athletes and rugby players show a relatively significant difference from the athletes in other sport types, they affect skinfold thickness and muscle mass. According to these results, the average of muscle masses of judo athletes was 50.66 kg and that of taekwondo athletes was 45.26 kg and the average of muscle masses of rugby players, who are non-martial arts athletes, was relatively great at 50.07 kg compared to 45.26 kg of taekwondo athletes, 47.80 kg of handball players, 44.86 kg of badminton players and 41.88 kg of table tennis players.

The reason why the muscle masses of judo athletes are relatively greater than those of athletes in other sports is as follows: The average of their weights, which are used in the formula of muscle mass estimation, is relatively high at 87.78 kg compared to athletes in other sport types; the average of the sum of their skinfold thickness is also relatively high at 36.98 kg; furthermore, judo athletes showed high values in most variables related to their body circumferences as 31.41 kg of corrected upper arm circumference. Based on these results, it is surmised that judo athletes' muscle mass is relatively great because judo athletes need a considerable amount of muscular strength. Rugby players, as non-martial arts athletes, also need great muscle mass. Rugby is an aerobic exercise, which uses high muscular strength in a short time and thus rugby players are thought to have considerably high muscular strength. In the percentages of muscle masses of athlete groups, the handball player group was highest at 64.34% followed by the badminton player group (63.91%), rugby player group (63.50) and taekwondo athlete group (45.26). The formula of muscle mass percentage suggests that body weight affects muscle mass percentage. The average of overall muscle masses of athletes by sport types is 48.09 kg, which is relatively overestimated compared to the 25.3 kg estimated by the Brussels study targeting 25 corpses. However, it should be noted that the subjects targeted by corpse studies fell under the category of prisoners or elderly people.

According to study on muscle mass targeting the athletes in athletics, gymnastics, bodybuilding, baseball and basketball, their muscle masses range from 38.4 kg, which corresponds to a long-distance runner, to 58.7 kg, while the results of this study show that muscle mass ranges from 41.88 to 53.70 kg. It can be surmised that the subjects of the study are different from those of this study according to the sport types in which they are involved. However, it can be found that, since the same muscle mass was used in estimating all their muscle masses, foreign athletes' muscle masses are similar to Korean athletes'. Taking these study results into account overall, it can be said that the formula applied in this study was appropriate for the comparison of muscle masses between athlete groups. It is confirmed that the formula used by this study was appropriate for determining the ranking of muscle masses of athletes by sport types and available for their comparison with the muscle masse of a corpse, while it is considerably difficult to calculate accurate values using the formula. The formula used in this study can cause relatively large errors as it is an estimation formula developed to target foreigners. Thus, there is a need to develop an estimation formula targeting Korean people in the future. In addition, it will also be necessary to conduct studies targeting females and people of different ages.

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