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Differences in Fat-Free Mass and Muscle Thicknesses at Various Sites According to Performance Level Among Judo Athletes

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Abstract. Kubo, J., T. Chishaki, N. Nakamura, T. Muramatsu, Y. Yamamoto, M. Ito, H. Saitou, and T. Kukidome. Differences in the fat-free mass and muscle thicknesses at various sites according to performance level among judo athletes. *J. Strength Cond. Res. 20(3):654–657. 2006.*—The purpose of this study was to investigate differences in fat-free mass and thicknesses of various muscles among judo athletes of different performance levels. The subjects were 69 male judo athletes of 3 different performance levels. Group A was composed of athletes who participated in the Olympic Games or Asian Games ($n = 13$). Groups B ($n = 21$) and C ($n = 35$) were composed of judo athletes at a university who did or did not participate in intercollegiate competitions (including qualifying matches), respectively. Muscle and fat thicknesses were measured by B-mode ultrasound at 9 sites. Fat percentage was calculated from fat thicknesses using a previously reported equation. Fat-free mass was calculated from fat percentage and body weight. Muscles thicknesses were normalized to the height of the individual. Group A had significantly larger fat-free mass than Group C ($p < 0.05$). The normalized thicknesses of the elbow extensor and flexor muscles were significantly larger in Group A than in Group C. The normalized thickness of the elbow flexor muscle was significantly larger in Group A than in Group B. The results of this study showed that judo athletes with low performance levels such as those in Group C had lower fat-free mass, and the degree of development of the brachialis muscles differed according to performance level.

Key Words. ultrasonography, Olympic Games, training

Introduction

The fat-free mass of the entire body is generally used to estimate the total volume of skeletal muscle in an individual. There have been a few reports on the relationship between fat-free mass and performance level among athletes of strength sports such as weightlifting (6, 7) and power lifting (2). In judo, which is another strength sport, 2 opponents throw and restrain each other with their bare hands. Therefore, it is assumed that a judo athlete with larger fat-free mass would have higher performance. However, there has been no report on the relationship between fat-free mass and performance level among judo athletes.

Judo is a weight-classified sport. Therefore, an increase in fat-free mass that results in an increase in weight is not necessarily advantageous for a judo athlete, because there is a possibility that the athlete would have to compete in a heavier weight class. It is assumed that elite judo athletes have developed muscles at sites that are advantageous for judo athletes. Although it was reported that judo athletes have great upper-body anaerobic power and capacity (10), there is no report on which muscle sites are more developed in high-level judo athletes. During the last decade, imaging techniques such as magnetic resonance imaging, computed tomography, and ultrasonography have advanced greatly, allowing observation of the degree of muscle development at various sites. Muscle sites that are more highly developed in elite judo athletes might become clear using these techniques.

The purpose of this study was to investigate the differences in fat-free mass and the thicknesses of various muscles among judo athletes of different performance levels. We hypothesized that elite judo athletes would have larger fat-free mass and thicker upper-body muscles than judo athletes of lower performance levels.

Methods

Experimental Approach to the Problem

Male judo athletes of 3 performance levels were studied. The fat-free mass, which was used as an index of the total skeletal muscle volume, and the distribution of muscles throughout the body were determined and compared among the 3 groups. This information will be useful for developing training regimens for judo athletes.

Subjects

The subjects were 69 male judo athletes of 3 different performance levels. Group A ($n = 13$) was composed of judo athletes who had participated in the Olympic Games or the Asian Games. Groups B ($n = 21$) and C ($n = 35$) were composed of judo athletes at a university who did or did not participate in intercollegiate competitions (including qualifying matches for intercollegiate competitions), respectively. The Group B subjects were members of the Judo Club of a university that won high ranks in a weight-classified group intercollegiate competition (placed in the top 8) and in an open group intercollegiate competition (placed in the top 3) in 2002. Measurements were taken for the university athletes in 2002. Measurements were taken for the Olympic athletes in 2001 and for the Asian athletes in 2002. The heights and weights of the subjects in Groups A, B, and C are shown in Table 1. This study included judo athletes in 7 weight classes (−60 kg, −66 kg, −73 kg, −81 kg, −90 kg, −100 kg, +100 kg). Group A consisted of 2 athletes in each of 6 weight classes and 1 athlete in the −90-kg weight class. Group B consisted of 3 athletes in each of the 7 weight classes,

TABLE 1. Height, body weight, fat-free mass, and normalized muscle thicknesses at 9 sites in the body.*

Group	Height (cm)	Body weight (kg)	FFM (kg)	Muscle thickness								
				Forearm	Elbow flexor	Elbow extensor	Knee extensor	Knee flexor	Dorsiflexor	Plantar flexor	Abdomen	Subscapula
A	174.4 ± 8	90.2 ± 22	74.9 ± 13†	1.6 ± 0.1	2.2 ± 0.2†‡	2.8 ± 0.4†	3.5 ± 0.4	3.9 ± 0.9	1.9 ± 0.1	4.5 ± 0.4	1.1 ± 0.1	1.8 ± 0.3
B	174.7 ± 6	85.3 ± 19	69.9 ± 9	1.6 ± 0.1	2.0 ± 0.2	2.6 ± 0.3	3.4 ± 0.3	3.6 ± 0.4	1.8 ± 0.1	4.2 ± 0.3	1.1 ± 0.2	1.8 ± 0.3
C	172.2 ± 6	84.1 ± 19	66.5 ± 8	1.6 ± 0.2	2.0 ± 0.3	2.5 ± 0.4	3.5 ± 0.5	3.6 ± 0.5	1.8 ± 0.2	4.3 ± 0.4	1.1 ± 0.2	1.7 ± 0.3

* Values are mean ± *SD*. Muscle thicknesses were normalized by height and multiplied by 100. FFM = fat-free mass.
† Significant difference between Groups A and C.
‡ Significant difference between Groups A and B.

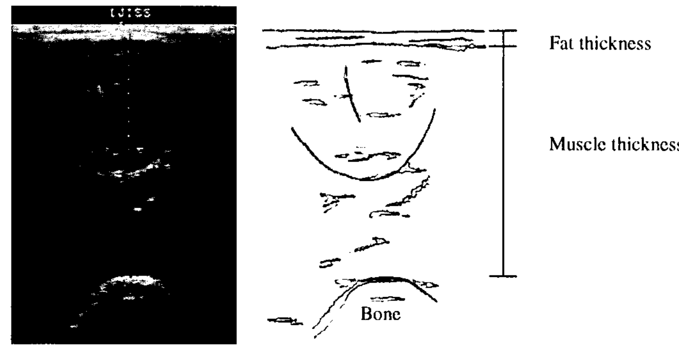

FIGURE 1. Determination of muscle and fat thickness in a representative ultrasonographic image of the knee extensor muscle of a judo athlete.

and Group C consisted of 5 athletes in each of the 7 weight classes. The heights and body weights of the subjects in Groups A, B, and C did not significantly differ (Table 1).

All subjects gave informed consent to participate in this study after they were given a detailed explanation of the purpose, procedure, and possible risks associated with the experiment. This study was approved by the ethics committee of the Japan Institute of Sports Sciences.

Measurement of Muscle and Fat Thicknesses

An ultrasonic apparatus (SSD-900; Aloka, Tokyo, Japan) with an electronic linear array probe (7.5 MHz wave frequency, UST-7.5; Aloka) was used to measure muscle and fat thicknesses. Measurements of muscle and fat thicknesses were made at the following 9 sites: right knee extensor and flexor muscles (at 50% of thigh length), right dorsiflexor and plantar flexor muscles (at 30% of lower-leg length from knee), right lateral forearm (at 30% of forearm length from elbow), right elbow flexor and elbow extensor muscles (at 60% of upper arm length from acrominon), abdomen, and subscapula (for further information, see previous study) (1). During the measurement of muscle and fat thicknesses at the 9 sites, the subject was instructed to stand in a relaxed manner to prevent his muscles from exerting force, which would alter the results. The ultrasonic probe was coated with a water-soluble transmission gel to provide acoustic contact without depressing the dermal surface. The probe was placed perpendicular to the skin and was gently held to prevent deformation of the skin and underlying tissues by a technician. The interfaces between fat, muscle, and bone were confirmed in the ultrasonic photographs, and the muscle and fat thicknesses were measured in these photographs (Figure 1). The precision of this method of determining muscle and fat thicknesses has been confirmed in previous studies (1, 2, 7, 8). We evaluated the reproducibility of the measurements of muscle and fat thicknesses by performing measurements twice on the same day on each of 10 subjects. The test–retest reliability correlation coefficient (r) of the measurements of muscle and fat thicknesses ranged from 0.97 to 0.99 for muscle thicknesses and from 0.94 to 0.98 for fat thicknesses.

Calculation of Fat-Free Mass

Body density was calculated using ultrasound data and the equation developed by Abe et al. (1) (Equation A). Next, the body fat percentage was calculated by the equation of Brozek et al. (3) (Equation B), using the body density that had been calculated in Equation A.

$$\text{Body density} = 1.090 - 0.0005 \times (\Sigma \text{ fat thicknesses at 9 sites}) \quad \text{(A)}$$

$$\text{Body fat percentage} = \left(\frac{4.570}{\text{body density}}\right) - 4.124 \quad \text{(B)}$$

Fat weight was calculated from body weight and body fat percentage. Fat-free mass was calculated by subtracting fat weight from body weight. The validity of the equation of Abe et al. (Equation A) for calculating body density was previously demonstrated by comparing hydrostatic weighting (1).

Statistical Analyses

The significance of differences in measured variables among Groups A, B, and C was assessed using 1-way analysis of variance (ANOVA). The Tukey test was used for post hoc analysis when significant main effects were found with ANOVA. The level of significance was set at $p \leq 0.05$. As mentioned earlier, in each group, there were the same number of athletes in each weight class (with 1 exception), and there were no significant differences in height and body weight among Groups A, B, and C.

RESULTS

Fat-free mass and normalized muscle thicknesses at 9 sites in the body were compared among 3 groups of judo athletes of different performance levels. The fat-free mass of Group A was significantly larger than that of Group C, and it tended to be larger than that of Group B. (Table 1). The thickness of each muscle was normalized to the height of the individual. The normalized thicknesses of the elbow extensor and flexor muscles were significantly larger in Group A than in Group C ($p < 0.05$). The normalized thickness of the elbow flexor muscle was significantly larger in Group A than in Group B ($p < 0.05$, Table 1). There were no significant differences in the normalized thicknesses of muscles at the other 7 sites among Groups A, B, and C. There were no significant differences in fat-free mass and the normalized thicknesses of any of the 9 muscles between Groups B and C.

DISCUSSION

Our hypotheses were that elite judo athletes have a high fat-free mass and thicker upper-body muscles compared with judo athletes of lower performance level.

Fat-free mass is generally used to estimate the total skeletal muscle volume because 80–90% of lean tissue consists of skeletal muscle. Therefore, we thought that individuals with a larger fat-free mass would have higher performance on combative sports that require muscular strength and power. In this study, the fat-free mass of Group A was significantly larger than that of Group C (Table 1). It has been reported that in power lifting, a sport that requires a large amount of strength, performance is strongly and positively associated with fat-free mass (3). A small fat-free mass, which might result in lower strength, might be one of the factors restricting judo performance. Among judo athletes, it has been reported that more successful, higher-ranked male athletes had lower percentages of body fat than lower-ranked male athletes (5.1 ± 0.6% vs. 8.2 ± 0.8%) (4). It was assumed that the more successful judo athletes maintained a lower percentage of body fat and larger fat-free mass. However, in this study, there was no significant difference in fat-free mass between Groups A and B. Group B was composed of athletes who participated in intercollegiate competitions and athletes who participated in qualifying matches for intercollegiate competitions. The difference between the performance of Group B athletes and that of higher-level athletes (Group A) may be attributable to factors other than fat-free mass.

To our knowledge, this is the first report describing the differences in the thicknesses of muscles at various sites among judo athletes of different performance levels. Our results showed differences in the normalized thicknesses of the elbow flexor and extensor muscles, which are upper-body muscles, between Groups A and C. However, there were no differences in the normalized thicknesses of the lateral forearm and subscapular muscles among the 3 groups. The normalized thicknesses of the elbow flexor and extensor muscles of Group A were significantly larger than those of Group C. Because muscular strength is proportional to muscle size (5, 9, 11), the elbow extension and flexion strengths may be higher in Group A than in Group C. In judo, the player throws and restrains the opponent by holding the collar and sleeve of the judo jacket of the opponent. To throw the opponent, it is important that the judo player maintain an advantageous distance from the opponent. When a player is holding the opponent's judo jacket and wants to increase his distance from the opponent, it is necessary for the player to extend the elbow joint by contracting the elbow extensor muscle. Conversely, to reduce the distance from the opponent, it is necessary to flex the elbow joint by contracting the flexor muscle. Differences in the strengths of these movements might influence judo performance. In this study, Group A also had a significantly larger normalized thickness of the elbow flexor muscle than Group B. This difference would lead to higher elbow flexion strength in Group A than in Group B, and hence to a difference in judo performance. However, the factors that caused the differences in muscle thicknesses among the 3 groups could not be clarified from our results; they may include differences in the amount or frequency of judo practice, type of resistance training, genetics, or their interaction. However, it would be reasonable to assume that having large elbow extensor and flexor muscles is advantageous for judo performance.

There were several limitations in this study. Although we measured muscle thicknesses, we did not measure muscular strength. We speculated that there were differences in muscular strength because there were differences in muscle thickness between the 3 groups. In a previous study on weightlifters that compared the muscle cross-sectional area and strength between elite senior lifters and college lifters, the elite senior lifters had a higher ratio of force to muscle cross-sectional area compared with the college lifters (6). Further studies on the size and strength of muscles are needed to clarify this issue. Moreover, Groups A, B, and C each contained athletes of all weight classes, and within each group, there were the same number of athletes in each weight class (with 1 exception). In a previous study of judo athletes, it was reported that factors responsible for success might be specific to each weight class (4). Further studies on judo athletes in each weight class are necessary.

In conclusion, the Group A athletes had a significantly larger fat-free mass and significantly larger normalized thicknesses of the elbow extensor and flexor muscles than the Group C athletes. The Group A athletes also had a significantly larger normalized thickness of the elbow flexor muscle than the Group B athletes. The results of this study showed that the elite judo athletes had a larger fat-free mass than the Group C judo athletes, and that the degree of development of the brachialis muscles differed according to performance level.

PRACTICAL APPLICATIONS

Based on the results of this study, judo athletes of different performance levels should focus on different aspects during resistance training. In judo athletes at low performance levels, training should focus on increasing fat-free mass, whereas in higher-level judo athletes and judo athletes who want to avoid gaining weight, training should focus on strengthening the brachialis muscles. However, the mechanism of how these differences in fat-free mass and muscle distribution arose was not clarified. Therefore, whether increases in fat-free mass and brachialis muscles as a result of resistance training can contribute to judo performance is another issue.

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