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ABSTRACT. The purposes of this study were to disclose the anthropometrical characteristics of elite Japanese female wrestlers and to compare them with those of other athletes reported in the literature. To this end, we tested 17 elite Japanese female wrestlers (nine and eight wrestlers, in light and heavyweight categories, respectively), most of who had won gold medals at the internationally recognized tournaments. Body composition, circumferences, and limb lengths were tested based on multi-frequency bioimpedance analysis (InBody 730, Biospace, Inc.) and whole-body scanning system (Body Line Scanner, Hamamatsu Photonics KK). The main results indicate that the participants are characterized as having great FFMI (fat-free mass divided by height squared, 18.8 ± 0.8 in light and 20.5 ± 0.8 in heavyweight groups) with intensely enlarged circumference especially within the arms (30.0 ± 2.7 cm for upper arms and 24.2 ± 1.5 cm for forearms). These findings suggest that elite female wrestlers have site-specific hypertrophied musculature only in the upper body, despite a general awareness of difficulty in developing upper limb muscles in women. We concluded that extreme development of fat-free tissue, specifically around the upper body, is an important requirement for female wrestlers to win the worldwide prestigious tournaments.

Keywords: combat, woman, profile, wrestling, judo

Competitive wrestling is a combat sport that requires athletes to have a highly trained physical capacity and body composition to be successful (Horswill, 1992; Horswill et al., 1992; Horswill, Scott, & Galea, 1989; Hübner-Woźniak, Kosmol, Lutoslawska, & Bem, 2004; Kraemer et al., 2001; Sharratt, Taylor, & Song, 1986). Therefore, physiological and anthropometrical tests are commonly used to assess fitness of wrestlers (García-Pallarés, López-Gullón, Muriel, Diaz, & Izquierdo, 2011; García-Pallarés, López-Gullón, Torres-Bonete, & Izquierdo, 2012; Horswill, Scott, & Galea, 1989; Horswill, 1992; Horswill et al., 1992; Uter, O’Bryant, Haff, & Trone, 2002; Zi-Hong, Lian-shi, & Hao-jie, 2012) as well as other combat athletes (Ball, Nolan, & Wheeler, 2011; Bridge, Ferreira da Silva Santos, Chaabène, & Franchini, 2014; Chaabène, Hachana, Franchini, Mkaouer, & Chamari, 2012; Franchini, Del Vecchio, Matsusighe, & Artioli, 2011; Franchini, Huertas, et al., 2011; Franchini, Nunes, Moraes, & Del Vecchio, 2007; Franchini, Takito, Kiss, & Strerkowicz, 2005; Silva, Fields, Heymsfield, & Sardinha, 2010). In order to set guidelines for individual training and for selecting promising talent, the physiological and anthropometrical profiles of successful wrestlers serve as a benchmark. Several studies have so far investigated the physiological and anthropometrical profiles of male wrestlers at different competitive levels with a view to identifying the factors needed for success (Callan et al., 2000; García-Pallarés, López-Gullón, Muriel, et al., 2011; Horswill et al., 1989; Mirzaei & Curby, 2009; Mirzaei, Curby, Barbas, & Lotfi, 2011; Song & Garvie, 1980; Yoon, 2002). Meanwhile, relatively few studies have been done concerning female wrestlers, leaving insufficient information available.

Two recent studies have investigated the physiological and anthropometrical profiles of elite female Chinese (Zi-Hong et al., 2012) and European (García-Pallarès, López-Gullón, Torres-Bonete, et al., 2012) wrestlers. These studies
examined upper-class female athletes and disclosed their functional characteristics, including their aerobic capacity, anaerobic power, and muscle strength (García-Pallarés, López-Gullón, Torres-Bonete, et al., 2012; Zi-Hong et al., 2012). In comparison, limited data has been gathered on the anthropometrical aspects. García-Pallarés investigated the percent of body fat (%BF) and fat-free mass (FFM) for European female wrestlers, mostly teenagers, based on the three-location skinfold technique (García-Pallarés, López-Gullón, Torres-Bonete, et al., 2012). However, other information concerning anthropometrical characteristics, such as the body composition based on other modalities (e.g., bioimpedance analysis), muscle thicknesses, or circumferences of extremities, remains unavailable. Further examining the profiles of anthropometry for elite female wrestlers might lead to identifying distinguished physical traits that are specific to successful female wrestlers.

We therefore attempted to examine the features of anthropometry in successful elite female wrestlers. In 2014, we carried out a comprehensive physical test for elite Japanese female wrestlers, most of whom had won gold medals at internationally recognized tournaments run by the United World Wrestling (UWW). The purposes of this study were to disclose the body composition, whole body circumferences, and lengths of limbs of elite Japanese female wrestlers and to compare them to those of other athletes reported in the literature.

METHODS

Experimental Design

This study was designed to reveal the anthropometrical profiles of successful Japanese female wrestlers. To this end, 17 members of the Japanese female freestyle national team were tested, and the results were compared with those in the literature. Even though the test was intended primarily to assess the physical condition of the wrestlers, the measurement was executed as a carefully controlled experimental design with at least moderately experienced examiners. All athletes and coaches were informed in detail about the procedures and the possible risks and benefits involved. All of the participants had won at least one medal at the official international tournaments run by UWW. Additionally, 15 out of the 17 medalists had won gold medals. Out of the 15, seven and three had won gold medals at the Golden Grand Prix Finals and World Championships, respectively. In addition, 10 of the wrestlers had won gold medals at the Asian Championships or Asian Games. The participants were divided into two groups according to their weight categories for the competitions: the lightweight group (LW), 48–58 kg, and the heavyweight group (HW), 60–75 kg. Subsequently, nine wrestlers were assigned into LW (21.3 ± 3.2 years), and eight into HW (24.0 ± 5.2 years). The physical characteristics are summarized in Table 1.

Tests

The following anthropometric aspects were measured: height, body weight, percentage of body fat, whole body circumference, and whole body limb length. The tests included two folds, body composition, and morphological measurements. The two were completed within a single day for all the athletes.

Body composition was assessed by multi-frequency bioimpedance analysis with 8-point contact electrodes (MF-BIA) using a commercially available apparatus (InBody 730, Biospace, Inc.). To avoid the influence of changes in body fluid on the reliability of bioimpedance analysis, all measurements were implemented in the early morning after micturition and before breakfast. All subjects were wearing a short-sleeved T-shirt and lightweight shorts over their underwear. Each subject’s body weight was lowered by 0.5 kg for the weight of the clothes, using a weight-adjusting system from InBody 730. To reduce the electrical resistance of contacting surfaces between participant’s skin and electrodes, the measurements were performed after the subject’s hands and feet were dampened by a pre-moistened wipe. Among the data obtained from this system, body weight, body mass index (BMI: body weight [kg] divided by height [m] squared), percentage of body fat (%BF), fat-free mass (FFM), and fat-free mass index (FFMI: fat-free mass [kg] divided by height [m] squared) were used for further evaluation and comparison with the literature.

Morphological data were obtained by means of a three-dimensional, whole-body scanning method (Body Line Scanner, BLS, Hamamatsu Photonics KK, Shizuoka, Japan). This system scans the shape of the whole body and recon-
structs it into a three-dimensional polygon figure as depicted in Figure 1. From the scanned data, the system automatically divides the whole body polygon into 14 segments (head, trunk, upper arms, forearms, hands, thighs, shanks, and feet) based on the coordinates of 72 landmarks identified by reflecting markers (Hakamada & Funato, 2012). Then, the system arbitrarily calculates anthropometrical parameters, including circumferences and limb lengths, at any place on

| TABLE 1 General Characteristics and Results of Body Composition of the Present and the Previous Studies |
|---------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|
| **Elite Japanese Female Wrestlers**                          | **Elite European Female Wrestlers**                           | **Non-elite Female Wrestlers and Judokas**                    |
| (Present Study)                                              | (Garcia-Pallares, 2012)                                       | (Santos, 2014)                                                |
| **Light Weight**                                             | **Middle Weight**                                            | **Wrestling and Judo**                                       |
| [N = 9]                                                      | [N = 8]                                                      | [N = 24]                                                     |
| **LW (48-55kg)**                                             | **HW (58-75kg)**                                             |                                                              |
| **Total**                                                    |                                                              |                                                              |
| [N = 17]                                                     |                                                              |                                                              |
| Modalities                                                   |                                                              |                                                              |
| Age [y]                                                      | 21.3 ± 3.2                                                   | 24.0 ± 5.2**                                                 | 22.6 ± 4.3                                                   |
| Height [cm]                                                  | 158.0 ± 4.4                                                 | 163.4 ± 3.6**                                                | 160.5 ± 4.8                                                 |
| Weight [kg]                                                  | 55.9 ± 4.0                                                  | 68.4 ± 5.3**                                                 | 61.8 ± 7.8                                                 |
| BM Index [kg / cm²]                                          | 22.4 ± 1.2                                                  | 25.6 ± 1.4**                                                 | 23.9 ± 2.0                                                 |
| Fat Free Mass [kg]                                           | 46.8 ± 3.2                                                  | 54.7 ± 3.8**                                                 | 50.5 ± 5.3                                                 |
| FFM Index [kg / cm²]                                         | 18.8 ± 0.8                                                  | 20.5 ± 0.8**                                                 | 19.6 ± 1.2                                                 |
| % Body Fat [%]                                               | 16.2 ± 2.0                                                  | 20.0 ± 2.5**                                                 | 18.0 ± 2.9                                                 |

**Note.** Values are means ± SD for the present study and Garcia-Pallares, López-Gullón, Torres-Bonete, et al. (2012), whereas means and the 95% ranges of confidence interval were shown with parentheses for Santos et al. *p < .05, **p < .01, significant difference between LW and HW. LW = light weight, HW = heavy weight; BM = body mass; FFM = fat free mass; MF-BIA = multi-frequency bioimpedance analysis; DXA = dual-energy X-ray absorption.**
the body. In this study, 12 circumferences (neck, upper arms, forearms, thighs, lower legs, chest, waist, and hip) and four lengths (arms and legs) were computed. The reference locations of circumferences for the four extremities were set at the positions of 60%, 30%, 50%, and 30% lengths from the proximal ends for upper arms, forearms, thighs, and lower legs, respectively, according to the guideline of anthropometry commonly used in Japan.

Data Analysis
Standard statistical methods were used to calculate the mean and standard deviations (SD). A two-tailed, unpaired t test was used to determine whether the mean values were different between the weight categories. The significance level was set at \( p < .05 \).

RESULTS
General characteristics and body composition data are shown in Table 1. The ages did not significantly differ between the weight divisions, although HW tended to be older than LW (LW, 21.3 ± 3.2 vs. HW, 24.0 ± 5.2 years, \( P = .118 \)). Several profiles having to do with general characteristics and body composition were significantly greater in HW than in LW (\( p < .01 \)).

For evaluating the development of muscle and the leanness, FFMI and %BF were used (Table 1 and Figure 2). These two evaluation criteria were compared with those of non-elites assessed by dual-energy X-ray absorptiometry in a preceding study (DXA, Santos et al., 2014). The averaged FFMIs were larger (18.8 ± 0.8 in LW and 20.5 ± 0.8 in HW, respectively) than those of ordinary, non-elite judo and wrestling athletes (Santos et al., 2014; on average, the FFMI = 16.7 with a 95% confidence interval between 15.6 and 17.8). Notably, the minimum values of FFMI were 17.5 and 19.1 for each weight division, LW and HW, respectively, with the result that no subject was below the reference value of non-elites (16.7). Concerning the %BF (Table 1 and Figure 2C), the average results for these athletes (16.2 ± 2.0% in LW and 20.0 ± 2.5% in HW) were lower than those for non-elites (23.0%; Santos et al., 2014).

The circumferences and the lengths of extremities were evaluated according to the BLS system (Table 2 and Figure 3). All parts of the circumferences were significantly larger in HW than in LW (Table 2, \( p < .05 \)). As for the lengths of extremities, there is a significant difference between weight classes only in the absolute arm lengths (Table 2, \( p < .05 \)). No significant differences between HW and LW were found in the absolute leg lengths (\( P = .076 \) for right and \( P = .053 \) for left), the normalized arm lengths (\( P = .427 \) for right and \( P = .488 \) for left), and the normalized leg lengths (\( P = .193 \) for right and \( P = .236 \) for left).

FIGURE 2 Scatter diagrams of the body composition parameters for the present participants. The black-filled circles (●) represent averaged values of all the plots within each weight category. The horizontal lines represent averaged values of the non-elite wrestlers and judokas referenced by Santos et al. (2014). BMI = body mass index; FFMI = fat free mass index; LW = light weight; HW = heavy weight.
To examine whether there are region-specific enlargements of circumferences, the results were compared with those of Japanese elite athletes engaged in other sports (Japan Institute of Sports Sciences, 2012). The upper arm and the forearm circumferences were greater in the present subjects than in the other athletes, by 15.9% for the upper arm (30.0 ± 2.7 cm for the present wrestlers vs. 25.9 cm for other athletes, on average), and by 9.6% for the forearm (24.2 ± 1.5 cm for the present wrestlers vs. 22.1 cm for other athletes, on average). By contrast, smaller differences were found regarding thigh circumferences (greater by 1.9% in the present wrestlers) and lower leg circumferences (smaller by 1.6% in the present wrestlers).

## DISCUSSION

The data for this study were obtained from the elite female wrestlers belonging to the Japanese women’s national wrestling team, which has been uppermost in competitiveness since female wrestling was launched at the World Championships in 1987. To our knowledge, the female wrestlers engaged in this study are more competitive and have greater achievements than those examined in preceding studies. Therefore, it seems valid to suppose that the competitive level of the present elite athletes suffices for discussing the factors needed for being successful.

As far as we know, our study is the first to investigate the body composition based on bioimpedance analysis, whole body circumferences, and lengths of extremities for elite female wrestlers. The main findings of this study indicate that elite female wrestlers are characterized as having greater BMI (HW), FFM (HW), and FFMI (LW and HW), and smaller %BF (LW and HW) than non-elites, with site-specific enlarged circumferences only in the upper body (LW and HW) compared to elite Japanese athletes engaged in the other sports. These results suggest that the enlargement of FFMI as well as the development of skeletal muscles, especially within the upper body, will give female wrestlers a decisive advantage that are comparable to men’s wrestling in high-level competitions.

According to the results of the body composition test (Table 1 and Figure 2), the elite Japanese female wrestlers turned out to have an extraordinarily large FFMI (18.8 ± 0.8 in LW and 20.5 ± 0.8 in HW; respectively). For both weight divisions, the averaged FFMI values were far greater in the current wrestlers than in the non-elite female judo and wrestling athletes examined in a preceding study (FFMI = 16.7 based on DXA; Santos et al., 2014), slightly greater than in elite European female wrestlers (FFMI = 18.6 in light and heavy weight divisions).
20.3 in middleweights based on skinfolds, García-Pallarés, López-Gullón, Torres-Bonete, et al., 2012), and evenly matched with that of non-elite male athletes (e.g., basketball players: FFMI = 18.8; swimmers: FFMI = 19.0; Santos et al., 2014). Furthermore, the FFMI for every subject exceeded the non-elite’s average (16.7) without exception (Figure 2B). Taking these observations into account, we can infer that the intense development of fat-free tissue is an es-

FIGURE 3 Scatter diagrams of the circumferences for the present participants. The black-filled circles (●) represent averaged values of all the plots within each weight category. The horizontal lines represent averaged values of the elite Japanese athletes engaged in the other sports referenced by Japan Institute of Sports Sciences (2012). LW = light weight; HW = heavy weight.
sential requirement for being supremely successful in high-
level female wrestling.

Nevertheless, it should be noted that the reference values
of non-elite wrestlers in the preceding study (Santos et al.,
2014) were based on DXA, whereas in the current study,
they were based on multi-frequency bioimpedance analysis
with 8-point contact electrodes. In the literature, extensive
studies have compared the results by multi-frequency bio-
electrical impedance analysis with those by DXA for assess-
ment of body composition (Anderson, Ercge, & Schroeder,
2012; Esco et al., 2014; Leahy, O’Neill, Sohon, & Jakeman,
2012; Sun et al., 2005; Uter, & Lambeth, 2010; Velazquez-
Alva, Irigoyen-Camacho, Huerta-Huerta, & Delgadillo-
Velazquez, 2014). Among those studies, the participants in
Esco et al. (2014) shared a similar background with those
in the present study as young female athletes (age = 21.2
± 2.0 years, height = 166.1 ± 7.1 cm, weight = 62.6 ± 9.9
kg). Esco et al. underestimated body fat by 3.3% with In-
Body compared to DXA, which means an overestimation
of FFIM with multi-frequency bioelectrical analysis (Esco
et al., 2014). In reckoning the possible impact of an under-
estimation of 3.3% for body fat percentage, the calculation
follows that an overestimation of FFIM with InBody is at
most +0.8%. Therefore, even when the discrepancy of test-
ing modes between studies is taken into account, it is reason-
able to suppose that the elite female wrestlers in this study
possessed exceptionally great musculature.

As for anthropometrical results, the most interesting
point is the region-specific development of upper-arm and
forearm circumferences in the present participants (Table 2)
compared to the elite athletes engaged in the other sports
(Japan Institute of Sports Sciences, 2012). This finding sug-
gests that the highly successful female wrestlers have in-
tensely hypertrophied musculature for women, specifically
around the upper body. So far, it has been generally agreed
that male athletes engaged in grappling-combat sports have
hypertrophied muscle tissues or developed circumferences
on the upper body (Franchini et al., 2005). Franchini et al.
(2005) examined entire body circumferences for elite Bra-
zilian judo male athletes, and found that upper limb circum-
ferences were greater in the elites than in the non-elites.
Similarly, there is also a region-specific improvement of
anaerobic muscular function within the upper body in elite
American male wrestlers (Horswill et al., 1992). The present
results are consistent with those of the preceding studies in
that the pronounced enhancement was specifically found in
the upper body.

Above all, we must note that the current study examined
women, who supposedly have quite a bit of difficulty in de-
veloping upper body musculature. In general, men become
more muscular than women after adolescence. Typically,
the sex difference in muscle development is apparent in
the upper extremities compared to the hips and legs (Ma-
lina & Bouchard, 1992). This tendency is true not only of
the general population (Abe, Kearns, & Fukunaga, 2003),
but also of athletes such as sprinters, volleyball players, and
body builders (Alway, Grumbt, Gonyea, & Stray-Gundersen,
1989; Kanehisa, Fukunaga, Ikegawa, & Ishida, 1985). Speci-
fically, female athletes generally have a definite low
trainability of muscles, in particular within the upper body.
Contrary to the general idea of region-specific muscle de-
development owing to one’s sex, the female wrestlers in this
study showed prominently large circumferences only in the
arms, not in the legs. Such an exceptional mode of adapta-
tion could be explained by the following reasons: (1) high-
intensity force and power generation are required in com-
petitive wrestling, and (2) the wrestlers who participated in
this study were supremely selected elites.

Lastly, the limitations of the study should be mentioned.
The major limitation is the lack of the control group within
the present research setting. Since the data of the compari-
ative athletes were incorporated herein by references (Japan
Institute of Sports Sciences, 2012; Santos et al., 2014; Zi-
Hong et al., 2013), no statistical analysis was undertaken
between the present elite Japanese female wrestlers and
other athletes. In addition, we did not investigate the fit-
ness profiles, the relation of which with anthropometry is of
importance. Whereas we have disclosed anthropometrical
data in this study, we have also obtained the results of fitness
tests for the elites who participated in this study. Therefore,
further research will be carried out to reveal relationships
between the anthropometry and fitness profiles of elite Japa-
nese female wrestlers.

CONCLUSION

We can conclude from the results that (1) internationally
successful female wrestlers have extremely enlarged FFMI
as well as skeletal muscles regardless of weight classes, and
(2) elite female wrestlers are characterized as having site-
specific hypertrophied musculature only in the upper body,
despite a general awareness of difficulty in developing up-
per limb muscles in the case of women. Taking these find-
ings into account, we can infer that the intense development
of fat-free tissue, specifically around the upper body, is an
essential requirement for female wrestlers to attain interna-
tional competitiveness. The outcomes help define a direction
for effective training programs and selecting promising tal-
ent for practitioners and coaches so as to win the worldwide
prestigious tournaments.

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