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A comparative analysis of the physical fitness profile of Korean women's national amateur boxers by weight category

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The purpose of this study was to examine the differences in specific physical fitness of the national amateur women's boxer. The Korean women's national amateur boxers were classified into the lightweight category (LWC, n=21) and middleweight category (MWC, n=13), and body composition (percentage body fat and body mass index) and specific physical fitness (maximal muscle strength, anaerobic power, isokinetic muscle strength, cardiopulmonary endurance) were measured. The Mann–Whitney *U*-test was conducted to determine the differences in the body composition and specific physical fitness in women's boxers. The percentage body fat ($P=0.004$) and body mass index ($P<0.001$) were significantly higher in the LWC compared to MWC. In addition, LWC showed significantly higher isokinetic muscle strength ($P<0.001$), upper anaerobic mean power ($P=0.002$), maximal muscle strength ($P=0.003$), and maximal heart rate at anaerobic threshold ($P=0.029$), maximal oxygen consumption ($P<0.001$) and the 20-m shuttle-run exercise ($P=0.004$) compared to MWC. In conclusion, the body fat percentage and body mass index levels among body composition were significantly higher in the MWC than in the LWC, and the constant muscle strength, maximum muscle strength, and cardiopulmonary endurance levels were significantly higher in the LWC than in the MWC. The results of this study are expected to provide useful data for planning future strategies for efficient and scientific training programs for each weight category.

Keywords: Women's national amateur boxers, Physical fitness, Muscle strength, Cardiopulmonary endurance

INTRODUCTION

Boxing is an Olympic combat sport where athletes use their fists to take down their opponent in putting together both attack and defense (Arseneau et al., 2011). Amateur boxing competition is a representative sport that moves violently for 3 min×3 rounds, with a break of 1 min between rounds without sufficient recovery (El-Ashker et al., 2018). Amateur boxers throw between 61 and 78 punches per round, in addition to defensive actions (Davis et al., 2018), corresponding to a work to rest ratio of 18:1 (Slimani et al., 2017). To lead such an intensive boxing competition, sufficient physiological, biochemical, and psychological preparation is required (Slimani et al., 2018).

Recently, it gives a high score to a player who has an excellent powerful attack and overwhelms the round (Bruzas et al., 2014). For this reason, it is necessary to have the ability to continuously perform powerful attacks for three rounds and to achieve successful results, excellent physical fitness must be accompanied (Davis et al., 2018). Bruzas et al. (2014) also reported that aerobic and anaerobic capacity is an important determinant of performance in boxers as evidenced by a blood lactate concentration of 12 mmol during a boxing competition. Because of these factors, it is important that scientific boxing training promotes both aerobic capacity and anaerobic endurance to increase resistance to fatigue

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during a boxing match.

Korean amateur boxing has gradually moved away from the public's great interest in hosting the 1986 Asian Games and the 1988 Seoul Olympics. However, women's boxing has continued to be a powerful country by winning gold medal (-60 kg) at the 2018 Jakarta Asian Games for the first time and winning gold medals at the 2022 Asian Championships. Therefore, it is very meaningful to study the relationship between specific physical fitness for improving the performance of female boxers and scientific training plans.

According to a preliminary study, analyzed the characteristics of body composition and physical fitness of Korean men's national boxers, lightweight and heavyweight groups reported a lack of upper body anaerobic power and lower body peak power (Kim et al., 2016). And heavyweight players should make intensive efforts to strengthen core and cardiovascular endurance along with maintaining an ideal body fat. These findings provide the basis for enabling scientific training for national boxers. Davis et al. (2018) also reported that the winner of the boxing competition should have successful physical training and technical elements added. However, the studies examining the relationship between specific physical fitness in amateur boxers have been very inadequately reported. Moreover, there are very few research results of physical fitness evaluation and analysis of top-class amateur female boxers.

Therefore, the purpose of this study was to analyze and examine the differences in specific physical fitness of the national amateur women's boxers by weight category. These findings can be used as useful data in planning efficient and scientific training program strategies for conditioning and improving the performance of Korean female boxers.

MATERIALS AND METHODS

Participants

The subjects of this study consisted of 34 Korean female national boxers (29.53±4.39 years, 165.74±5.12 cm, 63.72±9.12 kg) selected for the national team from 2021 to 2023, who measured their body composition and specific physical fitness and the national boxers classified (a) flyweight (-51 kg), featherweight (-57 kg), and lightweight (-60 kg) as lightweight category (LWC), (b) welterweight (-69 kg) to middleweight (-75 kg) as middleweight category (MWC). The subjects' physical fitness was measured over a total of 2 days, and on the first day, body composition (height, body weight, percentage body fat and body mass index), maximal muscle strength (bench press, squat), isokinetic muscle strength (knee and trunk strength), and upper and lower anaerobic power (peak power, mean power, and power drop rate) were measured, and on the second day, variables related to cardiopulmonary endurance (anaerobic threshold, maximal heart rate [HRmax], and maximal oxygen consumption [VO_{2max}]) were measured through the maximal graded exercise test. The physical characteristics of the subjects who participated in this study are shown in Table 1. Ethical approval of this experimental study was given by the Institutional Review Board (IRB) of the Korea Institute of Sport Science, and all subjects provided their written informed (IRB No. KISS 21005-2104-02).

Table 1. Baseline characteristics of all subjects

Characteristic	Total sample (n=34)	MWG (n=13)	LWG (n=21)	*P*-value
Age (yr)	29.53±4.39	28.62±4.35	30.10±4.43	0.3475
Height (cm)	165.74±5.12	170.06±2.52	163.07±4.46	<0.001
Body weight (kg)	63.72±9.12	73.78±3.99	57.50±4.62	<0.001
Body fat (%)	20.04±4.55	22.76±4.58	18.37±3.73	0.004
Body mass index (kg/m^2)	23.10±2.36	25.51±1.50	21.61±1.31	<0.001

Values are presented as mean±standard deviation.
MWG, middleweight group; LWG, lightweight group.
Statistical significance test was done by Mann–Whitney *U*-test.

Body composition assessment

The body composition was measured by bio-electrical resistance method using a multifrequency impedance device (Inbody 720, Biospace Co., Seoul, Korea) to measure the height (cm), body weight (kg), body fat percentage (%fat), and body mass index (kg/m^2) after maintaining fasting before measurement. The subject stepped on the foot-board electrode measured their weight and height, and then input body information (age and gender). The players held the electrodes of both hands correctly, opened their arms about 30° so that they fell from their torso, and did not move until the measurement was over (Kim et al., 2016).

Maximal muscle strength assessment

The maximal muscle strength was measured using a multifunction dynamometer (ACE-2000 Multi-Function, Ariel Dynamics Inc., Trabuco Canyon, CA, USA), and the maximal strength that can be lifted once for the upper and lower limbs was measured using a bench press and squat. First, each subject performed warm-up using stretching for 10 min, then performed 8–10 times at an intensity of 30%–50% of one-repetition maximum, and after taking a 3–5 min break, the intensity was increased by 5%–10% for each set until it could be repeated once. At this time, a break

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time of at least 3 min was set for each set (Kim et al., 2016).

Anaerobic power assessment

For the measurement of the anaerobic power of the upper and lower extremities, the peak power (w/kg), average power (w/kg), and power drop rate (%) was measured using a bicycle-ergometer (824E bike ergometer, MONARK, Vansbro, Sweden), and arm-ergometer (Brachumera Sports, LODE, Groningen, Netherlands). In this test, the maximal value of each 5-sec section record during the 30-sec exercise time was set to the peak power (w/kg), and the mean power (w/kg) was the sum average of the average values in each 5-sec section. The warm-up of the arm and bicycle ergometer applied in this study was performed at 60 rpm and 100 w for 3 min and measured for 30 sec, and the intensity was calculated by the relative exercise strength (lower body weight × 0.075 kp, upper extremity: 0.7 Nm/kg). In the order of measurement, the lower extremity Wingate test was conducted first, and then the upper arm Wingate test was conducted after a sufficient recovery time by rest for more than 60 min (Kim et al., 2016).

Isokinetic muscle strength assessment

Isokinetic muscle strength was measured using HUMAC NORM Isokinetic Dynamometer (Humac Norm CSMi, Stoughton, MA, USA), the knee at an angular velocity of 60°/sec, and the trunk at an angular velocity of 30°/sec. When the posture adjustment for each measurement and the setting of the equipment were completed, the subject was asked to perform several warm-ups after sufficient explanation of the measurement method, and the measurement was performed. After measuring the angular muscle strength, the trunk muscle strength was measured after taking sufficient rest, and after flexion and extension were performed 3 times with maximal strength in both areas, the peak torque (%BW) and the left/right and extension/flexion ratio were calculated (Kim et al., 2016).

Cardiopulmonary endurance assessment

The cardiopulmonary endurance test was measured through a maximal graded exercise test using an automatic respiratory gas analysis device (TM55 treadmills; Quinton Cardiology Systems, Inc., Seattle, WA, USA), and VO_{2max} and HRmax were evaluated. The measurement protocol was measured using the KISS protocol developed for elite athletes by the Korea Institute of Sport Science. The initial load starts at a speed of 80 m per minute at a 6% slope and is increased by 20 m/min every 2 min until the subjects are out. The maximal oxygen uptake is determined as the maximal oxygen uptake at the time of measurement, and the predicted HRmax and respiratory exchange rate are referred to as 1.15 and finally evaluated (Kim et al., 2016).

Statistical analyses

Statistical analyses were performed using IBM SPSS Statistics ver. 25.0 (IBM Co., Armonk, NY, USA). The mean and standard deviation were calculated for all the measured parameters. A Mann–Whitney U-test was conducted to find out the differences in the body composition and professional physical fitness measurement variables of female boxers divided into two groups. The threshold for statistical significance was considered with a P-value < 0.05.

RESULTS

Table 1 shows the results of baseline characteristics between the groups, which divided a total of 34 Korean women's national amateur boxers (age: 29.53 ± 4.39 years, height: 165.74 ± 5.12 cm, body weight: 63.72 ± 9.12 kg, % body fat: 20.04% ± 4.55%, body mass index: 23.10 ± 2.36 kg/m^2), into middleweight group and lightweight group. As a result of the investigation, it was found that there were significant differences between groups in height ($P < 0.001$), body weight ($P < 0.001$), body fat percentage ($P = 0.004$), and body mass index ($P < 0.001$) among body composition.

As a result of comparing the variables of maximal muscle strength and isokinetic muscle strength among specific physical fitness between groups, there was a significant difference between the two groups in the bench press ($t = -4.176$, $P = 0.003$) and squat ($t = -2.544$, $P = 0.003$) in maximal muscle strength (Table 2). Among isokinetic knee muscle strength, there was a significant difference in left and right extension ratio ($t = 3.313$, $P = 0.001$) and right flexion/extension ratio ($t = -7.707$, $P < 0.001$), but there was no significant difference in left and right flexion ratio and left flexion/extension ratio. In addition, there was a statistically significant difference between the two groups in the right ($t = -5.484$, $P < 0.001$) and left flexion ($t = -4.452$, $P < 0.001$), but there was no statistically significant difference in the right and left extension. On the other hand, there was a statistically significant difference in the trunk muscle strength in the extension ($t = -3.094$, $P = 0.006$), but there was no statistically significant difference in the flexion/extension ratio and flexion.

Among specific physical fitness, the anaerobic power was measured by dividing the lower and upper limbs, and as a result of comparing the variables between the groups, the mean power ($t = -3.067$, $P = 0.002$) in the upper extremities showed a statisti-

Table 2. Comparison of maximal muscle strength and isokinetic muscle strength between groups

Variable	Total sample (n=34)	MWG (n=13)	LWG (n=21)	*T*-value	*P*-value
Maximal strength					
Bench press (kg/BW)	0.83±0.17	0.72±0.07	0.90±0.18	-4.176	0.003
Squat (kg/BW)	1.39±0.33	1.22±0.33	1.50±0.30	-2.544	0.003
Isokinetic strength					
Knee Flex L/R ratio (%)	-3.06±11.50	-8.82±15.14	0.51±6.76	-2.096	0.112
Knee Ex L/R ratio (%)	1.80±7.88	6.78±6.88	-1.29±6.92	3.313	0.001
Knee Flex: right (%BW)	113.30±19.37	96.42±16.19	123.75±12.72	-5.484	<0.001
Knee Ex: right (%BW)	219.98±21.53	219.57±24.68	220.24±19.97	-0.086	0.624
Knee Flex: left (%BW)	115.38±15.22	103.59±12.27	122.68±12.08	-4.452	<0.001
Knee Ex: left (%BW)	215.93±30.20	204.74±31.08	222.86±28.17	-1.753	0.076
Knee Flex/Ex ratio: right (%)	51.56±7.55	43.94±4.69	56.28±4.45	-7.707	<0.001
Knee Flex/Ex ratio: left (%)	53.95±7.40	51.40±8.80	55.52±6.09	-1.616	0.016
Trunk Flex/Ex ratio (%)	85.77±15.91	92.79±15.93	81.43±14.62	2.128	0.060
Trunk Flex (%BW)	295.28±42.97	286.88±35.31	300.49±47.16	-0.895	0.552
Trunk Ex (%B/W)	352.05±61.60	315.04±49.47	374.97±57.88	-3.094	0.006

Values are presented as mean±standard deviation.
MWG, middleweight group; LWG, lightweight group; BW, body weight; Flex, flexion; Ex, extension; L/R, left/right.
Statistical significance test was done by Mann–Whitney *U*-test.

Table 3. Comparison of anaerobic power between groups

Variable	Total sample (n=34)	MWG (n=13)	LWG (n=21)	*T*-value	*P*-value
Anaerobic power: lower					
Mean power (w/kg)	4.71±1.17	4.28±0.74	4.98±1.32	-1.742	0.104
Peak power (w/kg)	6.34±2.19	5.56±1.39	6.82±2.47	-1.679	0.120
Power drop rate (%)	53.88±9.80	50.23±8.10	56.07±10.26	-1.681	0.070
Anaerobic power: upper					
Peak power (w/kg)	9.60±1.69	9.62±1.88	9.59±1.60	0.051	0.972
Mean power (w/kg)	3.21±0.53	2.90±0.43	3.40±0.49	-3.067	0.002
Power drop rate (%)	87.41±9.22	86.00±9.00	86.00±9.00	1.136	0.181

Values are presented as mean±standard deviation.
MWG, middleweight group; LWG, lightweight group.
Statistical significance test was done by Mann–Whitney *U*-test.

Table 4. Comparison of cardiopulmonary endurance between groups

Cardiovascular endurance	Total sample (n=34)	MWG (n=13)	LWG (n=21)	*T*-value	*P*-value
HRmax at AT (beats/min)	171.62±11.31	175.62±11.22	169.14±10.90	1.664	0.029
HRmax (beats/min)	187.62±5.76	189.15±4.71	186.67±6.25	1.232	0.276
VO_{2max} (mL/kg/min)	51.57±4.57	47.80±4.01	53.90±3.15	-4.949	<0.001
20-m shuttle-run (repetition)	72.35±14.34	63.54±13.18	77.81±12.39	-3.186	0.004

Values are presented as mean±standard deviation.
MWG, middleweight group; LWG, lightweight group; AT, anaerobic threshold; VO_{2max}, maximal oxygen consumption.
Statistical significance test was done by Mann–Whitney *U*-test.

cally significant difference between the two groups, but neither the upper nor lower extremities showed a significant difference in peak power and power drop rate (Table 3).

Table 4 shows the results of cardiopulmonary endurance among specific physical fitness, and the VO_{2max}, HRmax, and number of repetitions were measured through the maximal graded exercise test and shuttle-run exercise. As a result of comparing variables between groups, there was a statistically significant difference be-

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tween the two groups in the HRmax at anaerobic threshold (t = 1.664, P = 0.029), VO_{2max} (t = -4.949, P < 0.001) and the 20-m shuttle-run exercise (t = -3.186, P = 0.004), but there was no significant difference in the HRmax.

DISCUSSION

This study was to analyze and examine specific physical fitness (muscle strength, anaerobic power, and cardiopulmonary endurance) differences by weight classification by classifying a total of 34 Korean women's national amateur boxers into two groups: flyweight to lightweight as LWC and welter to middleweight as MWC.

Boxing is a combat sport that is performed at various weight classes and requires high levels of muscle strength, anaerobic power, and cardiopulmonary endurance (Chaabène et al., 2015; Slimani et al., 2017). In general, domestic and international amateur boxing championships are throughout 4 to 14 days, ranging from 4–6 times. In this style of matches, it is essential for boxers to manage their weight and body fat even during the off-season, as excellent physical function and weight management can result in good performance and must pass new weights before each competition (Reale et al., 2017). Therefore, it is essential for boxers to reduce their weight by minimizing body fat percentage while optimizing their muscle mass so that they can perform successfully. Previous studies have shown that Olympic team boxers have used rapid weight loss procedures, including intermittent fasting and wearing sweatpants, before the championships (Chaabène et al., 2015), and that such rapid weight loss has been reported to negatively affect anaerobic ability, so boxers must maintain proper weight throughout the tournament while making rapid recovery from previous matches while preparing for performance loss (Franchini et al., 2012). These findings show that body composition is an important variable for amateur boxers that can directly affect specific physical fitness and performance, so this study also compared and analyzed the percentage body fat and body mass index levels of boxers by weight category, and found that there were significant differences in percentage body fat (P = 0.004) and body mass index levels (P < 0.001) in the LWG (18.37 ± 3.73, 21.61 ± 1.31, recently) and MWG (22.76 ± 4.58, 25.51 ± 1.50, recently) groups. These results are considered to maintain appropriate body composition, given that the percentage body fat of female amateur boxers is 14%–26% in previous studies (Chaabène et al., 2015). However, it is noteworthy that there is a lack of research on female boxers at the elite level, and as far as we know, there are no studies dealing with physical function and body fat percentage except for Khanna and Manna (Khanna and Manna, 2006). Therefore, it is assumed that this study could be a new investigation.

It is reported that muscle strength and power must be well developed to effectively implement tactical requirements in amateur boxing matches (Piorkowski et al., 2011; Stone et al., 2022). Muscle power and strength is the ability to generate large amounts of force in a relatively short time (Cormie et al., 2011; Kawamori and Haff, 2004). Both high levels of power and strength are required to effectively increase punching, a key component of boxing (Piorkowski et al., 2011). In this context, it has been suggested that the ability to generate high levels of muscle power and strength is considered one of the main basic prerequisites supporting successful performance among elite amateur boxers. In particular, lower limb muscle strength and power are closely related to various punching accelerations and power (Loturco et al., 2014; Loturco et al., 2016). Importantly, a recent study has shown that strong-strength boxers are more active during games, which also show higher effects in head-punch and attack hit rates (Loturco et al., 2021). However, since most boxers have to lose weight quickly before a match, training methods that induce massive hypertrophy can be extremely counterproductive (Reljic et al., 2015; Schoenfeld et al., 2016) and training methods to improve muscle strength and muscle power should be carefully chosen (Loturco et al., 2016). Thus, power training methods using high-speed to light/medium loads, in general, may induce greater adaptation in this part of the force-speed curve (de Villarreal et al., 2011; Saez et al., 2013; Yoon et al., 2017; Yoon et al., 2023) than in the low-speed training of heavy loads. In this study, the comparison between the LWC and MWC groups did not show any significant difference between the groups in all upper and lower anaerobic power results except for the upper extremities anaerobic mean power, and importantly, muscle strength as well as anaerobic power also showed lower levels in the MWC group than in the LWC group. These results are difficult to directly compare due to the lack of previous studies, but the results of this study showed that the upper and lower extremities' anaerobic power levels in the MWC group were insufficient. Since anaerobic power is well established to be related to performance in amateur boxing, further studies are needed to evaluate differences in the level of anaerobic performance with different weights and medalist boxers.

Cardiopulmonary endurance is one of the most important factors of performance in boxing, and well-developed aerobic capacity helps maintain repetitive high-intensity behavior within boxing competition, accelerate the recovery process, and maintain a boxer's performance until the final round (Davis et al., 2014; de Lira et al., 2013). Unfortunately, however, studies on the cardiopulmonary endurance of women's amateur boxers are insufficient, and VO_{2max} is reported to have improved from 48.6±6.8 to 50.9±7.4 due to the 6-week training effect on 45 elite female boxers in India, and a study of 20 elite-level Indian women's boxers reported that the average VO_{2max} value was 52.1±6.9 mL/kg/min. As such, to the best of our knowledge, no studies have been conducted despite the close relationship between aerobic capacity and performance in boxing. In this study, cardiopulmonary endurance results of LWC and MWC showed significant differences between groups in VO_{2max} and 20-m shuttle-run and HRmax at anaerobic threshold, with both variables indicating that MWC was significantly lower than LWC. These results show the consistency with this study, as a study of Indian amateur elite boxers found that the VO_{2max} of heavyweight athletes was rated lower than that of other weight classes (Ghosh et al., 1995).

To the best of our knowledge, this is the first study to be studied on Korean women's national amateur boxers and is expected to provide useful data for planning future strategies for efficient and scientific training programs. Furthermore, this study is expected to serve as the basis for the classification of improvements through customized training programs for each weight class and analysis of specific physical fitness variables. This study has several limitations. First, participants in this study may not be representative of the sample. This is because the results may be biased. After all, they were only targeting athletes from national teams. Second, biochemical and psychological parameters other than physical variables were not measured. In conclusion, this study was conducted to compare and analyze the characteristics of body composition and specific physical fitness between the two groups after dividing four Korean women's national amateur boxers into LWC (n=21) and MWC (n=13). Among body composition, percentage body fat and body mass index levels were significantly higher in the MWC than in the LWC, and among specific physical strength, Isokinetic muscle strength, maximal muscle strength, and cardiopulmonary endurance levels were significantly higher in the LWC than in the MWC. Accordingly, the results of this study are expected to provide useful data for planning future strategies for efficient and scientific training programs for each weight class.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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