ORIGINAL ARTICLE

Respiratory function of the Korean elite judo athletes and non-athletes

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Abstract

Background and Study Aim: Respiratory function (respiratory system) is important for patients including judo athletes who require sports rehabilitation. The purpose of this study was knowledge about respiratory function of Korean elite judo athletes and non-athletes.

Material and Methods: We measured the respiratory function of both 21 elite judo athletes and 21 non-athletes. Respiratory measurements were performed in a sitting position using a spirometer, and the circumference of the participants' chests and abdomens was measured. Respiratory measurements were focused on a forced vital capacity (FVC) graph.

Results: Chest circumference was significantly increased in the elite judo athletes compared with the non-athletes. In respirogram phasic analysis, the expiratory, inspiratory, and total area of FVC were significantly increased in the judo athletes compared to the non-athletes. The slopes of respirogram phases, such as the tangent angles, of the FVC were compared between non-athletes and judo athletes. The tangent for athletes at AS2 and AS3 were significantly increased compared to non-athletes. In addition, the tangent of the DS2 and DS3 were significantly increased in judo athletes, respectively. Furthermore, in the correlative analysis, chest and abdominal circumference were not correlated with the area of the FVC. However, the correlation coefficients for the chest circumference and tangent were significantly correlated with the slope of the FVC in AS1 and AS2, respectively.

Conclusions: The results suggest that the differences in changes in the phases of the respirogram between the non-athletes and Korean elite judo athletes may in part contribute to our expanding of understanding of respiratory function for professional sports and rehabilitation through sport.

Key words: cardiovascular disease • forced vital capacity • rehabilitation through sport

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Forced vital capacity – ***noun*** the amount of air that can be expelled after inhaling the maximum possible amount into the lungs

Respiratory system – ***noun*** a series of organs and passages that take air into the lungs and exchange oxygen for carbon dioxide [40].

Respiratory tract (respiratory function) – ***noun*** the parts of the body that are responsible for breathing, including the lungs, trachea, mouth and nose [40].

Respire – verb to breathe air in and out [40].

Respirometer – ***noun*** an instrument for measuring and studying the process in which oxygen is taken into the body, delivered to tissues and cells, and used by them [40].

Spirometer – noun a device used for measuring oxygen consumption [40].

Expiration – ***noun*** the act or process of breathing out [40].

Expiratory loop – ***noun*** the volume of air that is expired at each point during a full forced expiration. A normal expiratory loop should involve a gradual tapering of the amount expired towards the end [40].

Tidal air, tidal volume – ***noun*** the volume of air that passes in and out of the body during normal breathing [40].

Cardiovascular disease – ***noun*** reduced function of the heart and arteries caused by excessive intake of saturated fats. Abbreviation **CVD** [40].

Randori – sparring in judo in which both participants practice attacking and defending [41].

INTRODUCTION

Judo is one of the most popular sports worldwide of the area of combat sports and martial arts [1-3]. The martial arts and combat sport of judo was highlighted at the 1964 Olympic Games, and 187 countries are now members of the International Judo Federation (IJF) [4]. Judo involves throwing one's opponent back using different techniques, such as a fixed or elbow joint lock, to score points. Therefore, it is important for athletes to be in excellent physical condition in terms of strength and flexibility [5].

Competitors are matched by weight, and overall body strength is considered important [6]. Each the judo bout normally lasts up to five minutes and is characterized by high-intensity intermittent exercise similar to wrestling; however, chokes and joint lock manipulations are allowed. In order to perform these techniques, the participants overload their muscles and joints, especially those used in shoulder, trunk, and hip movements [5, 7, 8]. Resistance training appears to be a potential strategy to improve strength and flexibility, as judo athletes have little time for additional training and flexible training can interfere with performance [9-11].

Athletes in most types of combat and martial arts, such as judo, wrestling, boxing, taekwondo, and airborne, compete with each other within certain weight categories. Competitors usually strive to be the heaviest in their weight category to have a physical and tactical advantage over lighter-weight opponents. Judo athletes often weigh more than the upper limit of the weight category during training [12]. That is why heavyweight athletes, including those who participate in judo, football, and rugby, have a significant impact on athletic performance, so they must intentionally increase their weight [13]. However, heavyweight athletes have recently been reported to be at a higher risk of cardiovascular disease compared to non-heavyweight athletes, despite being actively involved in sports [14–16]. Obesity is a major risk factor for cardiovascular disease due to an accumulation of visceral fat [14, 15].

Physiotherapy specialists play an essential role in healthcare systems worldwide and contribute to medical specialties, such as those relating to the musculoskeletal, nervous, and respiratory systems [16]. Good respiratory function is important for patients, including athletes who require sports rehabilitation for respiratory dysfunction. Respiratory rehabilitation is a core specialty in the field of physiotherapy and plays a key role in the management and treatment of respiratory disease patients [17, 18]. In particular, the spirometry is a well-known and commonly used method for evaluating pulmonary function. Previous studies have found that physical activity and exercise training promotes cardiovascular and thus pulmonary health [19].

Sports injury in coastal areas is related to maintenance of athletes' performance and health. Respiratory rehabilitation is an important way to potentially improve pulmonary function in patients including athletes with respiratory problems

The purpose of this study was knowledge about respiratory function of Korean elite judo athletes and non-athletes.

MATERIAL AND METHODS

The present study consisted of 21 elite judo athletes and 21 non-athletes (Table 1). Forty-two volunteers who had no abnormal physical or psychological conditions provided written informed consent to participation in this study (Table 1) [20]. Participants were asked to complete a questionnaire via individual in-depth interviews, which took 30 minutes per person.

All participants rested for 30 minutes before their measurements were taken. Chest and abdominal circumference were measured at rest under expiratory and inspiratory conditions [20, 21]. Chest circumference was measured at the height of the axilla, and abdominal circumference was measured at the height of the navel.

The respiration ability of participants was measured. The participants were measured by lung function testing using the SCHILLER SP-260 spirometer (SCHILLER AG, Baar, Switzerland) [20, 21]. The spirometric indicators, including forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), FEV1/FVC, peak expiratory flow (PEF), peak inspiratory flow (PIF), slow vital capacity (SVC), inspiratory reserve volume (IRV), expiratory reserve volume (ERV), tidal volume (TV), maximum voluntary ventilation (MVV), minute or expired ventilation (MV), and respiratory rate (RR) were recorded and analyzed by methods of resting breathing and forced breathing [20, 21].

Measurement was focused on the FVC graph, which was divided into the expiratory area (ExA) and the inspiratory area (InsA) (Figure 1A). The pixel values were measured using Adobe Photoshop 7.0.1. The ExA was divided into **A** and **B** sections based on the PEF. Analogously, the InsA was divided into **C** and **D** sections based on the PIF. Each **A**, **B**, **C**, and **D** section was further subdivided to four areas (Figure 1A). From left to right, the connections between each of the divided points of the **A** area were designated as the first slope (AS1), the second slope (AS2), and the third slope (AS3). Correspondingly, from left to right, the first, second, and third slopes defining the **B** area were designated BS1, BS2, and BS3, respectively; the first, second, and third slopes defining the **C** area were designated CS1, CS2, and CS3, respectively; and the first, second, and third slopes defining the **D** area were designated DS1, DS2, and DS3, respectively (Figure 1A) [20, 21].

After creating these subdivisions, the tangent and angle of each point were measured. The angle of each point and the respiratory area of the FVC were each measured in triplicate at each measurement time, and the mean values were calculated. The formula for the tangent is given in Equation 1, where r is the radius of a circle composed of the coordinates of the x and y axes. The cos θ is the value obtained by dividing x by r; sin θ is the value obtained by dividing y by r. The tan θ is equivalent to the ratio of the sin θ to the cos θ [20–22].

$$\tan\theta = \frac{1-(1-2\sin^2\theta)}{2\sin\theta\cos\theta} = \frac{2\sin^2\theta}{2\sin\theta\cos\theta} = \frac{\sin\theta}{\cos\theta} \quad (1)$$

The angle was determined (Equation 2) using the arctangent in order to verify the tangent θ. In Equation 2, x represents the unknown quantity, and i represents an imaginary quantity (Figure 1A) [20, 21, 23].

$$\arctan x = x - \frac{x^3}{3} + \frac{x^5}{5} - \frac{x^7}{7} + \cdots = \sum_{n=0}^{\infty} \frac{(-1)^n x^{2n+1}}{2n+1};\ |x| \le 1,\ \ x \ne i, -i \quad (2)$$

The IBM SPSS Statistics software (Version 22.0, IBM Corp., Armonk, NY, USA) was used for the statistical analysis. The significance level was set to α=0.05, and all data are presented as the mean ± standard error (SE) of the measurements. One-way ANOVA was conducted to compare the significance between the groups. The Pearson correlation coefficient test was performed to identify correlations between the variables.

The protocol for this study was approved by the Committee of Ethics in Research of Yongin University in accordance with the terms of Resolution 5-1-20.

RESULTS

Chest circumference was significantly increased in the elite judo athletes compared with the non-athletes (Table 1).

Significant differences were found in all respiratory measurement values, except the IRV of SVC and the TV of MVV in spirometry indicators (Table 2).

In respirogram phasic analysis, the expiratory (ExA), inspiratory (InsA), and total area (Total) of FVC were significantly increased in the judo athletes compared to the non-athletes (Figure 1B and Table 3). Furthermore, the slopes of respirogram phases, such as the tangent angles, of the FVC were compared between non-athletes and judo athletes. The tangent for athletes at slopes 2 and 3 of area A (AS2 and AS3) was increased compared to non-athletes (Figure 1B and Table 3). In addition, the tangent of the 1 slope of area C (CS1) and the 2 and 3 slopes of area D (DS 2 and DS3) were significantly increased in elite judo athletes, respectively (Figure 1B and Table 3).

Area and slope of the FVC and respiratory indicators were determined, as described in the Material and Methods section. FVC, forced vital capacity; AS1–3, first, second, and third slopes of the A area; BS1–3, first, second, and third slopes of the B area; CS1–3, first, second, and third slopes of the C area; DS1–3, first, second, and third slopes of the D area; ExA, expiratory area; InsA, inspiratory area.

In the correlative analysis, chest and abdominal circumference were not correlated with the area of the FVC (Table 4). However, the correlation coefficients for the chest circumference and

Table 1. Characteristics of the non-athletes and Korean elite judo athletes.

Variable		Non–athletes (n = 21)	Judo athletes (n = 21)
Age (yr)		22.9 ±1.7	20.7 ±0.9
Gender	Male (%[a]/%[b])	21 (100.0/50.0)	21 (100.0/50.0)
	Female (%[a]/%[b])	–	–
Height (cm)		175.8 ±4.2	174.0 ±5.4
Weight (kg)		75.9 ±9.8	77.0 ±8.7
BMI (kg/cm)		24.7 ±3.0	25.4 ±2.8
Career (yr)		–	8.5 ±1.2
Training Frequency		–	3/day (18/week)
Training Time		–	5.8 ±0.2 h/day (34.5 ±1.5 h/week)
Aero Ex		–	2.3 ±0.1 h/day (13.8 ±0.6 h/week)
Anaero Ex		–	3.2 ±0.4 h/day (19.2± 2.4 h/day)
Wei Div	–60 kg (%[a]/%[b])	–	1 (4.8/2.4)
	–66 kg (%[a]/%[b])	–	4 (19.1/9.5)
	–73 kg (%[a]/%[b])	–	5 (23.8/11.9)
	–81 kg (%[a]/%[b])	–	7 (33.3/16.7)
	–90 kg (%[a]/%[b])	–	4 (19.1/9.5)
Che Cir (cm)	Rest	96.5 ±6.7	101.3 ±3.0*
	Exp	94.9 ±6.8	99.7 ±3.0*
	Insp	99.6 ±6.7	104.2 ±3.4*
	DER	1.7 ±1.1	1.6 ±0.7
	DIR	3.0 ±1.5	2.9 ±1.1
Abd Cir (cm)	Rest	87.7 ±7.3	82.7 ±5.5*
	Exp	86.1 ±7.9	81.0 ±5.6*
	Insp	90.9 ±7.5	84.3 ±5.6*
	DER	2.9 ±1.4	1.7 ±1.1*
	DIR	2.7 ±1.3	1.6 ±0.6*

All data are presented as the mean, ±SE; [a]percentage of judo athletes; [b]percentage of all participants; BMI body mass index; **Che Cir** chest circumference; **Abd Cir** abdominal circumference; **Aero Ex** aerobic exercise; **Anaero Ex** anaerobic exercise; **Wei Div** weight division; **Exp** expiration; **Insp** inspiration; **DER** differences between expiration and rest; **DIR** differences between inspiration and rest; *significantly different from non-athletes, $p<0.05$

Table 2. Differences in respiratory function between the non-athletes and Korean elite judo athletes.

Variable	Non-athletes (n = 21)	Judo athletes (n = 21)
FVC (L)	4.7 ±0.5	5.3 ±1.2*
FEV1.0 (L)	4.0 ±0.5	4.7 ±1.1*
FEV1.0/FVC (%)	83.9 ±6.2	89.0 ±5.7*
PEF (L/s)	9.1 ±1.5	11.1 ±2.2*
PIF (L/s)	6.3 ±1.3	7.4 ±2.2*
SVC (L)	4.7 ±0.5	5.5 ±1.3*
ERV (L)	1.4 ±0.5	1.9 ±0.9*
IRV (L)	2.4 ±0.8	2.3 ±0.6
TV (L)	0.6 ±0.4	1.2 ±0.5*
MVV (L/min)	161.3 ±30.6	190.0 ±51.6*
RR (L/min)	94.2 ±17.8	109.1 ±16.3*
TV (L/min)	1.7 ±0.6	1.8 ±0.7
MV (L/min)	12.6 ±6.0	18.0 ±6.1*
RR (L/min)	27.5 ±6.7	22.3 ±6.9*
TV (L/min)	0.4 ±0.3	0.9 ±0.4*

All data are presented as the mean, ±SE; **FVC** forced vital capacity; **FEV1.0** forced expiratory volume in one second; **FEV1.0/FVC** FEV1.0/FVC ratio, **PEF** peak expiratory flow; **PIF** peak inspiratory flow; **SVC** slow vital capacity; **IRV** inspiratory reserve volume; **ERV** expiratory reserve volume; **TV** tidal volume; **MVV** maximum voluntary ventilation; MV minute ventilation; **RR** respiratory rate. *significantly different from non-athletes p<0.05

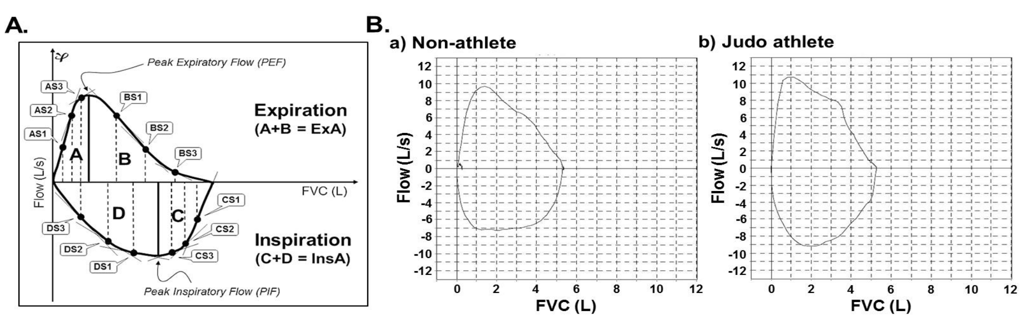

Figure 1. Differences in FVC and respirogram phase between the non-athletes (n = 21) and Korean elite judo athletes (n = 21).

Table 3. Differences in respirogram phases of forced vital capacity between the non-athletes and Korean elite judo athletes.

Variable		Non-athletes (n = 21)	Judo Athletes (n = 21)
aFVC	ExA	22302.3 ±4631.1	27422.3 ±12703.9*
	InsA	23728.2 ±6597.2	28862.7 ±18099.2*
	Total	46037.5 ±9558.9	56285.0 ±29864.9*
sFVC	AS1	10.5 ±3.2	11.3 ±2.8
	AS2	5.5 ±2.6	7.0 ±2.0*
	AS3	1.8 ±1.1	2.8 ±1.4*
	BS1	−1.5 ±0.9	−1.7 ±0.8
	BS2	−1.4 ±0.8	−1.5 ±0.4
	BS3	−1.4 ±0.9	−1.3 ±0.5
	CS1	2.6 ±1.8	4.0 ±2.4*
	CS2	0.6 ±0.4	1.5 ±1.0
	CS3	0.5 ±0.4	0.5 ±0.4
	DS1	−0.4 ±0.4	−0.5 ±0.5
	DS2	−0.6 ±0.6	−1.0 ±1.0*
	DS3	−1.6 ±1.1	−3.1 ±2.6*

All data are presented as the mean ±SE; **aFVC** area of forced vital capacity; **sFVC** slope of forced vital capacity; **ExA** expiratory area; **InsA** inspiratory area; **Total** total area; **AS1** first slope of the A area; **AS2** second slope of the A area; **AS3** third slope of the A area; **BS1** first slope of the B area; **BS2** second slope of the B area; **BS3** third slope of the B area; **CS1** first slope of the C area; **CS2** second slope of the C area; **CS3** third slope of the C area; **DS1** first slope of the D area; **DS2** second slope of the D area; **DS3** third slope of the D area; *significantly different from non-athletes p<0.05

Table 4. Correlation coefficients of the circumference and area of forced vital capacity.

aFVC	Chest Circumference					Abdominal Circumference				
	Rest	ExP	InsP	DER	DIR	Rest	ExP	InsP	DER	DIR
ExA	0.132	0.119	0.149	0.098	0.084	−0.165	−0.136	−0.161	−0.128	−0.015
InsA	0.035	0.028	0.064	0.051	0.142	−0.116	−0.089	−0.121	−0.125	−0.059
Total	0.081	0.071	0.107	0.076	0.127	−0.147	−0.117	−0.148	−0.136	−0.044

aFVC area of forced vital capacity; **ExP** expiratory condition; **InsP** inspiratory condition; **DER** differences between expiration and rest; **DIR** differences between inspiration and rest; **ExA** expiratory area; **InsA** inspiratory area; **Total** total area

tangent are shown in Table 5, with slope 1 and 2 of the A area (AS1 and AS2) showing significant correlation, respectively.

DISCUSSION

Frequent exercise training and physical fitness are associated with lowering the risk of cardiovascular disease and death in the general population [24-26]. Current evidence, however, has shown contradictory results regarding cardiovascular outcomes in people who perform

Table 5. Correlation coefficients of the circumference and slope of forced vital capacity.

sFVC	Chest Circumference					Abdominal Circumference				
	Rest	ExP	InsP	DER	DIR	Rest	ExP	InsP	DER	DIR
AS1	0.299**	0.289**	0.277**	0.079	–0.108	0.053	0.059	0.042	–0.034	–0.061
AS2	0.259**	0.247**	0.244**	0.090	–0.072	0.060	0.073	0.036	–0.069	–0.143
AS3	0.171	0.169	0.155	0.021	–0.078	–0.052	–0.031	–0.073	–0.098	–0.156
BS1	–0.062	–0.056	–0.058	–0.045	0.020	–0.032	–0.041	–0.030	0.044	0.009
BS2	–0.070	–0.064	–0.052	–0.048	0.090	0.033	0.051	0.024	–0.088	–0.055
BS3	–0.015	–0.048	0.019	0.236*	0.166	0.030	0.029	0.032	0.001	0.022
CS1	0.034	0.050	0.051	–0.119	0.083	–0.107	–0.099	–0.128	–0.031	–0.168
CS2	–0.004	0.020	0.003	–0.175	0.035	–0.084	–0.094	–0.093	0.054	–0.079
CS3	–0.133	–0.108	–0.123	–0.178	0.048	–0.151	–0.163	–0.138	0.070	0.050
DS1	–0.041	–0.041	–0.020	–0.004	0.101	0.088	0.078	0.102	0.046	0.109
DS2	–0.014	–0.027	–0.005	0.098	0.045	0.066	0.044	0.095	0.104	0.210*
DS3	–0.092	–0.101	–0.071	0.065	0.107	0.104	0.065	0.132	0.185*	0.210*

sFVC slope of forced vital capacity; **ExP** expiration condition; **InsP** inspiration condition; **DER** differences between expiration and rest; **DIR** differences between inspiration and rest; **AS1–3** first, second, and third slopes of the A area; **BS1–3** first, second, and third slopes of the B area; **CS1–3** first, second, and third slopes of the C area; **DS1–3** first, second, and third slopes of the D area; *p<0.05

repetitive and violent movements [27, 28]. For example, in patients with typical atherosclerotic risk factors, cardiac remodeling, such as left ventricular dysfunction, dilation, mitral reperfusion, and arrhythmia (which are well-known predictors of poor prognosis of acute cardiac events), is common; this includes elite athletes [29-31]. Sports injury in coastal areas and others also is directly or indirectly related to maintaining athletic performance. Therefore, the cardiovascular health status of athletes should be known. This can be determined through respiratory function tests [32].

According to previous research, height and weight affect the spirometry indicators [33]. Among Korean wrestler athletes, height, weight, and body mass index have been found to be greater compared to non-athletes, which affected the respiratory function test results [34]. However, as seen in Table 1 of the present study, there are no significant differences in height, weight, and BMI between judo athletes and non-athletes. In addition, the present results showed that the FVC graph of the judo athletes is larger than those of the non-athletes. In particular, in our respirogram analysis, data of the FVC graph revealed that the expiratory, inspiratory, and total area of FVC of the judo athletes and non-athletes were significantly different. The AS2, AS2, DS2, and AS3 values were also significantly different. These results support that the respiratory muscles of the judo athletes were anticipated to be better than those of the non-athletes.

Meanwhile, previous studies have shown that respiration is affected by exercise training [35, 36]. Judo athletes can also expect to experience a positive effect on respiratory function with continuous training every week in the present study. Muscle strength and respiratory function are closely related to each other, because poor respiratory function is an indicator of muscle weakness [37]. The respiratory muscles can be divided into inspiration and expiration muscles [38]. The major inspiratory muscles that engage during inspiration are the diaphragm and external intercostal muscles. The accessory inspiratory muscles involved in spinal movement are the sternocleidomastoid, scalene, trapezius, and serratus anterior muscles [38]. In judo sports, athletes develop the muscles associated with respiration [39]. The greater chest circumference of judo athletes compared to non-athletes is due to this muscle development according to Table 1 of the present results. In addition, the correlation between chest circumference and FVC by Table 5 was found to be significant of our results.

These results partially demonstrated the previous studies [38, 39].

Based on the present results, it was also initially expected that the cardiovascular health of judo athletes would not be good due to their weight; however, it was found that they maintained good cardiovascular health through regular training. Our respirogram analysis may in part contribute to the knowledge base relating to the rehabilitation of elite judo athletes by providing a better understanding of the features of judo sparring match (randori). Furthermore, further systematic and scientific studies in the area of sports science research and therapeutic approach, especially for respiratory problems related to various sports, are needed.

CONCLUSIONS

Sports injury in coastal areas is related to maintenance of athletes' performance and health. Respiratory rehabilitation is an important way to potentially improve pulmonary function in patients including athletes with respiratory problems. Therefore, the results suggest that the differences in changes in the phases of the respirogram between the non-athletes and Korean elite judo athletes may in part contribute to our expanding of understanding of respiratory function for professional sports and rehabilitation through sport.

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