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Original Article

Analysis of the respirogram phase of Korean wrestling athletes compared with nonathletes for sports physiotherapy research

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Abstract. [Purpose] Respiratory function is important for patients including athletes who require physical therapy for respiratory dysfunction. The purpose of the present study was to analyze the differences in the respirograms between Korean wrestling athletes and nonathletes according to phase for the study of sports physiotherapy. [Subjects and Methods] Respiratory function was measured using spirometry in both the athletes and nonathletes while they were in a sitting position. [Results] Spirometry parameters in the athletes were significantly higher than in the nonathletes. In respirogram phasic analysis, the expiratory area and total area of forced vital capacity were significantly increased in the athletes compared with the nonathletes. The slopes of the forced vital capacity for athletes at slopes 1, 2, and 3 of the A area were significantly increased. In correlative analysis, chest circumference was significantly correlated with slope 3 of the A area of the forced vital capacity. [Conclusion] The results suggest that the differences in changes in the phases of the respirogram between the Korean wrestling athletes and nonathletes may in part contribute to our understanding of respiratory function in sports physiotherapy research.

Key words: Respirogram analysis, Korean wrestling, Sports physiotherapy research

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INTRODUCTION

Respiratory physiotherapy is an important way to potentially improve lung function in patients including athletes with respiratory dysfunction caused by genetically determined neuropathy, chronic obstructive pulmonary disease, asthma, or sports injury of the chest[1–4]. In particular, sports injury in coastal areas is directly or indirectly related to maintenance of athletes' performance[5–8]. Korean wrestling, also called ssireum, is unique to the traditional culture and folklore of Korean spectator sports[9–11]. The rules for matches are simple, and the outcome is clear to young and old observers alike. A Korean wrestling match is a gentlemanly sport focused on manners in which the participants do not hit each other[9–11]. Male athletes are categorized into seven divisions according to body weight, while female athletes compete in two weight divisions. The objective of Korean wrestling is to overcome the opponent by utilizing the muscles of the whole body based on fitness and skill[9–11]. Therefore, participation in Korean wrestling results in balanced development of the whole body. In Korean wrestling, the participants hold onto each other's belt (satba) and try to cause part of their opponent's body above the knee to touch the ground[9–11]. Ultimately, the body movements used in the attempt to knock over opponents cause development of muscle strength and endurance[9–11]. We selected a pulmonary function test to characterize the exercise of Korean wrestling. Cardiorespiratory fitness represents a human health condition of the entire body[12–14]. In contrast, pulmonary function testing provides a quantitative assessment of lung function, which is important for estimating an individual's health[15]. Respiratory function is influenced by exercise and training[15, 16]. As a result, lung function may change depending on the frequency of the sport activity[17, 18]. To date, however, no study has analyzed the respiratory function of Korean wrestling athletes. Therefore, the objectives of this research were to analyze and compare the respiratory function of Korean wrestling athletes and nonathletes for the study of sports rehabilitation.

SUBJECTS AND METHODS

The present study consisted of 16 elite Korean wrestling athletes and 95 nonathletes. Measurements were performed from March 2015 to August 2015. One hundred and eleven volunteers who had no abnormal physical or psychological conditions provided written informed consent to participation in this study[9]. Participants were asked to complete a questionnaire via individual in-depth interviews, which took 30 minutes per person[9]. There were seven weight categories: gyungjang (less than 75 kg), sojang (less than 80 kg), chungjang (less than 85 kg), yongjang (less than 90 kg), yongsa (less than 95 kg), yeoksa (less than 110 kg), and jangsa (less than 150 kg)[9, 10]. The criteria for the inclusion of participants in the study were as follows: (1) 20–23 years of age, (2) male, (3) history of respiratory disease, (4) experience of stress during exercise, (5) psychological factors, (6) history of injuries, and (7) primary technology used. Before measurement, all participants rested for 30 minutes[9]. Chest and abdominal circumference were measured at rest under expiratory and inspiratory conditions[2]. 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). Spirometric parameters, 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. Measurement was focused on the FVC graph, which was divided into the expiratory area (ExA) and the inspiratory area (InsA)[2]. 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 (Fig. 1**A**). 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 (Fig. 1A)[2]. 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[2, 19]. 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[2, 20].

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

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

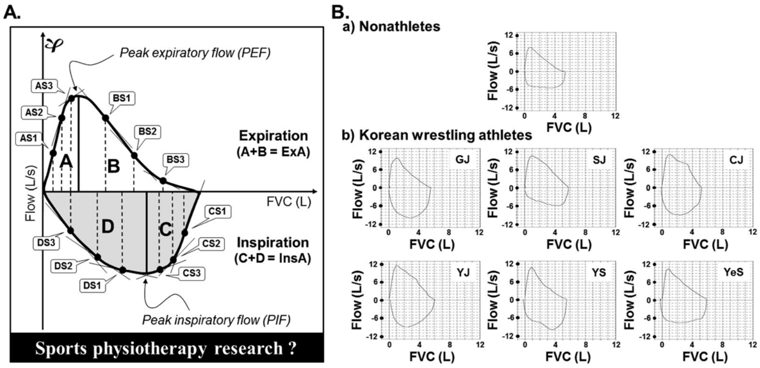

Fig. 1. Differences in FVC and respirogram phase between the Korean wrestling athletes and nonathletes[2, 9, 10]
Area and slope of the FVC and respiratory parameters were determined, as described in the Subjects and Methods section. FVC, forced vital capacity; AS1–3, first, second, and third slopes of 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
Weight classes of Korean wrestling athletes: GJ, gyungjang; SJ, sojang; CJ, chungjang; YJ, yongjang; YS, yongsa; YeS, yeoksa

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

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 Yong In University in accordance with the terms of Resolution 5-1-20.

RESULTS

Table 1 shows the general characteristics of the Korean wrestling athletes compared with those of the nonathletes. Spirometry parameters in the athletes group were significantly higher than in the nonathletes, but not ERV, IRV, and MVV (Table 2). Respirogram phasic analysis revealed that the expiratory (ExA) and total area (Total) of the FVC were significantly increased in the athletes compared with the nonathletes (Table 3 and Fig. 1B). The slopes of respirogram phases, such as the tangent angles, of the FVC were compared between nonathletes and athletes (Table 3, Fig. 1B). The tangents for athletes at slopes 1, 2, and 3 of the A area (AS1, AS2, and AS3) were significantly increased (Table 3, Fig. 1B). Furthermore, in the correlative analysis, chest and abdominal circumference were not correlated with the area of the FVC (Table 4). The correlation coefficients for the chest circumference and tangent are shown in Table 5, with slope 3 of the A area (AS3) showing significant correlation.

DISCUSSION

Respiratory exercise is a factor that affects balance and postural stability[22]. Balance is very important in ssireum, which is also called Korean wrestling[9, 10]. Regular physical training improves respiratory functions[23]. Therefore, the respiratory function of Korean wrestling athletes is better than that of nonathletes, as were other physical parameters such as height, weight, body mass index, chest circumference, and abdominal circumference. Analysis of the FVC graph revealed that the ExAs of the Korean wrestling athletes and the nonathletes were significantly different. The AS1, AS2, and AS3 values were also significantly different. The respiratory muscles of the ssireum athletes were anticipated to be better than those of the nonathletes. According to other studies, ssireum athletes have more muscle and fat mass compared with nonathletes[9–11]. Examination of the reasons for this development in ssireum athletes prompted respiratory analyses in this study. The primary techniques of the ssireum athletes were considered, including hand techniques, leg techniques, trunk techniques, and mixed techniques[9–11]. The preferred technique for ssireum athletes is the “Deul-baejigi”—one of the trunk techniques. Ssireum athletes are overweight compared with normal people[9–11]. Therefore, use of the “Deul-baejigi” technique is an advantageous. Muscle strength and respiratory function are closely related to each other, because poor respiratory function is an indicator of muscle weakness[24]. The interaction between respiratory and motor functions can be observed from normal functions, such as simple limb movements and muscle strength[25–28]. Korean wrestling is similar to another sport—Sumo wrestling in

Table 1. General characteristics of the participants

		Nonathletes	Korean Wrestling Athletes
Age (yrs)		24.9 ± 2.8	21.3 ± 1.0*
Height (cm)		174.1 ± 4.7	178.6 ± 4.3*
Weight (kg)		75.9 ± 10.1	94.6 ± 12.9*
BMI (kg/m^2)		24.9 ± 2.8	29.6 ± 3.8*
Career (yrs)		-	9.5 ± 0.5
Training frequency		-	3/day (18/week)
Training time		-	5.7 ± 0.3 h/day (34.2 ± 1.8 h/week)
Aerobic exercise		-	2.2 ± 0.2 h/day (13.2 ± 1.2 h/week)
Anaerobic exercise		-	3.1 ± 0.5 h/day (18.6 ± 3.0 h/week)
Ches Cir (cm)	Rest	96.1 ± 6.3	113.1 ± 13.8*
	Exp	94.0 ± 6.5	110.6 ± 16.9*
	Insp	100.3 ± 6.1	115.4 ± 12.1*
	DER	1.6 ± 1.4	2.4 ± 3.1
	DIR	3.3 ± 2.2	2.4 ± 1.9
Abd Cir (cm)	Rest	86.8 ± 7.5	101.5 ± 13.9*
	Exp	84.5 ± 8.0	98.1 ± 13.6*
	Insp	89.4 ± 7.9	104.1 ± 13.3*
	DER	2.1 ± 2.0	3.5 ± 2.0
	DIR	2.2 ± 1.8	2.6 ± 2.4
Weight category (%)	Gyungjang/Sojang	-	2 (12.5)/2 (12.5)
	Chungjang/Yongjang	-	3 (18.8)/2 (12.5)
	Yongsa/Yeoksa	-	4 (25.0)/3 (18.8)
	Jangsa	-	-
Hand technique (%)	AM-C/DM-C	-	1 (6.3)/- (-)
	O-C/YM-C	-	2 (12.5)/- (-)
	G-D/DS-J	-	1 (6.3)/1 (6.3)
Leg technique (%)	AD-G/BD-G	-	8 (50.0)/5 (31.3)
	H-G/BB-G	-	1 (6.3)/4 (25.0)
	B-G/C-D	-	1 (6.3)/- (-)
	D-G	-	4 (25.0)
Trunk technique (%)	J-C/Oe-B	-	6 (37.5)/5 (31.3)
	D-B/G-C	-	14 (87.5)/- (-)
Mixed technique (%)	Or-D/Oe-D	-	2 (12.5)/1 (6.3)
	D-D	-	1 (6.3)

All data are presented as the mean±SE. BMI: body mass index; Ches Cir: chest circumference; Abd Cir: abdominal circumference; Exp: expiration; Insp: inspiration; DER: differences between expiration and rest; DIR: differences between inspiration and rest; AM-C: Ap Mureup-Chigi; DM-C: Dwit Mureup-Chigi; O-C: Oguem-Chaegi; YM-C: Yeop Mureup-Chigi; G-D: Ggok-Dwijypgi; DS-J: Deung Satba-Jabachaegi; AD-G: Ahn Dari-Geolgi; BD-G: Bat Dari-Geolgi; H-G: Homi-Geoli; BB-G: Balmok Bitjang-Geoli; B-G: Baldeung-Geoli; C-D: Cha-Dolrigi; D-G: Deot-Geoli; J-C: Jab-Chaegi; Oe-B: Oen-Baejigi; D-B: Deul-Baejigi; G-C: Ggatdan-Chigi; Or-D: Oreun-Dwijypgi; Oe-D: Oen-Dwijypgi; D-D: Dwiro-Dwijypgi. *Significantly different from nonathletes, $p < 0.05$

Japan. Sumo has a simple match style and provides anaerobic training. Most matches end within one minute. Therefore, the aerobic energy system is affected by sumo matches and training[29]. Korean wrestling matches also end within less than one minute. Therefore, Korean wrestling athletes can expect type II muscle development to be enhanced by anaerobic exercise. Features of the type II muscles are used to demonstrate instantaneous power rather than endurance[28, 30]. This can be observed in the AS1, AS2, and AS3 sections of the graph. Therefore, instantaneous power, as opposed to endurance, is relatively weak, because the decrease in the B section of the PEF area has the same slope in athletes and nonathletes. Other sports similar to Korean wrestling are found throughout the world—Buh in Mongolia, Sambo in Russia, Kara Kucak and Yagli Gures in Turkey, Das Schwingen in Switzerland, Fang in Iceland, and Lucha Canaria in Spain[31]. In addition, these same athletes can anticipate similar development of the Type II muscles as a result of anaerobic exercise[31]. However, further systematic and scientific studies in the area of sports physiotherapy research and therapy, especially for chest injuries related to various sports, are needed[32–35].

Table 2. Differences in respiratory function between the nonathletes and Korean wrestling athletes

	Variable	Nonathletes	Korean Wrestling Athletes
FVC (L)		4.9 ± 0.5	5.2 ± 0.4 *
	FEV1.0 (L)	4.1 ± 0.4	4.6 ± 0.4 *
	FEV1.0/FVC (%)	84.1 ± 6.1	87.8 ± 4.5 *
	PEF (L/s)	9.2 ± 1.4	10.5 ± 1.4 *
	PIF (L/s)	6.4 ± 1.2	7.3 ± 1.7 *
SVC (L)		4.8 ± 0.6	5.2 ± 0.6 *
	ERV (L)	1.5 ± 0.4	1.5 ± 0.5
	IRV (L)	2.4 ± 0.6	2.6 ± 0.5
	TV (L)	0.7 ± 0.3	1.2 ± 0.6 *
MVV (L/min)		161.5 ± 30.5	171.6 ± 33.3
	RR (L/min)	94.5 ± 17.9	91.1 ± 32.7
	TV (L/min)	1.7 ± 0.4	1.9 ± 0.5
MV (L/min)		12.8 ± 6.0	19.0 ± 6.2 *
	RR (L/min)	27.1 ± 6.8	21.6 ± 7.3 *
	TV (L/min)	0.5 ± 0.3	0.9 ± 0.3 *

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 nonathletes, $p < 0.05$

Table 3. Differences in respirogram phases of forced vital capacity between the nonathletes and Korean wrestling athletes

Variable		Nonathletes	Korean Wrestling Athletes
aFVC	ExA	20,026.3 ± 2,966.2	24,429.5 ± 10,269.5*
	InsA	22,449.5 ± 6,610.4	25,101.1 ± 16,417.0
	Total	42,475.8 ± 8,039.3	49,530.6 ± 21,591.9*
sFVC	AS1	10.3 ± 3.1	12.1 ± 4.0*
	AS2	5.6 ± 2.4	7.1 ± 3.3*
	AS3	1.9 ± 1.0	2.6 ± 1.4*
	BS1	−1.4 ± 0.8	−1.5 ± 0.8
	BS2	−1.4 ± 0.6	−1.3 ± 0.4
	BS3	−1.4 ± 0.5	−1.2 ± 0.4
	CS1	2.7 ± 1.7	2.5 ± 1.0
	CS2	0.5 ± 4.4	1.0 ± 0.4
	CS3	0.5 ± 0.4	0.5 ± 0.3
	DS1	−0.3 ± 0.3	−0.4 ± 0.3
	DS2	−0.7 ± 0.5	−0.6 ± 0.4
	DS3	−1.7 ± 1.1	−1.8 ± 1.0

All data are presented as the mean±SE. aFVC: area of forced vital capacity; ExA: expiratory area; InsA: inspiratory area; Total: total area; sFVC: slope of forced vital capacity; 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 nonathletes, $p < 0.05$

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	0.038	0.038	0.073	−0.084	0.066	−0.256	−0.245	−0.261	−0.242	−0.177
InsA	−0.161	−0.156	−0.167	0.030	−0.008	−0.234	−0.261	−0.180	0.152	0.467
Total	−0.115	−0.111	−0.103	−0.015	0.024	−0.311	−0.329	−0.269	0.007	0.284

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

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	−0.247	−0.262	−0.192	0.080	0.156	−0.229	−0.212	−0.197	−0.301	0.174
AS2	0.025	−0.017	0.063	0.280	0.202	0.093	0.084	0.120	0.128	0.297
AS3	−0.571*	−0.600*	−0.588*	0.463	0.069	−0.464	−0.451	−0.470	−0.109	0.012
BS1	0.058	0.010	0.138	0.335	0.427	0.106	0.098	0.076	0.173	−0.143
BS2	0.081	0.042	0.137	0.059	0.071	0.064	0.035	0.113	0.084	0.269
BS3	−0.310	−0.365	−0.301	0.549*	0.305	−0.128	−0.154	−0.096	0.371	0.465
CS1	0.062	0.087	−0.001	0.036	−0.031	0.022	0.045	0.010	0.046	0.125
CS2	0.313	0.334	0.317	−0.305	−0.075	0.081	0.114	0.062	−0.333	−0.264
CS3	0.295	0.266	0.322	−0.093	−0.102	0.163	0.180	0.166	−0.268	−0.157
DS1	−0.063	0.038	−0.019	−0.578*	0.196	−0.110	−0.114	−0.128	−0.003	−0.175
DS2	−0.014	0.051	0.020	−0.016	0.516*	−0.080	−0.082	−0.081	0.328	0.339
DS3	0.340	0.374	0.366	−0.018	0.428	0.342	0.333	0.330	0.444	0.245

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

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