J. Phys. Ther. Sci. 28: 2495–2500, 2016

The Journal of Physical Therapy Science

Original Article

Differences in respirogram phase between taekwondo poomsae athletes and nonathletes

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Abstract. [Purpose] Respiratory physiotherapy is an effective approach to improving lung function in patient, including athletes with respiratory dysfunction caused by sports injury. The purpose of this study was to analyze the differences in the respirograms between taekwondo poomsae athletes and nonathletes according to the respirogram phase. [Subjects and Methods] Respiratory measurements for 13 elite taekwondo poomsae athletes were obtained. Respiratory function was measured using spirometry while the participant was seated. [Results] In respirogram phasic analysis, the inspiratory area of forced vital capacity were significantly increased in the athletes than in the nonathletes. The slopes of the forced vital capacity for athletes at slopes 1, 2, and 3 of the A area were significantly higher than those for the nonathletes. In correlation analysis, chest circumference was significantly correlated with slope 1 of the A area of the forced vital capacity. [Conclusion] Results indicate that differences in respirogram phasic changes between athletes and nonathletes may contribute to better understanding of respiratory function, which is important to sports physiotherapy research.
Key words: Respirogram, Taekwondo poomsae athletes, Sports physiotherapy research

(This article was submitted Mar. 25, 2016, and was accepted May 23, 2016)

INTRODUCTION

The check of pulmonary function is used to estimate an individual's fitness and athletes' performance[1, 2)]. Spirometry is a generally used method for evaluating pulmonary function in the same way that blood pressure provides important information about general cardiovascular health[1–3)]. Meanwhile, sports injury of the chest is closely related to maintenance

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of athletes' performance and health[1, 4]. In particular, chest injuries such as rib stress fracture and thoracic chance fracture are directly or indirectly associated with swimmer, rodeo athlete, wrestler, and rower[5–8]. Therefore, respiratory physiotherapy is an important method in patients with respiratory dysfunction by sports injury[1, 2]. The respiratory system is also influenced by exercise training[9, 10]. Regular exercise may increase the strength and endurance of breathing and blood circulation[11]. Physical training can enhance health in many ways. It has been shown to improve cardiovascular performance[12, 13]. Respiratory rehabilitation from exercise training, along with a wide range of education and behavior change interventions, can be used to improve the physical and mental state of the people. On the other hand, respiratory function can be damaged when the strength of respiratory muscles decreases with comorbidity and loss of mobility[14]. Taekwondo is devised to improve the quality of spirit and life through the training of body and mind. Taekwondo can be divided into poomsae and kyorugi[15]. The poomsae is the style of conduct that expresses mental and physical refinements directly or indirectly, as well as the principles of offense and defense resulting from the cultivation of the Taekwondo spirit and techniques[16]. The poomsae is a series of movements for offense and defense techniques that can be practiced and trained, even without the presence of an instructor, in accordance with fixed patterns. Taekwondo combines agility, strength, speed, balance, flexibility, coordination, and stamina, which are all important attributes required for a Taekwondo athlete to be able to execute the highly demanding kicking combinations[17, 18]. Taekwondo is the price the torso or the head of kicking opponents[18]. Although a measure of the respiratory of taekwondo was performed in the previous study, there was no respirogram analysis. Therefore, the purpose of the present study is to analyze and compare the respiratory function of taekwondo poomsae athletes and nonathletes.

SUBJECTS AND METHODS

The present study consisted of thirteen taekwondo poomsae athletes and ninety-five nonathletes. Measurements were performed from September 2015 to December 2015. One hundred and eight volunteers who had no abnormal physical or psychological conditions provided written informed consent to participation in this study[1]. Participants were asked to complete a questionnaire via individual in-depth interviews, which took 30 minutes per person[1, 2]. The criteria for the inclusion of participants in the study were as follows: (1) 19–22 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[1, 2, 4]. We measured chest and abdominal circumference at rest, inspiratory, and expiratory conditions. Chest circumference was measured from axillary height, and abdominal circumference was measured from navel height. Similarly, the circumference of the thigh and calf were measured. Thigh circumference was measured at 1/3 the height below the straight line that connects the patella center from anterior superior iliac spine (ASIS), The calf circumference was measured at 1/3 the height above and below the straight line connecting the lateral malleolus at the fibular head[1]. 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)[1–3]. 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. 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 (Fig. 1A)[1–3]. 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[1, 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

Table 1 shows the general characteristics of the taekwondo poomsae athletes compared with those of the nonathletes. Chest, abdominal, thigh, and calf circumferences in nonathletes and TKDP athletes were compared. All measured values for nonathletes were larger, most significantly in the case of abdominal circumference (Table 1). Spirometry parameters in the TKDP athletes group were higher than in the nonathletes (Table 2). In particular, the FEV1.0/FVC ratio showed significant differences between the two groups of participants (Table 2). In respirogram phasic analysis, the inspiratory area of forced

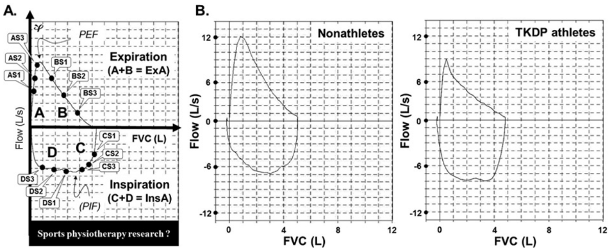

Fig. 1. Differences in FVC and respirogram phase between the TKDP athletes and nonathletes
Area and slope of the FVC and respiratory parameters were determined, as described in the Subjects and Methods section. FVC: forced vital capacity; AS1–3: first, second, and third slopes of the A area; BS1–3: first, 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; TKDP athletes: taekwondo poomsae athletes

Table 1. General characteristics of the participants

		Nonathletes	TKDP athletes
Age (yrs)		24.9 ± 2.8	20.6 ± 0.9*
Height (cm)/Weight (kg)		174.1 ± 4.7/75.9 ± 10.1	171.9 ± 5.5/65.5 ± 7.4
BMI (kg/m^2)		24.9 ± 2.8	22.2 ± 1.9
Career (yrs)		-	9.5 ± 3.0
Training frequency		-	1/day (5/week)
Training time		-	1.8 ± 0.2 h/day (9.0 ± 1.0 h/week)
Aerobic exercise		-	1.0 ± 0.1 h/day (5.0 ± 0.5 h/week)
Anaerobic exercise		-	0.6 ± 0.1 h/day (3.0 ± 0.5 h/week)
Ches Cir (cm)	Rest	96.1 ± 6.3	92.9 ± 5.1
	Exp/Insp	94.0 ± 6.5/100.3 ± 6.1	91.4 ± 5.0/97.7 ± 5.4
	DER/DIR	1.6 ± 1.4/3.3 ± 2.2	1.6 ± 1.4/4.7 ± 1.2*
Abd Cir (cm)	Rest	86.8 ± 7.5	80.3 ± 5.5*
	Exp/Insp	84.5 ± 8.0/89.4 ± 7.9	75.8 ± 5.6*/82.6 ± 5.8*
	DER/DIR	2.1 ± 2.0/2.2 ± 1.8	4.6 ± 2.1*/2.3 ± 1.1
Thigh Cir (cm)	Rt/Lt	55.1 ± 1.1/55.3 ± 1.9	55.0 ± 2.4/53.9 ± 2.4
Calf Cir (cm)	Above 1/3 Rt/Lt	39.5 ± 1.2/39.8 ± 1.3	39.0 ± 1.6/38.7 ± 1.9
	Below 1/3 Rt/Lt	25.9 ± 1.8/26.1 ± 1.5	24.0 ± 1.8/523.5 ± 1.1*

All data are presented as the mean ± SE. TKDP athletes: taekwondo poomsae athletes; BMI: body mass index; Ches Cir: chest circumference; Abd Cir: abdominal circumference; Thigh Cir: thigh circumference; Calf Cir: calf circumference; Exp: expiration; Insp: inspiration; DER: differences between expiration and rest; DIR: differences between inspiration and rest; Rt: right; Lt: left. *Significantly different from nonathletes, $p<0.05$

vital capacity were significantly increased in the TKDP athletes compared with the nonathletes (Fig. 1B, Table 3). The slopes of the forced vital capacity for TKDP athletes at slopes 1, 2, and 3 of the A area were significantly higher than in the nonathletes (Fig. 1B, Table 3). In correlative analysis, chest circumference was significantly correlated with slope 1 of the A area of the forced vital capacity (Table 4).

DISCUSSION

Respiratory physiotherapy is an important way to improve respiratory function in patients including taekwondo players with respiratory dysfunction caused by genetically determined neuropathy, obstructive pulmonary disease, asthma, rib fracture, and others[1–3, 8]. This function is impacted by items unrelated to level of physical activity, including weight and height[19]. However, in the present study, Circumference of the chest and abdomen are also greater for nonathletes than TKDP athletes. In particular, abdominal circumference is significantly greater because TKDP athletes tend to be slim[19]. For TKDP athletes, there was a larger number of pixel of InsA on the FVC graph than there were for nonathletes. Furthermore, in the previous study, the height and weight were observed to influence the spirometry results[20]. We know via our data that the

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

Variable		Nonathletes	TKDP athletes
FVC (L)		4.9 ± 0.5	4.6 ± 0.6
	FEV1.0 (L)	4.1 ± 0.4	4.1 ± 0.5
	FEV1.0/FVC (%)	84.1 ± 6.1	89.7 ± 6.5*
	PEF (L/s)/PIF (L/s)	9.2 ± 1.4/6.4 ± 1.2	10.1 ± 1.1*/7.9 ± 1.6*
SVC (L)		4.8 ± 0.6	4.7 ± 0.6
	ERV (L)/IRV (L)	1.5 ± 0.4/2.4 ± 0.6	1.5 ± 0.4/2.3 ± 0.6
	TV (L)	0.7 ± 0.3	1.0 ± 0.5*
MVV (L/min)		161.5 ± 30.5	168.8 ± 28.7
	RR (L/min)/TV (L/min)	94.5 ± 17.9/1.7 ± 0.4	120.9 ± 18.2*/1.4 ± 0.3*
MV (L/min)		12.8 ± 6.0	17.8 ± 7.5*
	RR (L/min)/TV (L/min)	27.1 ± 6.8/0.5 ± 0.3	24.2 ± 5.7/0.7 ± 0.3*

All data are presented as the mean ± SE. TKDP athletes: taekwondo poomsae athletes; 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 TKDP athletes

Variable		Nonathletes	TKDP athletes
aFVC	ExA	22,309.6 ± 4,630.2	20,017.8 ± 4,096.8
	InsA	23,728.6 ± 6,598.0	25,184.5 ± 3,470.4
	Total	46,038.3 ± 9,559.7	45,202.3 ± 5,958.4
sFVC	AS1/AS2/AS3	10.3 ± 3.1/5.6 ± 2.4/1.9 ± 1.0	12.4 ± 2.8*/7.7 ± 1.5*/2.7 ± 1.6*
	BS1/BS2/BS3	−1.4 ± 0.8/−1.4 ± 0.6/−1.4 ± 0.5	−1.5 ± 0.7/−1.4 ± 0.5/−1.2 ± 0.3
	CS1/CS2/CS3	2.7 ± 1.7/0.5 ± 4.4/0.5 ± 0.4	3.5 ± 3.0/1.3 ± 1.1/0.7 ± 0.5
	DS1/DS2/DS3	−0.3 ± 0.3/−0.7 ± 0.5/−1.7 ± 1.1	−0.4 ± 0.5/−0.9 ± 0.5/−2.5 ± 0.8*

All data are presented as the mean ± SE. TKDP athletes, taekwondo poomsae athletes; 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, $p<0.05$

weight was smaller for TKDP athletes than for the nonathletes. In addition, the values for AS1, AS2, and AS3 appear to be significantly greater for TKDP athletes. These results can be expected because of the larger number of certain muscle fibers in TKDP athletes as compared to nonathletes. Although the TKDP athletes' physiques were small compared to those of the nonathletes, the values in the 'A' area were larger for the athletes because a higher proportion of type II muscle fibers. Type II muscle provides good instantaneous power rather than endurance[21]. Therefore, a sudden increase in the 'A' area of the first expiratory graph of TKDP athletes is to be expected as a result of the type II muscle fibers' influence. The development of type II muscle fibers in TKDP athletes is believed to be related to their training and exercise, and therefore can be expected to be associated with the FEV1.0/FVC ratio. The FEV1.0/FVC ratio shows the forced expiratory volume of air per second as a percentage of the forced vital capacity, which means it is[22]. The importance of FEV1.0 is that respiratory symptoms and impaired lung function are indicated by reduction in FEV1.0. These symptoms, in turn, are well-described predictors of coronary artery disease, ventricular arrhythmias, and cardiovascular mortality[23, 24]. Statistical significance appeared in the differences between the FEV1.0/FVC values for TKDP athletes and nonathletes. Therefore, the respirogram analysis in our study revealed not only the respiration capacity of TKDP athletes as compared to nonathletes, but also the type of the muscle-fiber development that can be expected. However, further systematic and scientific studies in the area of healthy science and sports physiotherapy are needed[25, 26].

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

Variable	Chest circumference					Abdominal circumference				
	Rest	ExP	InsP	DER	DIR	Rest	ExP	InsP	DER	DIR
aFVC										
ExA	0.053	0.035	0.035	0.122	−0.085	0.020	0.019	0.045	0.000	0.177
InsA	−0.091	−0.094	−0.066	0.017	0.119	−0.011	−0.014	−0.003	0.016	0.055
Total	−0.036	−0.047	−0.028	0.073	0.039	0.002	0.000	0.021	0.011	0.126
sFVC										
AS1	0.239*	0.236*	0.240*	0.027	−0.003	0.041	0.006	0.039	0.159	−0.008
AS2	0.154	0.150	0.171	0.036	0.070	0.024	−0.003	0.008	0.121	−0.104
AS3	0.013	0.032	0.022	−0.125	0.037	−0.088	−0.086	−0.100	0.015	−0.099
BS1	0.006	0.009	0.012	−0.023	0.029	−0.020	−0.025	−0.019	0.025	0.008
BS2	−0.086	−0.069	−0.062	−0.112	0.114	0.022	0.030	0.008	−0.045	−0.086
BS3	−0.047	−0.077	−0.004	0.198*	0.199*	0.040	0.029	0.045	0.042	0.040
CS1	−0.026	−0.023	−0.016	−0.022	0.047	−0.069	−0.071	−0.092	0.025	−0.168
CS2	−0.039	−0.016	−0.029	−0.153	0.047	−0.082	−0.097	−0.089	0.088	−0.059
CS3	−0.146	−0.118	−0.136	−0.195*	0.054	−0.198*	−0.202*	−0.183	0.064	0.070
DS1	−0.084	−0.079	−0.083	−0.033	0.006	−0.042	−0.030	−0.030	−0.049	0.077
DS2	0.085	0.069	0.084	0.111	−0.008	−0.007	0.024	0.016	−0.147	0.156
DS3	0.076	0.060	0.079	0.109	0.011	0.038	0.066	0.060	−0.145	0.159

aFVC: area of forced vital capacity; 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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