Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 1, 2021, Pages. 1370 - 1381
Received 15 December 2020; Accepted 05 January 2021.

The Comparison of Cardiopulmonary Function of Smokers and Non-Smokers during Running and Rowing Exercise

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Abstract

Background/Objectives: The purpose of this study was to compare the volume of oxygen consumption(VO_2), volume of carbon dioxide production(VCO) and respiratory exchange rate(RER) of smokers and non-smokers during running and rowing exercise.

Methods: A total of 40 healthy males with a mean of 19 years participated in this study. Inbody 520 (Biospace, Korea) was used to measure height and weight, Q-STRESS TM55 was used to measure HR (heart rate) and BP (blood pressure), VO_2 , VCO_2 , RER were measured by Parvo Medics TrueOre Metabolic System-OUSW 4.3.4 (20170411) gas analyzer. Two-way ANOVA was used to compare the experimental values.

Findings: As a result, cardiopulmonary function was improved in both groups and there was no significant difference between the two groups. In the smoker group (SG), VO_2 , VCO_2 and RER were significantly improved during rowing and non-smoker group (NSG) during running.

Improvements: Running and rowing are both effective to improve cardiopulmonary function. According to the smoking status, rowing is more effective for smokers and for non-smokers, running is good to improve cardiopulmonary function.

Keywords: Cardiopulmonary function, Smokers, Non-smokers, Running, Rowing

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Date of Submission :2020-09-30

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 1, 2021, Pages. 1370 - 1381
Received 15 December 2020; Accepted 05 January 2021.

Introduction

Smoking is one of the major causes of cardiovascular disease and the prevalence of cardiovascular disease. It is the greatest risk factor for the development of pulmonary disease of the lungs as Chronic obstructive pulmonary disease (COPD), with detrimental effects on the structure and function of the lungs. Tobacco smoke affects not only the airways, but also lung tissue and pulmonary arteries, which can lead to irreversible problems with organs. Undoubtedly, smoking is associated with high blood pressure(HT), increasing resting heart rate(HR), and decreasing resistance to exercise and hard effort (Koubaaet al., 2015). The WHO has reported that 100 million people died from smoking in the 20th century, and it is estimated that 1 billion people will die from smoking during the 21st century (World Health Organization., 2008).

Running is a common exercise machine used to walk, run or climb in the same place. Regular participation in aerobic exercise training programs improves the health-related quality of life (Chanet al., 2013). Most studies have shown that aerobic exercise has a positive effect on improving lung function, and running has been recommended to maintain or improve lung function. In a previous study, it was reported that electromyography(EMG) of lower limb muscle is higher than the upper limb during a running exercise and clarified that running is a good exercise for the lower limb muscles (Sozen., 2010). There are a variety of systemic exercises that improve cardiopulmonary functions, among which rowing exercise (Lazovic-Popovicet al., 2014).

Rowing machines are used as a sport for prestigious schools and universities as standardized test, research equipment and educational equipment. Comparing to other exercises, Rowing exercises use both upper and lower muscles, and the main muscle groups used are ankles, knees, hips, waist, shoulders, elbows and wrists. The total number of muscles used during rowing is 9 upper extremity muscles, 14 lower extremity muscles and 23 in total. This has the beneficial effect of training many muscle groups and has a positive effect on improving endurance, cardiovascular and respiratory system function (Shaharudin et al., 2014).

As mentioned above, in many studies, rowing exercise has a beneficial effect on cardiopulmonary function. However, in a preceding study related to rowing, it is mentioned that a 6-week rowing exercise increased respiratory muscles in subjects but did not improve VO_2 max. In addition, no significant difference was observed in the maximum intake pressure before and after the test (Riganas et al., 2008). Another study reported that most of the patients complained of low back pain during rowing exercise and it is not recommended for a long-term therapeutic exercise (Strahanet al, 2011; Kisanet al., 2012). Moreover, it is found that running

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experiments were somewhat dangerous for falling and expensive equipment could be used to set the correct workload (Mitchell et al., 2010).

In a preceding study related to cardiopulmonary function in smokers and non-smokers, low-intensity continuous training improves cardiopulmonary function and reduces smoker lung deterioration. The smoker group who had the lowest forced vital capacity(FVC) before training showed the best improvement after training. They also evaluated whether running exercise improves lung function and aerobic capacity of smokers, as a result, exercise programs only partially changed the lung function of smokers, but both aerobic capacity and quality of life were improved (Koubaaet al., 2015). Another study investigating on exercises to improve physical performance during rowing and cycling in rowing athletes showed that rowing and cycling improved both cardiopulmonary function and muscle strength (Lindenthaleret al., 2018).

The purpose of this study was to compare the volume of oxygen consumption(VO_2), volume of carbon dioxide production(VCO_2) and respiratory exchange rate(RER) of smokers and non-smokers during running and rowing exercises. The second purpose of the present study was to provide more efficient exercise methods to smokers and non-smokers in order to improve cardiopulmonary function.

Materials and Methods

Participants

Participants of this present study were healthy male students between the age of 20 and 32. After enough explanation and guidance on the purpose and method of the study they were recruited from S university in A city. After the preliminary survey of the subjects who agreed to participate in the study, 40 males were selected. Patients with no history of lower limb surgery and cardiac respiratory disease, no history of cardiopulmonary disease, no recent orthopedic problems including fractures in the lower extremities and no neurological damage were designed as selection criteria.

Exclusion criteria were based on these followings: (a) subjects with history of heart disease and cardiopulmonary disease. (b) subject with lower limb pain and complete rupture of knee or ankle ligament (grade III). (c) history of fracture. (d) disinclination to participate in the study. This study was approved by the Institutional Review Board (SM-201904-018-1).

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Table1 : General characteristics (N= 40)

	Smoker(n=20)	Non-smoker(n=20)	t	*p*
Age(years)	21.45±2.25	19.60±1.09	0.179	N/S
Height(cm)	174.90±5.55	176.25±4.76	0.271	N/S
Weight(kg)	73.30±14.46	67.75±8.29	0.159	N/S

All values are mean ± standard deviation

Experimental procedures

The subjects of this study were divided into two categories: the smoker category (SG) and nonsmoker category (NSG). The smoker and nonsmoker category were divided each into two groups: rowing smoker (SG1) and running smoker (SG2), rowing non-smoker (NSG1) running non-smoker (NSG2). The experimental procedure is shown in Fig. 1.

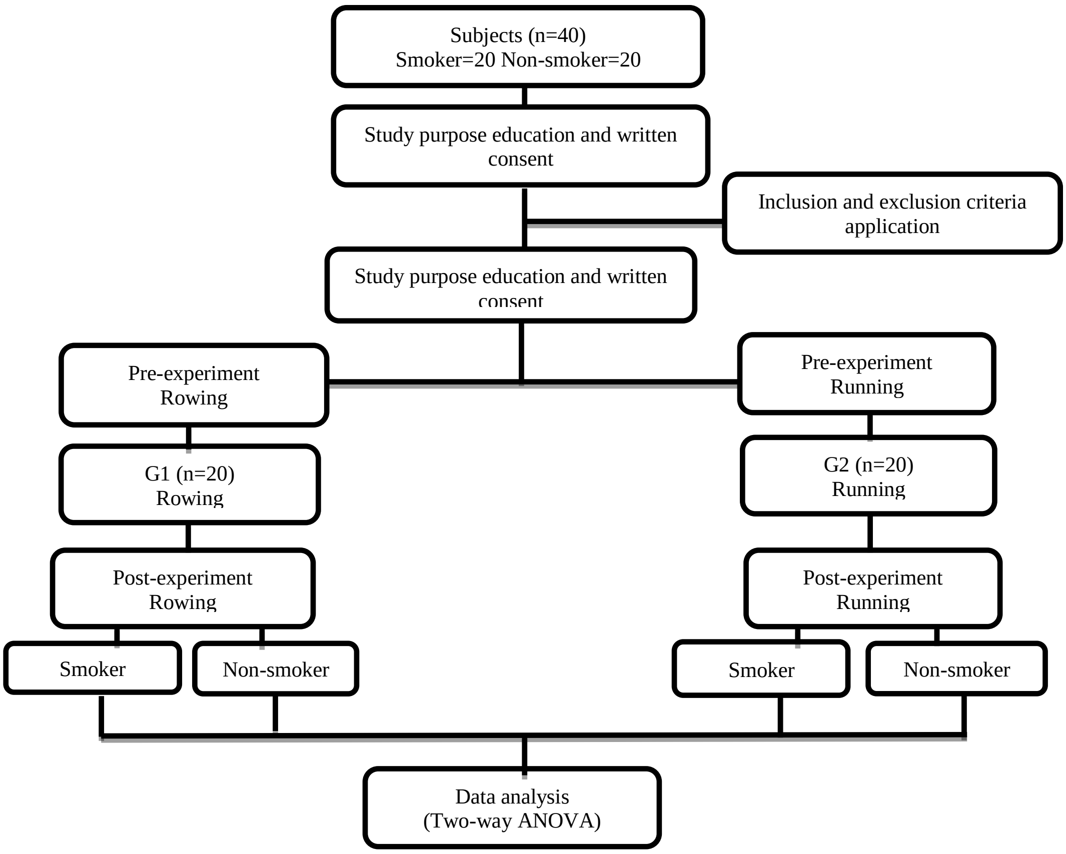

Figure 1Research procedure

Prior to the experiment, all the subjects were measured for their height and weight. Warming up and cooling down were performed for 1 minute before and after each session. The experiments were conducted three times a week for about 20 minutes per session. All the experiments were done for six weeks, with the midterm assessed in the fourth week and the final assessment completed in the sixth week. The values were compared from 1st to 4th week, 4th to 6th week

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and finally 1st to 6th week. Bruce protocol was used to automatically increase speed and slope gradually every three minutes. Upon reaching the target heart rate, according to the subject's age the subject automatically returned to the recovery mode and rested in a chair. During rowing, muscles that are involved vary according to the posture and the pulling order. Therefore, enough pre-training was conducted before the experiment for the SG1 and NSG1. The rowing experiment was conducted for up to 20 minutes per person and performed at maximum speed.

Measurement Equipment

In this study, Inbody 520 (Biospace, Korea) was used to measure weight and height of the subjects. CPX(Q-STRESS TM55 2017, USA) was used to measure HR(heart rate), BP(blood pressure), and the exercises were performed by using Water-Rowing(Water Rower,2012,Water Rower,USA) and treadmill(Q-STRESS TM55 2017, USA). VO_2 , VCO_2 , RER were measured using Parvo Medics TrueOre Metabolic System-OUSW 4.3.4 (20170411) gas analyzer. Submaximal exercise was performed by setting the intensity with Bruce protocol until reaching the target heart rate.<figure 2,3>

Figure 2.position of rowing exercise A: Start posture B: End posture

Data Analysis

For all statistical analyses, IBM SPSS statistical software ver 22.0 was used. Descriptive statistics were used to assess the general characteristics and all variables of the subjects produced mean (M) and standard deviation (SD). Two-way ANOVA was used to compare the improvement of the cardiopulmonary function during rowing and running exercises between smokers and non-smokers. The post hoc test was performed using Bonferroni. The significance level of statistical analysis was set to $p < 0.05$.

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Figure 3. CPX

Results and Discussion

Cardiopulmonary function was compared from the 1st ~ 4th week, 4th ~ 6th week, and 1st week before the exercise and the 6th week after the exercise. For the 1st ~ 4th week, SG showed higher VO_2 max, VCO_2 , and RER during rowing rather than running, and NSG improved VO_2 max, VCO_2 , RER during running[Table 2]. The results showed a significant difference of VO_2 max and VCO_2 between the two groups($p<.05$). From the 4th ~ 6th week, SG showed a large improvement of VCO_2 , RER during rowing and VO_2 max during running. For the NSG group, VO_2 max increased during running and VCO_2 and RER during rowing[Table 3,4]. But there was no significant difference between the two groups($p>.05$). Finally, during the comparison between the 1st and 6th week- before and after exercise, we found that SG improved VO_2 max, VCO_2 , and RER during rowing. For the NSG group, VO_2 max, VCO_2 and RER increased during running. The result as presented in [Figure 4-9] showed a significant difference of VO_2 max and VCO_2 between the two groups($p<.05$).

Table 2.Comparison of variables between smoker and non-smoker according to intervention in 1~4week

		Smoker		Non-smoker		Two-way ANOVA analysis		
						Exercise	Smoke	Exercise x Smoke
		G1	G2	G1	G2	*F (p)*	*F (p)*	*F (p)*
VO_2 max	Pre exercise	2.10±0.63	2.86±0.19	2.97±0.17	2.89±0.71	0.669 (0.419)	4.185 (0.048)	0.005 (0.943)
	After exercise	2.76±1.13	3.37±0.43	3.29±0.27	3.30±0.24			
	Difference	0.66±0.81	0.51±0.31	0.32±0.18	0.41±0.47			
VCO_2	Pre exercise	1.73±0.44	2.33±0.27	2.33±0.21	2.38±0.24	2.061 (0.426)	2.980 (0.871)	4.379 (0.043)
	After exercise	2.06±0.51	2.57±0.30	2.66±0.33	2.90±0.24			
	Difference	0.33±0.23	0.24±0.02	0.33±0.27	0.52±0.24			
RER	Pre	0.81±0.05	0.81±0.07	0.78±0.05	0.82±0.04	2.414	0.509	0.246

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	exercise					(0.129)	(0.526)	(0.623)
	After exercise	0.72±0.12	0.78±0.09	0.79±0.07	0.88±0.11			
	Difference	0.09±0.09	0.05±0.08	0.01±0.06	0.06±0.07			

All values are mean ± standard deviation
G1: Rowing, G2: Running, VO_2max: volume of oxygen consumption, VCO_2: volume of carbon dioxide production, RER: Respiratory exchange rate

Table 3.Comparison of variables between smoker and non-smoker according to intervention in 4~6week

		Smoker		Non-Smoker		Two-way ANOVA analysis		
						Exercise	Smoke	Exercise x Smoke
		G1	G2	G1	G2	*F (p)*	*F (p)*	*F (p)*
VO_2 max	Pre exercise	2.96±1.13	3.3±0.43	3.29±0.27	3.30±0.24	0.886 (0.353)	0.476 (0.495)	0.347 (0.559)
	After exercise	3.27±0.87	3.72±0.24	3.60±0.22	3.67±0.26			
	Difference	0.31±0.90	0.35±0.33	0.31±0.24	0.37±0.25			
VCO_2	Pre exercise	2.06±0.51	2.57±0.30	2.66±0.33	2.90±0.24	0.317 (0.577)	0.910 (0.346)	0.528 (0.472)
	After exercise	2.65±0.54	2.88±0.40	3.21±0.31	3.33±0.76			
	Difference	0.59±0.51	0.31±0.35	0.55±0.32	0.43±0.50			
RER	Pre exercise	0.72±0.12	0.76±0.09	0.79±0.07	0.88±0.11	2.746 (0.106)	1.112 (0.299)	1.731 (0.197)
	After exercise	0.87±0.15	0.77±0.09	0.85±0.07	0.92±0.05			
	Difference	0.15±0.13	0.01±0.09	0.06±0.07	0.04±0.08			

All values are mean ± standard deviation
G1: Rowing, G2: Running, VO_2max: volume of oxygen consumption, VCO_2: volume of carbon dioxide production, RER: Respiratory exchange rate

Table 4.Comparison of variables between smoker and non-smoker according to intervention in 1~6week

		Smoker		Non-smoker		Two-way ANOVA analysis		
						Exercise	Smoke	Exercise x Smoke
		G1	G2	G1	G2	*F (p)*	*F (p)*	*F (p)*
VO_2 max	Pre exercise	2.10±0.63	2.86±0.19	2.97±0.17	2.89±0.71	1.648 (0.207)	4.411 (0.043)	1.781 (0.190)
	After exercise	3.27±0.67	3.72±0.24	3.60±0.22	3.67±0.26			
	Difference	1.17±0.65	0.86±0.21	0.63±0.18	0.78±0.48			

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VCO_2	Pre exercise	1.73±0.44	2.33±0.27	2.33±0.21	2.38±0.24	0.573 (0.454)	4.048 (0.324)	4,414 (0.043)
	After exercise	2.65±0.54	2.88±0.40	3.21±0.31	3.33±0.76			
	Difference	0.92±0.44	0.55±0.33	0.88±0.29	0.95±0.51			
RER	Pre exercise	0.81±0.05	0.81±0.07	0.78±0.05	0.82±0.04	2.190 (0.220)	1.500 (0.229)	2.227 (0.144)
	After exercise	0.87±0.15	0.77±0.09	0.85±0.07	0.92±0.05			
	Difference	0.06±0.10	0.04±0.08	0.07±0.06	0.11±0.04			

All values are mean ± standard deviation
G1: Rowing, G2: Running, VO_2max: volume of oxygen consumption, VCO_2: volume of carbon dioxide production, RER: Respiratory exchange rate

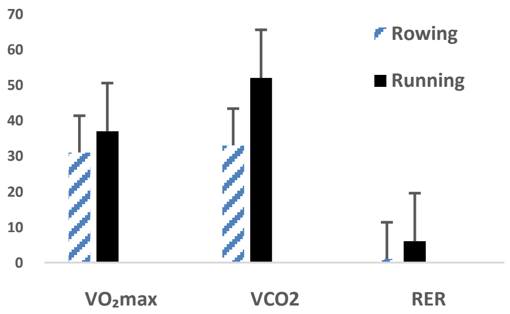

Figure 4. 1~4 Week Smoker group

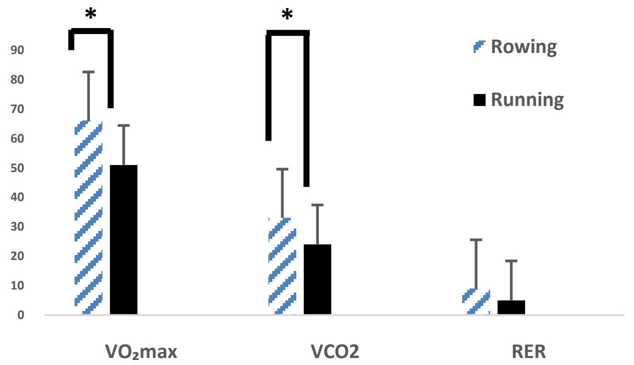

Figure 5. 1~4 Week Non-smoker group

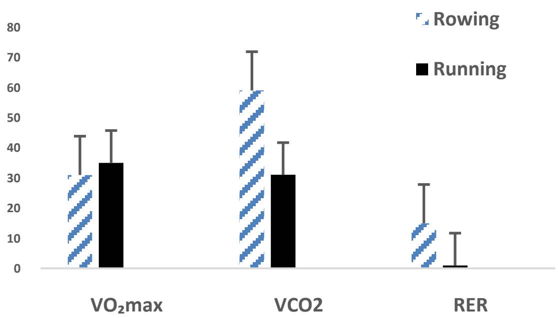

Figure 6. 4~6 Week Smoker group

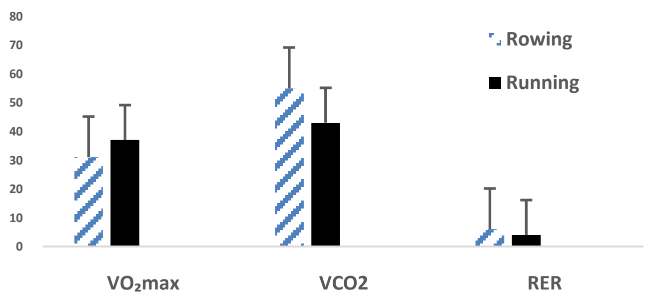

Figure 7. 4~6 Week Non-smoker group

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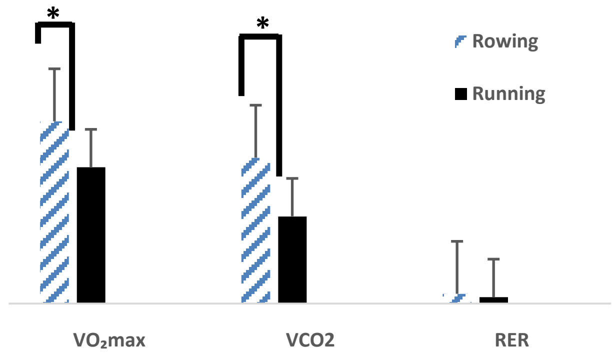

Figure 8. 1~6 Week Smoker group

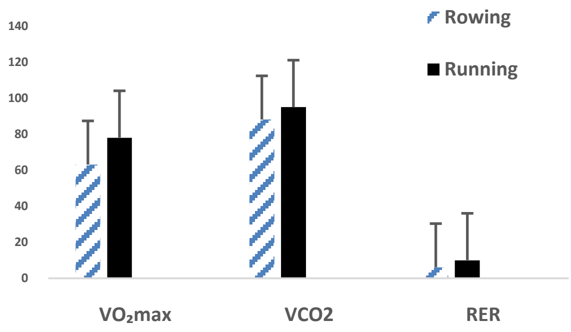

Figure 9. 1~6 Week Non-smoker group

This study was intended to compare the cardiopulmonary function of smokers and non-smokers during running and rowing exercises. As a result, according to smoking status, the cardiopulmonary function was improved in all groups. After comparing the total values between each group, SG1 showed a better improvement of VO_2 max, VCO_2, and RER than SG2. On the other side, VO_2 max and VCO_2, and RER, showed a large improvement in NSG2 than NSG1. As a result, cardiopulmonary function was improved in both groups.

According to a previous study, the training of experienced athletes during running five times a week for a total of six weeks was found to be effective in increasing the strength of the respiratory muscles. In addition, there was a slight improvement of VO_2 max, VCO_2 and RER after the training. In our study, instead of measuring the respiratory muscle strength, we focused on the improvement of cardiopulmonary capacity and proved that running is effective to increase VO_2 max, VCO_2, and RER. This shows a similarity with the previous study (oh et al., 2014). Additionally, in the study conducted by Durmic et al., 38 swimmers regardless of age and gender were divided in two groups and used spirometer to compare pulmonary function. According to the result of this study, rowing is effective in improving lung function. However, in our study we did not use spirometer but CPX for the measurement. Nevertheless, we found a similar result as that study (Durmicet al., 2017).

Another study examining the effects of specific inspiratory muscle training on inspiratory muscle strength, maximum oxygen uptake (VO_2 max), maximum lactate accumulation, shortness of breath, and rowing performance of rowers showed different results. In this study, 19 trained athletes were divided into 2 groups and tested 5 times for 6 weeks. As a result, there was no significant difference in cardiopulmonary function. In conclusion, they showed that there is not an effective improvement of cardiopulmonary function while using rowing machines, and it was not consistent with our study (Egan-Shuttleret al., 2017). According to these results, we can conclude that as trained athletes have a steady vital sign, they require a

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longer period to have a positive effect and improve their cardiopulmonary function.

Koubaa et al, conducted a 12-week low-intensity continuous running exercise on cardiopulmonary function on smokers and non-smokers. They concluded that low intensity of running, and continuous training reduces cardiopulmonary deterioration and improves aerobic capacity. Another previous study conducted on high-intensity exercise showed that running improves cardiopulmonary function after continuous training. No matter low or high the intensity, both studies showed an improvement of cardiopulmonary function. One possible explanation of these results is the long period of training performed during the experiments. These results are consistent with our study (Koubaa et al., 2016; Dunham & Harms., 2012).

Another study conducted by Koubaa et al, evaluated cardiopulmonary function and aerobic capacity in smokers and non-smokers through exercise programs. In this study, 12 smokers, 11 non-smokers, and 10 electronic cigarette smokers were divided into three groups. Rowing exercise was performed for 30 minutes at 3 times a week for 12 weeks, and lung function was measured using spirometry. As a result, cardiopulmonary function was greatly improved in both non-smokers and smokers, and the results agreed with our study (Koubaa et al., 2015). We can notice that this study also was conducted over a long period of time. This helps us to conclude that not only long-term training, but also long-term continuous training is effective to improve cardiopulmonary function.

Many previous studies showed a similar result to our study. We can argue the reasons for the improvement of cardiopulmonary function in the SG1 group is due to the metastasis developed during smoking. According to a previous study, rowing is a high-intensity sport requiring high strength, power, anaerobic, and aerobic capacity (Lindenthaleret al., 2018). Performing rowing exercises involves respiratory muscles (diaphragm, abdominal muscles, intercostal muscles) and helps to release and extend the chest for better expiration, which helps improvement of breathing and cardiopulmonary function. Running requires endurance, strength of the whole body, consumes a lot of energy and promotes smooth blood circulation. These are the reasons of the improvement of cardiopulmonary function during running. According to the previous studies, the minimum training period is 8 weeks, so it is necessary to train for a long period of time (Koubaaet al., 2015). These studies were used to support the improvement of cardiopulmonary functions according to smoking status' during running and rowing exercises. Therefore, it is thought that rowing exercise is effective to improve VO_2 max, VCO_2 and RER for smokers and running is for non-smokers.

The limitation of this study was that the training period was not enough. In addition, there was a lack of accurate identification of the number of cigarettes smoked by smokers during the

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training. Furthermore, we could not consider the subjects individual ability to exercise and there were no female students either. Therefore, it will be difficult to generalize the results to all genders and different age groups. In future studies, more efficient and effective training methods should be studied to supplement the training period and the subjects of various age groups

Conclusion

This study was conducted to compare the improvement of cardiopulmonary function during running and rowing according to smoking status. As a result, running and rowing are effective exercises to improve cardiopulmonary function. This study found that rowing for smokers and running for non-smokers can help improve cardiopulmonary function that is done continuously for a long period of time. Therefore, based on the results of this study, it is considered that smokers or non-smokers can apply effective exercise methods for health care or for clinical issues.

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