P-ISSN 2586-9000
E-ISSN 2586-9027
Homepage : https://tci-thaijo.org/index.php/SciTechAsia
Science & Technology Asia
Vol. 23 No.2 April - June 2018
Page: [37 – 45]
Original research article

The Effect of Inspiratory and Expiratory Muscle Warm-Up on Rowing Performance in Youth Rowers

Supattra Silapabanleng[1,*]
[1]*Faculty of Allied Health Sciences, Department of Sports Science and Sports Development, Thammasat University, Pathum Thani 12120, Thailand*

Sasipa Buranapuntalug[2]
[2]*Faculty of Allied Health Sciences, Department of Physical Therapy, Thammasat University, Pathum Thani 12120, Thailand*

Received 8 February 2018; Received in revised form 26 March 2018
Accepted 30 May 2018; Available online 30 June 2018

ABSTRACT

Warm-up is an essential part of preparation for rowing, especially in competitions. Respiratory muscle warm-up has been proposed to be the beneficial warm-up protocol for enhancing rowing performance. Therefore, the aim of this study is to determine the effect of inspiratory and expiratory muscle warm-up on rowing performance. The design of the study is a crossover study with controlled experiments. Fourteen youth rowers from the Rower and Canoeing Association of Thailand (six males, eight females) had to perform two warm-up protocols: specific rowing warm-up (SWU) and a combination of inspiratory and expiratory muscle warm-up with specific rowing warm-up (RWU+SWU). Afterwards, they had to perform a six minute all-out test. Mean power, distance, pre- and post-maximum inspiratory and expiratory muscle strength (MIP, MEP) of these results were compared. The results showed no significant differences in mean power ($p=0.233$) and distance ($p=0.177$) between SWU and RWU+SWU. Furthermore, pre-post MIP and MEP were not different in both warm-up protocols. However, mean power and distance in male rowers tend to increase under the RWU+SWU protocol, but both of parameters result in females conversely. In conclusion, the effect of RWU+SWU on rowing performance is not different from SWU, but if gender is considered, male and female rowers will react to the RWU+SWU protocol differently. Hence, this should be further investigated with a larger number of participants.

Keywords: inspiratory and expiratory muscle warm-up; specific rowing warm-up; rowing performance

*__Corresponding author__: msilapabanleng@gmail.com **doi**: 10.14456/scitechasia.2018.13

1. Introduction

Over two decades, there have been numerous studies focused on enhancing respiratory muscle function [1-5]. There are two essential pieces of information. Firstly, respiratory muscles can become fatigued [6,7]. Dempsy et. al (2006) said that respiratory muscles have the high aerobic ability and they naturally resist fatigue in low to moderate exercise intensities. But they are sensitive to fatigue during high intensity exercise (more than 80% of VO2 max) with long duration [8]. Secondly, exercise performance can be limited when they work heavily. The accumulation of lactate in inspiratory muscle stimulates " inspiratory muscle metaboreflex" causing limb fatigue by activating limb vasoconstriction and reducing blood flow [9]. In addition, the inspiratory muscle function has an influence upon perception of effort during exercise. When respiratory muscles work at a high level, the perception of effort is greater [10]. In competitive rowing, rowers need maximal physical capacities. One of the physical capacity factors that influences rowing performance is respiratory function [11]. The movement of rowing consists of four major phases: catch, drive, finish, and recovery. There is evidence that the rowing movement affects respiration by decreasing ventilation [12] and increasing workload of respiratory muscles [13]. According to all of these findings, respiratory muscles play an important role in rowing performance. Enhancing respiratory muscle function by preparing them during warm-up period is necessary.

Warm-up is an important part of preparation for rowing. Karvonen et. al. (1999) said that most general warm-up protocols are moderate in intensity and cause low ventilation demand. Whereas, the specific warm-up requires higher intensity and ventilation demand [14]. For rowing, performing a general warm-up followed by a specific warm-up can elevate ventilation which may prepare respiratory muscles for heavy work [15]. However, a study has shown that a specific respiratory muscle warm-up protocol is more effective in enhancing inspiratory muscle strength than a whole body specific rowing warm-up protocol [16]. In addition, a previous study found that the preparation of respiratory muscles during warm-up protocol has a positive effect on rowing performance by combining inspiratory muscle warm-up with specific rowing warm-up [17]. It seems that this combination can improve rowing performance by enhancing the ability of inspiratory muscle and decreasing respiratory muscle fatigue [17]. Therefore, the inspiratory muscle plays an important role in exercise performance. However, not only inspiratory muscle are required in heavy exercise, but also expiratory muscle, [18]. Suzuki et al. (1991) found that the expiratory muscle becomes fatigued after prolonged exercise which can affect exercise performance [19]. Moreover, the metaboreflex causing vasoconstriction in limb blood flow and decreasing exercise performance has been demonstrated in both expiratory and inspiratory muscles [20]. According to this study, the expiratory muscle function seems to play an essential role in rowing performance. Therefore, the ability of inspiratory and expiratory muscles may have an influence on exercise performance, especially in rowing. Furthermore, it is possible that the preparation of the respiratory muscles should be done for both inspiratory and expiratory muscles. The purpose of this study is to investigate the effect of inspiratory and expiratory muscle warm-up on rowing performance.

2. Materials and Methods

Fourteen rowers (six males and eight females) from the Rower and Canoeing Association of Thailand participated in the study. All subjects were informed and signed the consent form that had been approved by the Thammasat University Ethics Committee No. 118/2558. Originally, eight males were recruited, but two males had to leave this research project because of their previous injuries

This research was designed as a crossover study with controlled experiments. Participants were randomly assigned into two groups (group A and group B). Both groups had to attend three visits, on the first occasion to collect baseline information and to get familiar with the respiratory resistance training device, on the following two occasions to perform two warm-up protocols in random order followed by a six minute all-out test. After that, they had to rest for one week and then perform another warm-up protocol and test on the same day. The two protocols were specific rowing warm-up (SWU) and a combination of inspiratory and expiratory muscle warm-up with specific rowing warm -up (RWU+ SWU) . The respiratory muscle warm-up was performed by using a respiratory muscle-training device (Pressure threshold loading) [17]. Rowing performance was assessed with a six minute all-out test by using the rowing ergometer (Model C, Concept II, Nottingham, UK)

2.1 Specific rowing warm-up (SWU)

This warm-up protocol was created by Volianitis et al. (1999) [21] for preparation of rowing racing. The protocol consists of light jogging while maintaining the heart rate at 110–130 beats/ min, 10 minutes of stretching and 12 minutes of rowing by increasing gradually the training intensity and keeping the heart rate at 148–178 beats/min. Finally, five sprints with increasing stroke rate and power output were done. The participants performed light paddling for two minutes between each set. After that, participants rested for five minutes and then performed a six minute all-out test.

2.2 Respiratory muscle warm-up with specific rowing warm-up (RWU+SWU)

This warm-up protocol was a combined inspiratory and expiratory muscle warm-up that followed Griffiths et al. (2006) [22]. It consists of 50% of MIP and MEP, two sets of 30 breaths using a respiratory resistance training device designed by the Project of Research and Development of Biomedical Instrumentation, Institute of Molecular Biosciences, Mahidol University. Following the respiratory muscle warm-up protocol, all participants had to perform a specific rowing warm-up.

The respiratory resistance training device was used so as to enhance respiratory muscle function. Buranapuntalug et.al.(2013) found that respiratory muscle training with a respiratory muscle resistance training device can enhance respiratory muscle strength and endurance with higher results than a controlled group [23]

2. 3 Respiratory muscle resistance training device

Using the respiratory muscle resistance training device mentioned in the previous section, participants breathed via a two-way low resistance, non-rebreathing valve (Hans Rudolph, USA) Inspiratory and expiratory muscle training was performed by using a closed solenoid valve that connected to the inspiration and expiration pressure gauges with a control shutter. The training was designed to sustain inspiration for three seconds and expiration for six seconds at target pressure as indicated by the gauges. Subjects performed progressive inhalation up to target pressure and held for three seconds, followed by exhalation to target pressure and held for six seconds. Within the inspiration tube, air was heated and humidified.

2.4 Rowing performance

After that, participants had to perform a six minute all-out test by using a rowing ergometer (Model C, Concept II, Nottingham, UK). The six minute all-out test was initially developed in order to simulate rowing performance (the standard world championship race distance of 2,000 meters) [24]. All participants had to row at maximum effort for six minutes and then mean power output and distance were measured

2.5 Maximum inspiratory pressure (MIP) and Maximum expiratory pressure (MEP)

MIP and MEP were used to measure inspiratory and expiratory muscle strength. Both were recorded before performing SWU and SWU+RWU warm-up protocols and after the six minute all-out test by using a portable hand-held mouth pressure meter (Precision Medical, London, UK).

2.6 Statistical analysis

Wilcoxon signed ranks test was used to analyze the difference between mean power and distance in both warm-up protocols (SWU, SWU+RWU) and Friedman test was used to assess the difference pre-post MIP and MEP between the SWU and SWU+RWU warm-up protocols.

3. Results and Discussion

Subject characteristics are shown in Table1.

Table 1. Characteristics of participants

Characteristic	Participants(6 males and 8 females)	
	Mean	SD
Age (year)	17.14	0.36
Weight (kg)	65.01	8.76
Height (cm)	169.43	9.10
MIP (cmH_2O)	119.93	32.34
MEP (cmH_2O)	114.93	26.34

MIP = Maximal inspiratory pressure
MEP = Maximal expiratory pressure

3.1 Rowing performance

There were not significant differences in mean power and distance between the SWU and SWU+RWU warm-up protocols as shown in Table 2. Mean power after SWU+RWU was 3.43% lower than SWU and distance after SWU+RWU was 1.21% lower than SWU. However, if gender is considered, rowing performance of both sexes was different.

In male rowers, mean power after SWU+RWU was 1.98 % higher than SWU and distance after SWU+RWU was 0.68% higher than SWU. While in female rowers, mean power after SWU+RWU was 9.95% lower than SWU and distance after SWU+RWU was 2.87% lower than SWU (Table 2)

3.2 Maximum inspiratory and expiratory muscles strength (MIP,MEP)

There were no significant differences in pre-post MIP and MEP between both warm-up protocols (SWU, SWU+RWU) as can be seen in Table 3.

Table 2. The effect of SWU and SWU+RWU warm-up protocols on rowing performance.

	SWU		SWU+RWU		p-value[a]
	Mean	**SD**	**Mean**	**SD**	
Male and female rowers(14)					
Distance (m)	1517.21	132.52	1498.86	158.07	0.177
Mean power (W)	214.29	56.00	206.93	67.28	0.233
Male rowers (6)					
Distance (m)	1653.67	51.94	1665.00	37.35	0.249
Mean power (W)	272.17	24.87	277.67	18.69	0.248
Female rowers (8)					
Distance (m)	1414.88	52.50	1374.25	63.28	0.035*
Mean power (W)	170.88	18.91	153.88	25.50	0.036*

a= Wilcoxon signed ranks test
* = Significantly different at p< 0.05

Table 3. The effects of SWU and SWU+RWU warm-up protocols on MIP and MEP.

	SWU				SWU+RWU				p-value[a]
	pre		**post**		**pre**		**post**		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Male and female rowers(14)									
MIP(cmH_2O)	116.14	27.15	122.07	30.69	121.64	27.88	124.07	32.81	0.110
MEP(cmH_2O)	118.43	29.82	120.71	29.21	127.79	32.40	129.07	39.76	0.580
Male rowers(6)									
MIP(cmH_2O)	121.17	35.41	132.83	37.55	133.83	29.45	135.50	41.94	0.097
MEP(cmH_2O)	131.33	39.15	131.83	21.93	150.50	31.70	146.50	36.71	0.441
Female rower(8)									
MIP(cmH_2O)	112.38	20.87	114.00	23.85	113.00	25.03	115.50	23.37	0.415
MEP(cmH_2O)	108.75	17.52	112.38	32.48	110.75	21.40	116.00	39.96	0.930

a = Friedman Test
*= Significantly different at p < 0.05

The main finding of this study was no significant differences in mean power (p=0.233) and distance (p=0.177) in SWU and RWU+ SWU protocols. Similarly, MIP and MEP also did not have a significant difference in pre-post MIP and MEP. Nonetheless, if the results were split by genders, then it was found that the mean power and distance tend to increase in male rowers, but not enough to make a significant difference. Conversely, mean power and distance of SWU+ RWU in female rowers were significantly lower than SWU. According to this result, it seems that male and female rowers react differently to inspiratory and expiratory muscle warm-up protocol.

From other studies, male and female athletes in running, swimming, and badminton, use the same inspiratory muscle warm-up protocol [25–27]. The intensity at 40% of MIP two sets of 30 breaths was used in both genders of athletes and it was recommended to combine with a specific rowing warm-up protocol for enhancing rowing [17]. On the contrary, there were studies which found that these warm-up protocols did not improve exercise performance [28,29]. Arend et. al. (2015) [29] said that 40% of MIP intensity warm-up does not have a significant influence on submaximal endurance performance in highly trained male rowers. Unfortunately, there were no studies that investigated the effect of both inspiratory and expiratory muscle warm-up on exercise performance. Only two studies examined inspiratory and expiratory muscle training, and both studies determined intensity at 50% of MIP and MEP [23,30]. However, the respiratory training devices were different from this study.

In this study, the result showed that 50% of MIP and MEP two sets of 30 breaths with a specific rowing warm-up protocol tend to enhance rowing performance in male rowers. The enhancement of rowing performance could be due to the improvement of respiratory muscle function. According to related studies, inspiratory muscle warm-up can improve inspiratory muscle function which contributes to decreased dyspnea [17] breathless sensation [26,28]; likewise, inspiratory muscle warm-up can attenuate muscle deoxygenation [31]. However, the effects of expiratory muscle warm-up were not investigated in those studies. As the study's result, expiratory muscle warm-up may enhance expiratory muscles to collaborate with inspiratory muscles and effectively contribute to reduce the work of breathing while rowing.

On the other hand, the intensity at 50% of MIP and MEP seems to impair rowing performance in female rowers. The negative effect in female rowers may be caused by excessive intensity for females. Consequently, respiratory muscles will work heavily before the subsequent performance test. There is evidence that exercise performance is reduced when inspiratory and expiratory muscles become fatigued prior to starting exercise [32,33]. Aamir et al. (2016) found that females tend to have lower inspiratory and expiratory muscle strength than males [34]. Moreover, McClaran et al. (1998) [35] found that females have smaller lung volumes and maximal flow rates, especially in highly fit women and this caused expiratory flow limitation during heavy exercise. According to physiological characteristics of females, the suitable intensity of inspiratory and expiratory muscle warm-up protocol for females should be lower than 50% of MIP and MEP.

This study has some limitations which have to be clarified in 2 points. First, it did not investigate other physiological parameters such as blood lactate, oxygen uptake, and RPE. Second, this study focused on only youth rowers from the Rower and Canoeing Association of Thailand. Hence, the number of participants in this study was too small to conclude with certainty the observed gender-specific differences. Therefore, further studies are required to examine in more depth the proper intensity of respiratory muscle warm-up which can improve rowing performance in both male and female rowers.

4. Conclusion

The effect of combined inspiratory and expiratory muscle warm-up with specific rowing warm-up is not different from specific rowing warm-up. But, if gender is considered, male and female rowers react differently to the RWU+SWU protocol. Hence, this should be further investigated with a larger number of participants.

Acknowledgements

The authors gratefully acknowledge the financial support provided by a New Generation Research Scholarship from the Faculty of Allied Health Sciences, Thammasat University. We highly appreciate the assistance from the Rower and Canoeing Association of Thailand who allowed all rowers to participate in this study and provided all facilities. Moreover, we sincerely thank Assoc. Prof. Rungchai Chaunchaiyakul (College of Sports Science and Technology, Mahidol University) and Asst. Prof. Sumethee Thanungkul (Development of Biomedical Instrumentation, Institute of Molecular Biosciences, Mahidol University) for making available the respiratory resistance training device that was used in this study.

References

[1] Edwards AM, Cook CB. Oxygen uptake kinetics and maximal aerobic power are unaffected by inspiratory muscle training in healthy subjects where time to exhaustion is extended. Eur J Appl Physiol. 2004; 93, 139-144.

[2] Edwards AM, Well C, Butterly R. Concurrent inspiratory muscle and cardiovascular training differentially improves both perceptions of effort and 5000 m running performance compared with cardiovascular training alone. Br J Sports Med. 2008; 42, 823-827.

[3] Mcconnell AK,Romer LM. Respiratory Muscle Training in Healthy Humans: Resolving the Controversy. Int J Sports Med. 2004; 25, 284-293.

[4] McConnell AK, Sharpe GS. The effect of inspiratory muscle training upon maximum lactate steady-state and blood lactate concentration. Eur J Appl Physiol. 2005; 94(3), 277-84.

[5] McConnell AK, Lomax M. The influence of inspiratory muscle work history and specific inspiratory muscle training upon human limb muscle fatigue. J Physiol. 2006; 15(557), 445-457.

[6] Loke J, Mahler DA, Virgulto JA. Respiratory muscle fatigue after marathon running. J Appl Physiol. 1982; 52, 821-4.

[7] Lomax ME, McConnell AM. Inspiratory muscle fatigue in swimmers after a single 200 m swim. J Sports Sci. 2003; 21, 659-64.

[8] JA Demsey, L Romer, J Rodman, J Miller, C Smith. Consequence of exercise-induce respiratory muscle work. Respire Physiol. Neurobiol. 2006; 151, 242-250

[9] Romer LM, Lovering AL, Haverkamp HC, Pegelow DF, Dempsey JA. Effect of inspiratory muscle work on peripheral fatigue of locomotor muscles in healthy humans. J Physiol. 2006; 571, 425-39.

[10] Mcconnell AK. Respiratory muscle training as an ergogenic aid. J Exerc Sci Fit. 2009; 7(2), S18-S27.

[11] Secher NH. Physiological and biomechanical aspects of rowing: implications for training. Sports Med. 1993; 15, 24-42.

[12] Siegmund GP, Edward MR, Moore KS, Tiessen DA, Sanderson DJ, DC McKenzie. Ventilation and locomotion coupling in varsity male rowers. J Appl Physio. 1999; 87, 233-242.

[13] Volianitis S,McConnel AK, Koutedakis Y, cnaughton LM, Bacxx K, and Jones DA. Inspiratory muscle training improve rowing performance. Med Sci Sports Exerc. 2000; 33(5), 803-809.

[14] Karvonen J. Important of warm-up and cool down on exercise performance. In: Karvonen J. Lemon PWR, lliev l (eds) . Medicine in sport training and coaching. Basel: Karger. 1992:260.

[15] Mahler DA. , Shuhart CR, Brew E, and Stukel TA. Ventilatory responses and entrainment of breathing during rowing. Med. Sci. Sports Exerc. 23: 186 – 192, 1991.

[16] VoliantisS. , Mcconnell AK, Koutedakis Y and Jones DA. The influence of prior activity upon inspiratory muscle strength in rowers and non-rowers. Int. J. Sports Med. 20:542–547, 1999.

[17] Volianitis S, McConnell AK, Koutedakis Y, Jones DA. Specific respiratory warm-up improves rowing performance and exertional dyspnea. Med. Sci. Sport Exerc. 2000; 33(7), 1189-1193.

[18] Fuller D, Sullivan J, Fregosi R. Expiratory muscle endurance performance after exhaustive submaximal exercise. J. Appl. Physiol. 1996; 80(5), 1495-1502.

[19] S Suzuki, J Suzuki, T Okubo. Expiratory muscle fatigue in normal subjects. J. Appl. Physiol. 1991; 70, 2632-2639.

[20] Derchak PA, Sheel AW, Morgan BJ, Dempsey JA. Effects of expiratory muscle work on muscle sympathetic nerve activity. J Appl Physiol. 2002; 92, 1593-1552.

[21] Volianitis S, McConnell AK, Koutedakis Y, Jones DA. The influence of prior activity upon inspiratory muscle strength in rowers and non-rowers. Int. J. Sports Med. 1999; 20, 542-547.

[22] Griffiths LA,McConnell AK. The influence of inspiratory and expiratory muscle training upon rowing performance. Eur J Appl Physiol. 2007; 99, 457-466.

[23] Buranapuntalug S,Jalayondeja W, Chaunchaiyakul R. Effectiveness of respiratory resistance training device on respiratory muscles strength and endurance. J Med Tech Phy Ther. 2013; 25(2), 181-192.

[24] Mahler DA,Nelson WN, Hagerman FC. Mechanical and physiological evaluation of exercise performance in elite national rowers. JAMA. 1984; 252, 496-499.

[25] Wilson EE, McKeever TM, Lobb C, Sherriff T, Gupta L, Hearson G, Martin N, Lindley MR, Shaw DE. Respiratory muscle specific warm-up and elite swimming performance. Br J Sports Med. 2013; 48(9), 789-791.

[26] Lin H, Tong TK, Huang C, Nie J, Lu K, Quach B. Specific inspiratory muscle warm-up enhances badminton footwork performance. Appl. Physiol. Nutr. Metab. 2007; 32, 1082-1088.

[27] Lomax M,Grant I, Corbett J. Inspiratory muscle warm-up and inspiratory muscle training: separate and combined effects on intermittent running to exhaustion. J Sports Sci. 2011; 29(6), 563-569.

[28] Ohya T, Hagiwara M and Suzuki Y. Inspiratory muscle warm-up has mo impact on performance or locomotor muscle oxygenation during high-intensity intermittent sprint cycling exercise. Springerplus.2015;4(556),1-11.

[29] Arend M, Maestu J, Kivastik J, Ramson R, Jurimae J. Effect of inspiratory muscle warm-up on submaximal rowing performance. J. strength cond. 2015;29,213-218.

[30] Wells GD, Plyley M, Thomas S, Goodman L, Duffin J. Effects of concurrent inspiratory and expiratory muscle training on respiratory and exercise performance in competitive swimmers. Eur J Appl Physiol. 2005; 94(5-6):527-40.

[31] Chenga CF, Tongb TK, Kuoc YC, Chena PH, Huangd HW, Lee CL. Inspiratory muscle warm-up attenuates muscle deoxygenation during cycling exercise in women athletes. Respiratory Physiology & Neurobiology 186 (2013) 296– 302.

[32] Gandevia SC, Killian KJ, Campbell EJ (1981) The eVect of respiratory muscle fatigue on respiratory sensations. Clin Sci (Lond) 60:463–436.

[33] Verges S, Sager Y, Erni C, Spengler CM. Expiratory muscle fatigue impairs exercise

performance. Eur J Appl Physiol. 2007; 101, 225–232.

[34] Magzoub A, Musa O, Bashir A. Could the difference in respiratory muscle power explain gender variation in lung function. International Journal of Latest Research in Science and Technology. 2016; 5(1), 57-60.

[35] McClaran SR, Harms CA, Pegelow DF, Dempsey JA. Smaller lungs in women affect exercise hyperpnea. J Appl Physiol. 1998; 84, 1872-1881.