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นิพนธ์ต้นฉบับ
ORIGINAL ARTICLE

ผลของการอบอุ่นกล้ามเนื้อหายใจต่อสมรรถภาพของการออกกำลังกาย ในผู้ที่ไม่ได้ออกกำลังกายเป็นประจำ

จุฑามาศ คันทะสอน[1], วรรธนะ ชลายนเดชะ[1]*, รุ่งชัย ชวนไชยะกูล[2], ฉกาจ ผ่องอักษร[3]

บทคัดย่อ

การอบอุ่นกล้ามเนื้อหายใจสามารถเพิ่มสมรรถภาพของการออกกำลังกายในนักกีฬาได้แต่ยังไม่เคยมีการศึกษาในผู้ที่ไม่ได้ออกกำลังกายเป็นประจำ ซึ่งมีกล้ามเนื้อหายใจที่แข็งแรงน้อยกว่าและล้าได้ง่ายกว่านักกีฬา การศึกษานี้มีวัตถุประสงค์เพื่อพิจารณาผลของการอบอุ่นกล้ามเนื้อหายใจต่อสมรรถภาพของการออกกำลังกายและระดับความรู้สึกเหนื่อยในผู้ที่ไม่ได้ออกกำลังกายเป็นประจำ และศึกษาหาระดับความหนักที่เหมาะสมที่สุดระหว่างระดับความหนักที่ร้อยละ 30, 40 และ 50 ของค่าความแข็งแรงสูงสุดของกล้ามเนื้อหายใจเข้า โดยมีอาสาสมัครจำนวน 22 คน (ชาย 11 คน และหญิง 11 คน) ผลการศึกษาพบว่าสมรรถภาพของการวิ่งบนลู่วิ่งไฟฟ้า 6 นาที เพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติ ($P < 0.05$) หลังจากการอบอุ่นกล้ามเนื้อหายใจทั้ง 3 ระดับ โดยได้ระยะทางมากที่สุดเมื่ออบอุ่นกล้ามเนื้อหายใจที่ระดับความหนักร้อยละ 40 ส่วนระดับความรู้สึกเหนื่อยนั้นมีการเพิ่มขึ้นตลอดการออกกำลังกาย ยกเว้นนาทีที่ 4 และ 6 ของระดับความหนักที่ร้อยละ 40 และยังพบว่า ณ นาทีที่ 6 ของระดับความหนักนี้ มีระดับความรู้สึกเหนื่อยน้อยกว่าเมื่อไม่มีการอบอุ่นกล้ามเนื้อหายใจอย่างมีนัยสำคัญทางสถิติ ($P < 0.05$) สรุปได้ว่าการอบอุ่นกล้ามเนื้อหายใจสามารถเพิ่มสมรรถภาพของการออกกำลังกายได้ โดยระดับความหนักที่ร้อยละ 40 เป็นระดับที่น่าจะมีความเหมาะสมที่สุด เนื่องจากสามารถเพิ่มสมรรถภาพของการออกกำลังกายได้สูงสุดและมีระดับความรู้สึกเหนื่อยน้อยที่สุดเมื่อสิ้นสุดการออกกำลังกาย ดังนั้นนอกจากการอบอุ่นร่างกายทั่วไปเพื่อเตรียมสำหรับการออกกำลังกาย การอบอุ่นกล้ามเนื้อหายใจจึงเป็นอีกวิธีที่ควรคำนึงถึง

คำสำคัญ: การอบอุ่นกล้ามเนื้อหายใจ, ความรู้สึกเหนื่อย, สมรรถภาพของการออกกำลังกาย

[1] คณะกายภาพบำบัด มหาวิทยาลัยมหิดล

[2] วิทยาลัยวิทยาศาสตร์และเทคโนโลยีการกีฬา มหาวิทยาลัยมหิดล 999 ถ.พุทธมณฑลสาย 4 ต. ศาลายา อ. พุทธมณฑล จ. นครปฐม 73170

[3] ภาควิชาเวชศาสตร์ฟื้นฟู คณะแพทยศาสตร์ศิริราชพยาบาล มหาวิทยาลัยมหิดล

* ผู้รับผิดชอบบทความ

Effect of respiratory muscles warm-up on exercise performance in sedentary subjects

Juthamard Kantasorn[1], Wattana Jalayondeja[1]*, Rungchai Chaunchaiyakul[2], Chakarg Pongurgsorn[3]

Abstract

Specific respiratory muscle warm-up can improve exercise performance but these effects have been studied only in the athletes. Previous study reported that sedentary subjects have lower respiratory muscles strength and are easier to have fatigue than athletes. The purposes of this study were to investigate the effect of respiratory muscles warm-up on exercise performance and perception of dyspnea in sedentary subjects and to investigate the optimal intensity among respiratory muscles warm-up (RWU) at 30 %, 40 % and 50 % of maximal inspiratory mouth pressure (MIP). Twenty-two subjects (11 males, 11 females) participated in this study. Result showed that all levels of RWU can significantly ($P < 0.05$) improve running distance of 6-minute run on treadmill (6MRD) when compared to no RWU and RWU 40 % was the highest 6MRD. For the perception of dyspnea, there were significant increase ($P < 0.05$) in dyspnea scale among the starting point, 2nd, 4th and 6th minute during the 6-minute run on a treadmill of all pairs of each condition except the pair of 4th - 6th minute of RWU 40 %. Additionally, dyspnea scale at the 6th minute of RWU 40 % was significantly ($P < 0.05$) lower than no RWU. RWU before exercise improves exercise performance, whereas 40 % MIP is an optimal intensity. At this level, subjects showed the highest exercise performance and the lowest intensity of dyspnea at the end of exercise. RWU before exercise in addition to a general warm up protocol should be introduced.

Keywords: Respiratory muscles warm-up, Dyspnea, Exercise performance

1 Faculty of Physical therapy,
2 College of Sports Science and Technology,
3 Department of Rehabilitation Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University
* Corresponding author: (e-mail: ptwjl@mahidol.ac.th)

Introduction

Respiratory system is one of the main systems that as influence over the exercise performance[1, 2]. Several studies showed that during maximal exercise, the ventilation increased over than 20 folds from the resting value[3, 4]. It is possible that the respiratory muscles are induced to their fatigue level during heavy exercise. Moreover, maintaining of pressure generation by the fatigued respiratory muscles will be perceived as an increase in breathing effort and dyspnea level. This respiratory sensation is believed to be one of the subcluster of the overall perceived exertion that is responsible for exercise intolerance[5, 6].

Apart from the exercise training, warm-up is used to enhance physical performance[7-9]. Most general warm-up protocols are performed at mild to moderate intensity and characterized by low ventilatory demand. They cannot elicit an elevated ventilatory response that prepares the respiratory muscles enough for demanding entrained breathing of exercising[10]. Volianitis et al in 1999[11] and 2001[12] studied the effects of specific respiratory muscles warm-up upon inspiratory muscles strength and exercise performance in rowers. They found that the specific respiratory warm-up muscles induced a significant increase in inspiratory mouth pressure and rowing performance.

Up to now, effects of respiratory muscles warm-up have been studied only in athletes. It is demonstrated that sedentary subjects have lower respiratory muscles strength and easier to be affected with fatigue than athletes[13-15]. Therefore, the purpose of this study was to investigate the effects of respiratory muscles warm-up on exercise performance and perception of dyspnea in sedentary subjects. Furthermore, the optimal warm-up intensity depends on many factors such as the physical characteristics of individuals. Previous studies[11, 12] used only 40% of maximal inspiratory mouth pressure as a load for respiratory muscles warm-up and their study groups were athletes. The present study also aimed to investigate the optimal warm-up intensity for sedentary subjects.

Materials and Methods

Subjects

Healthy volunteers aged between 18 and 25 years were recruited according to the following inclusion and exclusion criteria. The inclusion criteria were BMI was between 18.5-24.9 kg/m^2, pulmonary function was within normal values[16] and physical activity level were in inactive or moderate active level[17]. Exclusion criteria were having cardiovascular diseases, pulmonary diseases, or any conditions that involved respiratory muscle function and exercise performance.

Procedure

All volunteers were explained clearly about the study objective and protocol before they were asked to sign the written informed consent with the approval of Mahidol University Institutional Review Board if they agreed to participate. Subjects reported to the laboratory on five different occasions with at least 3 days separation. The purpose of the initial visit was to familiarize with the experimental protocols which were inspiratory mouth pressure measurement, dyspnea measurement and 6-minute run on treadmill. During session 2 to 5, subjects performed four randomly different respiratory muscles warm-up (RWU) loads including RWU at 30 % (RWU 30 %), 40 % (RWU 40 %) and 50% (RWU 50 %) of maximal inspiratory mouth pressure (MIP) and no RWU on different occasions. After each RWU load or no RWU, 6-minute run on treadmill was performed to assess exercise performance immediately.

Pulmonary function test (PFT) and Maximal inspiratory mouth pressure (MIP) measurement

The spirometer (Pony FX pulmonary function equipment, Cosmed Inc., Italy) was used to assess pulmonary function including force vital capacity (FVC), force expiratory in one second (FEV1) and ratio of FEV1/ FVC. The PFT was tested based on the guidelines recommended by the American Thoracic Society (ATS)[18] The best of three value was recorded. After 10-minute rest, the inspiratory muscle strength was assessed by a hand-held mouth pressure meter (Micro MedicalLTD, UK) during a brief, quasi-static contraction (Mueller manoeuvre)[19]. The highest of 3 measurements with 5% variability or within 5 cmH_2O difference was defined as maximum value. The MIP was measured before RWU and at 1st, 2nd and 3rd minute after 6-minute run. During the RWU protocol, the MIP was also measured between the two sets and immediately after RWU to evaluate the effects of RWU on MIP.

Respiratory muscles warm-up (RWU)

After the MIP measurement, subjects rested for 10 minutes before the RWU protocol. The highest of MIP was calculated to adjust load for RWU. Two sets of 30 breaths were performed with a Threshold® inspiratory muscle trainer, Model 64485 (FitnessMart®, New Jersey, USA) when the resistive load ranges from 7 to 41 cm H_2O. If the resistive load was more than 41 cmH_2O, a POWERbreath® inspiratory muscle trainer (Leisure Systems International Ltd., England, UK) was used instead. Subjects sat on a chair, breathed in forcefully through the mouthpiece of the above devices and then breathed out slowly. With the MIP, subjects were instructed to initiate every breath from their residue volume (RV). Because of the increased tidal volume (TV), a decrease but spontaneous breathing frequency was adopted by the subjects. To avoid hyperventilation, subjects performed 5 repetitions of breathing with 30-second rest interval. There was a short rest interval between the two sets.

Assessment of exercise performance

After the RWU, the heart rate as well as the modified Borg's scale was monitored (Polar Electro-series S810, Finland). This exercise performance started with 3-minute walk for warm-up by adjusting the speed to 4, 4.5 and 5 km/hr every minute, respectively, and followed with a 6-minute run. The speed was increased to individual comfortable level. However, subjects may increase or decrease the running speed at any time. The researcher informed about the remaining time at the 2nd and 4th minute and encouraged them to run with the maximal effort. Heart rate and dyspnea scale were recorded at starting point, after 3-minute walk warm-up and after 2, 4, and 6 minutes of running. The speed was adjusted to 4 km/hr for cooling down. During cool down, the MIP was measured at 1st, 2nd and 3rd minute after 6-minute run.

Data analysis

Kolmogorov Sminov Goodness of Fit test was used to test the distribution of data. Repeated-measures analysis of variance was used to test the differences in distance among the 4 RWU loads and Bonferroni correction was used as a pos-hoc test. Friedman test was used to test the differences in the dyspnea scale among 4 loads.

Results

The characteristics of subjects were shown in **Table 1.** Anthropometric data including weight and height and PFT of both male and female subjects fall in the normal range of Thai population at this age range of 18-25 years[20, 21].

Table 1 Characteristics and respiratory parameters of subjects (mean ± SD)

Subject characteristics	Total (n = 22)	Male (n = 11)	Female (n = 11)	*P* - value
Age (yr)	22.68 ± 1.76	22.64 ± 1.80	22.73 ± 1.79	0.907
Weight (kg)	56.75 ± 11.53	63.38 ± 12.42	49.82 ± 4.36	0.000 *
Height (cm)	163.41 ± 7.99	169.27 ± 6.08	157.55 ± 4.63	0.001 *
BMI ($kg.m^{-2}$)	21.16 ± 3.39	22.21 ± 4.18	20.11± 2.04	0.221
W/H ratio	0.78 ± 0.05	0.82 ± 0.04	0.74 ± 0.03	0.000 *
Physical activity score	19.23 ± 2.27	19.82 ± 2.09	18.64 ± 2.38	0.230
Respiratory parameters				
FVC (l, BTPS)	3.22 ± 0.64	3.77 ± 0.42	2.67 ± 0.17	0.000 *
FEV_1 (l, BTPS)	3.00 ± 0.61	3.51 ± 0.42	2.49 ± 0.17	0.000 *
FEV_1 /FVC (%)	93.48 ± 4.52	93.41 ± 4.98	93.54 ± 4.25	0.948
MIP (cmH_2O)	103.73 ± 25.29	119.55 ± 22.76	87.91 ± 16.56	0.001 *

* statistically different by unpaired t-test ($P < 0.05$) between male and female.

Effect of RWU on Exercise Performance.

The mean distance of the 6-minute run of the total subjects were 0.832, 0.866, 0.884 and 0.869 km for no RWU, RWU 30 %, RWU 40 % and RWU 50 %, respectively. Percent changes from the initial value (no RWU) were reported in **Table 2.** There were statistically significant differences ($P < 0.05$) between no RWU and RWU 30 %, no RWU and RWU 40 %, no RWU and RWU 50 %, RWU 30 % and RWU 40 % as presented in **Figure 1**.

Table 2. Distance in kilometers and percent differences (% changed from the initial) of distances from 6-minute run on treadmill of no RWU, RWU 30 %, RWU 40 % and RWU 50 % of the total subjects (mean ± SD).

Conditions	Distance (km.)	% Changed from the initial value
No RWU	0.8318 ± 0.14	100
RWU 30 %	0.8664 ± 0.13	106.40 ± 8.26
RWU 40 %	0.8836 ± 0.14	108.15 ± 8.75
RWU 50 %	0.8695 ± 0.14	106.47 ± 8.98

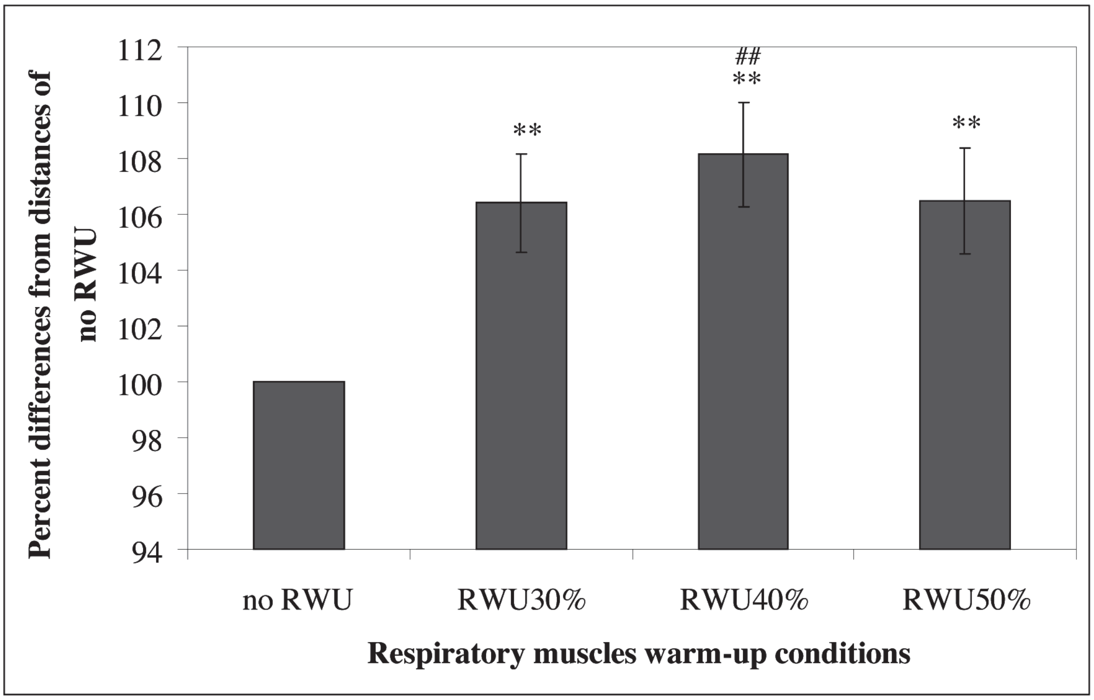

Figure 1 Comparison of the mean different (Bonferroni test) of percent differences (changed from the initial value) of distances from 6-minute run on treadmill (km.) of no RWU, RWU30%, RWU40% and RWU50% conditions of 22 subjects (Mean and SEM). **; significant difference from no RWU ($P < 0.05$), ##; significant difference from RWU30% ($P < 0.05$).

Effect of RWU on Perception of Dyspnea

There were significant differences of dyspnea scale among the starting points to 6th minute of all conditions ($P < 0.05$). Multiple comparisons model was then used to test the differences of all pairs of mean ranks of each condition. There were significant differences ($P < 0.05$) of all pairs of mean ranks except the pair of 4th - 6th minute of RWU 40 %. In addition, there were significant differences ($P < 0.05$) at the 6th minute of no RWU and RWU 40 %. **Figure 2** summarized statistical differences of all comparison.

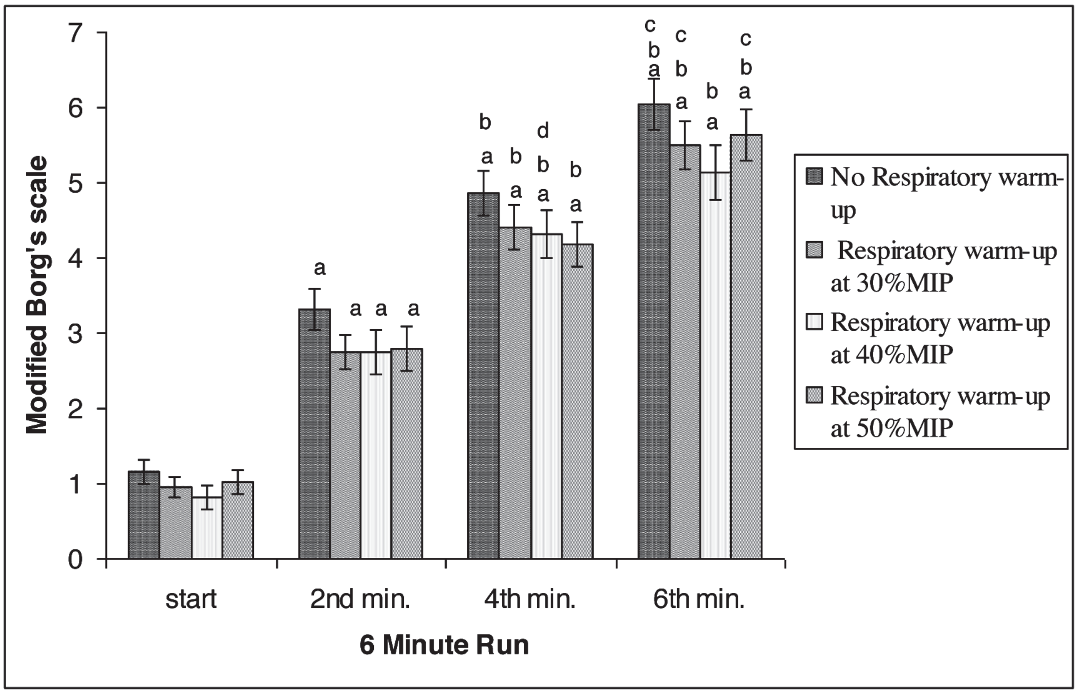

Figure 2 Perception of dyspnea from modified Borg's scale at start, 2nd, 4th and 6th minute during 6-minute run on treadmill of no RWU, RWU 30 %, RWU 40 % and RWU 50 % conditions of 22 subjects (mean and SEM). **a**; significant difference from start, **b**; significant difference from 2nd minute, **c**; significant difference from 4th minute and **d**; significant difference from no RWU at the same time.

Effect of RWU on MIP

The present study also found that MIP of RWU conditions tended to increase after RWU set 1 and set 2 when compared to baseline values while no RWU showed the constant outcomes. Percent differences (change from the initial) of baseline MIP and MIP after RWU set 1 and 2 of all conditions are presented in **Figure 3**.

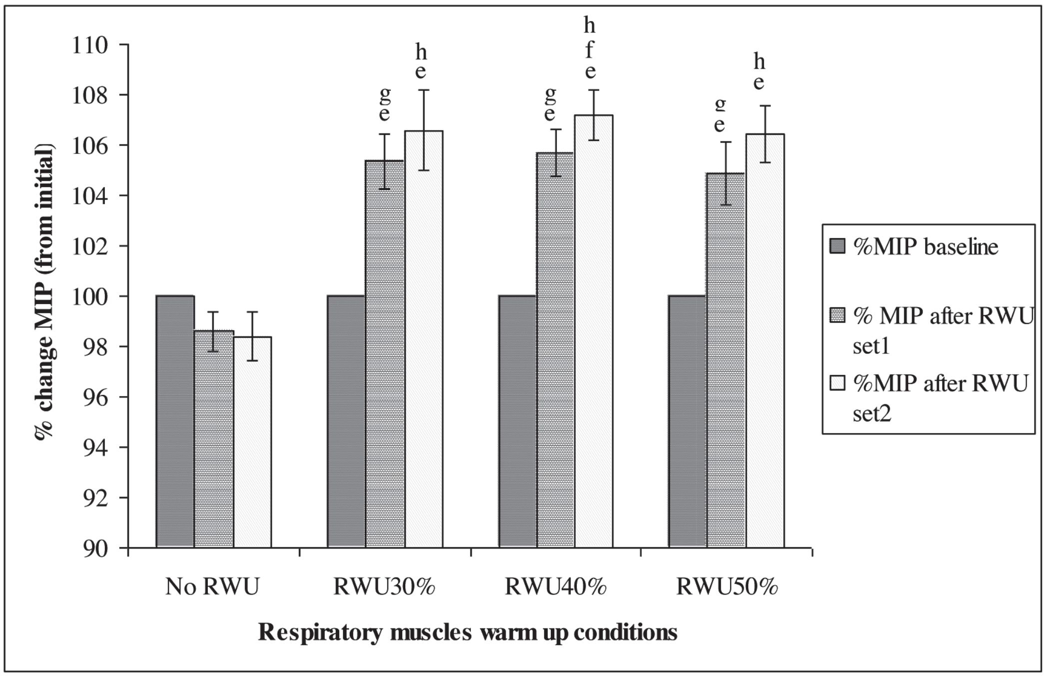

Figure 3 Comparison of relative values (% from baseline) of MIP after RWU set 1 and set 2 of no RWU, RWU30%, RWU40% and RWU50% conditions (Mean and SEM). e; significant differences from baseline, **f**; significant differences from MIP after warm up set 1, **g**; significant differences from MIP set 1 of no RWU and **h**; significant differences from MIP set 2 of no RWU.

Discussion

The main finding of this study demonstrated that RWU 30 %, RWU 40 % and RWU 50 % conditions significantly improved the distance of 6-minute run on treadmill when compared to No RWU. Subsequently, there were significant differences of 6-minute run distance between RWU 30 % and RWU 40 %. This implied that RWU before exercise in sedentary subject can improve exercise performance. These results were similar to Volianitis et al study in 2001 [12]. They compared effect of three different warm-up protocols which were submaximal rowing warm-up, specific rowing warm-up and the same specific rowing warm-up with addition of RWU upon rowing performance and perception of dyspnea. Their results showed that mean power output during 6-min all-out rowing effort significantly increased and dyspnea significantly decreased after specific rowing warm-up plus RWU.

Considering an increase in MIP after RWU at the same protocols, this present results were also accompanied with previous reports of Volianitis et al in 1999 [11] and 2001 [12]. Their results affirmed that skeletal muscle warm-up has an advantage on maximum isometric force because of the changed muscle temperature [29]. Increase in muscle temperature by RWU might be responsible for the increase in MIP in the similar fashion as in an experiment in other skeletal muscles [29]. The major effects of warm-up have been attributed to temperature-related mechanisms such as decreased body stiffness, increased nerve-conduction rate, altered muscle force-velocity relationship, increased anaerobic energy provision and increased thermoregulatory strain [22-24]. In addition, non temperature-related mechanisms have been proposed that effects of acidaemia, elevation of baseline oxygen consumption and increased postactivation potentiation [25-27]. It has also been hypothesized that warm-up may have a number of psychological effects via increased preparedness [28].

The process of elimination and altered motor control hypothesis suggested that co-ordination between inspiratory and expiratory muscles will be enhanced in the similar manner as in other skeletal muscles. Repeated performance of the specific recruitment might decrease the degree of co-contraction known to exist between inspiratory and expiratory muscles at residual volume (RV) and consequently improve force generation[11, 25]. Therefore, the inhibition of antagonistic muscle is subsided during repeated motion.

It should be noted that intensity adjustment perhaps relates to excellent performance [24]. Thus, the present study also investigated the effect of RWU intensities upon exercise performance. Because of RWU at 40 % of MIP were only studied in athletes [11, 12]. It is reasonable that 40% of maximum capacity is approximately the upper loading limit before the fatigue of the diaphragm [30]. However, previous studies suggested that a slightly lower intensity may be optimal for untrained participants. Whereas, more intense warm-up might worsen exercise performance [24].

The present results found that exercise performance was highest after RWU 40 %. Some physiological characteristics of skeletal muscle might be appropriate for the results of RWU 40 %. It had been proven that skeletal muscle exerts its maximal strength according to its working length. At optimal fiber length, muscle generates highest force and velocity of contraction whereas fiber length at less or greater than the optimal level generate less muscle tension. Another explanation for optimal intensity at 40 % MIP is related to muscle enzymes activity [11,12]. Therefore, an implication of the present study is that it is not necessary to use respiratory muscles warm-up intensity more than 40 % MIP

Respiratory discomfort or dyspnea during exercise is one of the exercise limiting factor[1,31]. The neurophysiology of dyspnea can be explained in term of length-tension inappropriateness [32]. It was suggested that change in the contractile properties of respiratory muscles alter the intensity of dyspnea by changing the required level of motor outflow to these muscles. Many factors that impaired the contractile properties of respiratory muscles such as functional weakening and fatigue have the potential to increase the intensity of dyspnea. Some factors can improve the contractile properties of respiratory muscles such as respiratory muscles training (RMT).

This present study result showed that RWU 40 % has the potential to decrease the intensity of dyspnea because the sensory of dyspnea remain unchanged between 4th and 6th minute during running and at the end of exercise and dyspnea intensity of RWU 40 % was less than No RWU condition. The present study also demonstrated the highest increase of inspiratory muscles strength after RWU 40 %. It supported the explanation that improving the contractile properties of respiratory muscles has the potential to decrease the intensity of dyspnea.

In conclusion, it is indicated that RWU before exercise can improve exercise performance. Fourty percent of MIP is an optimal intensity because this intensity showed the highest exercise performance and the lowest intensity of dyspnea at the end of exercise. For further study, other groups of subjects especially patients with respiratory problems should be studied whether it can improve their exercise performance or daily physical activities. However, the optimal intensity and repetition for warm-up respiratory muscles in these subjects should be further investigated.

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