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Effect of Inspiratory Muscle Warm-Up on Short-Distance Cycling Performance

Supattra Silapabanleng*, Narotsapol Boonkobkaew, Tharadon Singthongyam, Matinee Phangjaem, Vinitha Puengtanom, Worawee Nakpanom, Piriya Suwondit

Department of Sports Science and Sports Development, Faculty of Allied Health Sciences, Thammasat University, Pathum Thani 12120, Thailand

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ABSTRACT

Inspiratory muscle warm-up (IMW) has been proposed to be an advantageous warm-up protocol. However, to date there is little study on the effects of IMW on short-distance cycling performance; therefore, this study intends to examine the effects of IMW on short-distance cycling performance. The study design is a cross-over study with controlled experiments. Twenty-six healthy males performed two warm-up protocols: cycling warm-up (CW) and a combination of IMW and CW (CW+IMW). Afterwards, they performed a 3 minute all-out test. The mean critical power, distance, heart rate and rate of perceived exertion (RPE) of each group were compared. The results show that there were no significant differences in mean power ($p=0.430$) and distance ($p=0.257$) between CW and CW+IMW. Moreover, there were no significant differences between groups for RPE during the performance test. But heart rate at three minutes of the test for the group following CW+IMW protocol was significantly lower than the CW protocol group ($p=0.025$). In conclusion, the effect of CW+IMW on cycling performance is not different from CMW. But heart rate during the cycling performance test following CW+IMW tended to be lower than CW protocol. Hence, further study is needed in cyclists, investigating other physiological parameters.

Keywords: Inspiratory muscle warm-up (IMW); Rating of perceived exhaustion; Short-distance cycling performance; Three minutes all-out test

1. Introduction

The work of respiratory muscles in strenuous sports like cycling is just as important as the work of limb and core muscles. This is due to the fact that fatigue in respiratory muscles can diminish exercise performance [1]. The accumulation of lactate in inspiratory muscle stimulates "inspiratory muscle metaboreflex" causing limb fatigue by activating limb vasoconstriction and reduced blood flow [2]. Consequently, there have been studies focusing on inspiratory muscle work enhancement [3-5]. Inspiratory

***Corresponding author:** msilapabanleng@gmail.com
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muscle warm-up (IMW) is used as an ergogenic aid for enhancing exercise performance during the warm- up period. Previous studies found that IMW can improve inspiratory muscle function which contributes to a decrease in dyspnea [6], breathless sensation [4, 7], and attenuates muscle deoxygenation[8] during exercise. However, there has been less study on the effect of IMW on cycling performance.

Johnson et.al (2014) [9] compared the effect of cycling-specific warm-up (CW) (3 consecutive 5 minute bouts at 70, 80 and 90% of gas exchange threshold) and the combination of IMW and CW (CW+IMW) on 10-km cycling time-trial. The results showed that cycling performance following CW and CW+IMW were not different. But maximum inspiratory pressure (MIP) increased 8% immediately after CW+IMW. An increase of MIP after IMW has been found in previous studies [4, 5, 10]and these change improve the synergy of inspiratory muscles and increased voluntary activation of inspiratory muscle [11-12]. But the readings returned to near baseline levels after 15 minutes of relaxed recovery [11]. According to this finding, the effect of IMW seems to remain for around 15 minutes. Further, there have been studies that found that IMW can improve exercise performance in sports which last for less than 15 minutes like sprinting, rowing and swimming. [3, 6, 13] So, IMW may be effective in short-distance cycling more so than in long-distance cycling. Therefore, the present study intends to investigate the effects of IMW on short-distance cycling performance.

2. Materials and Methods

Twenty-six healthy males (Power (1-β) = 0.8, alpha (α) =0.05, effect size = 0.61[5]), 19-23 years old, none with any musculoskeletal or cardiovascular disease, who exercise for recreation at least 3 days per week participated in the study. Subjects were excluded if they had an injury during the experiment. All subjects were informed and signed the consent form that had been approved by the Faculty of Allied Health Science, Thammasat University Ethics Committee. Originally, thirty males were recruited, but four had to drop out because of previous injuries.

This study was designed as a cross-over study with controlled experiments. Participants were randomly assigned into one of two groups (group A and group B). Both groups had to attend three visits, the first visit to collect baseline information like age, weight, height, MIP and to be familiarized with the respiratory resistance training device; the following two visits were for performing two warm-up protocols in random order followed by performing a 3 minute all-out test. After that, they had to rest for one week in order to wash out any effects of the previous warm-up protocol and then performed the other warm-up protocol and test on the same day. The two warm-up protocols were CW and CW+IM. The inspiratory muscle warm-up was performed using a respiratory muscle-training device (Pressure threshold loading, Power breath K5, London UK). Cycling performance was assessed with a 3 minute all-out test using the cycle ergometer (Monark Egomedic 843E testing ergometer, Vansbro Sweden).

2.1 Cycling warm-up (CW)

This cycling warm-up protocol is a standardized warm-up for 3 minute all-out test. The protocol consists of 5 minutes of pedaling at 70 rev·min^{-1} and a resistance of 1 kg (power output = 420 kgm·min^{-1} or ~70W). After the warm-up, the subject rests for 5 minutes. After the rest period, the subject performs at all-out effort throughout the entire duration of the test by maintaining a pedaling cadence that is as high as possible at all times.

2.2 Combination of inspiratory muscle warm-up (CW+IMW) and cycling warm-up (CW)

This warm-up protocol consists of IMW and CW. After participants performed the cycling warm-up and rested for 5 minutes, they performed IMW, including 40% of MIP, two sets of 30 breaths by the respiratory muscle-training device (Pressure threshold loading, POWER breathe K5 inspiratory muscle trainer, Warwickshire, UK). An intensity level at 40% of MIP for two sets of 30 breaths can improve MIP after warm-up [11-12]. This intensity has been applied in many studies of male and female athletes from various sport disciplines like running, swimming, and rowing and it has been shown that this intensity has a positive effect on exercise performance [2, 3, 5].

2.3 Measurement maximum inspiratory pressure (MIP) by S-index program

Before the experimental period, participants performed an inspiratory muscle strength test by S-index program to determine the intensity of inspiratory muscle warm-up (40% of MIP).

The S-index program is used for measuring inspiratory muscle strength by using the POWERbreathe K5 inspiratory muscle trainer. The S-index program can estimate a participant's MIP (represented in cmH2O) [14].

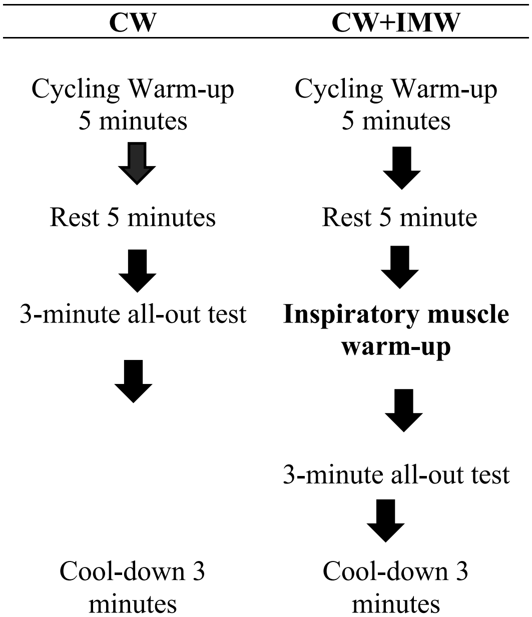
2.4 Cycling performance test

After the warm-up protocol had been performed, participants then performed the 3 minute all-out test using the Cycle ergometer (Monark,). The 3 minute all-out test is used to determine critical power (CP) [15]. CP is the relationship between power output and time-to-exhaustion [16]. The CP can be applied to predict some kinds of exercise performance, most relevant to continuous activities lasting approximately 2 to 30 minutes, like short-distance cycling (1 km time trial) [16]. Participants start with 3 minutes of unloaded cycling at 70 rev•min^{-1}. During the last 5 seconds of the unloaded phase, the cadence should be increased to 110 rev•min^{-1}. On command "Go", the subject pedals as fast as possible for 3 minutes with the resistance set at 0.045 kg per kg of body weight within the first 2 to 3 seconds of the test. After this, participants continue to pedal for 2 to 3 minutes with no resistance [17].

2.5 Heart rate and rate perceive of exertion (RPE) measurement

Hear rate was measured by heart rate monitor (polar RS300X, UK) and RPE was measured by 0-10 modified borg scale every minute during the 3 minute all-out test and one minute after the test.

2.6 Experimental protocol



2.7 Statistical analysis

Paired T-test was used to analyze the difference in mean powers, distance, heart rate, and RPE between both warm-up protocols groups (CW, CW+IMW) at $p < 0.05$ by SPSS Statistic 17.0 program.

3. Results and Discussion

Subject characteristics are shown in Table1.

Table 1. Characteristics of participants.

Characteristic	Participants(n=26)	
	Mean	SD
Age (year)	19.77	0.76
Weight (kg)	69.68	8.28
Height (cm)	174.94	5.90

MIP (cmH_2O)	137.00	25.92

3.1 Cycling performance

There were no significant differences in mean CP and distance between the CW and CW+IMW protocols as shown in Table 2. Mean CP and distance in CW+IMW protocols tended to be a little lower than the CW group.

3.2 Heart rate measurement during 3 minute all-out test.

Heart rate measurements at the first and second minutes of the test and one minute after the test for the CW+IMW group tended to be lower than those of the CW group but not significantly different. Only heart rate measurements at the third minute of the test were significantly lower for the CW + IMW group (*p*=0.025) (Fig. 2).

3.3 RPE measurement during 3 minutes all-out test

There were no significant differences in RPE between the CW+ IMW and CW groups (Fig. 3).

Table 2. The effect of CW and CW+IMW protocols on cycling performance.

	CW		CW+IMW		p-value[a]
	Mean	**SD**	**Mean**	**SD**	
Distance (km)	17.06	2.18	16.79	2.20	0.257
Critical power (W)	272.94	36.50	270.84	39.13	0.430

*= Significantly different at $p < 0.05$.

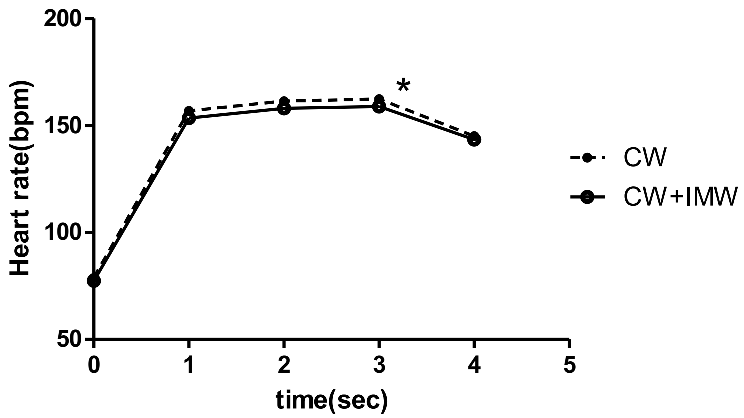


Fig. 2. Heart rate measurements during the 3 minute all-out test. Mean ± SD of Heart rate during 3 minutes in the CW+IMW and CW groups. Baseline (CW+IMW = 77.42±24.08, CW = 78.77 ±24.43). 1 minute (CW+IMW = 153.54±46.25, CW =156.77±47.37). 2 minute (CW+IMW = 158.08±47.89, CW =161.35±48.46). 3 minute (CW+IMW = 158.85±47.80, CW =162.27±48.76). 1 minuet after test (CW+IMW = 143.42±30.91, CW =145.04±31.90).

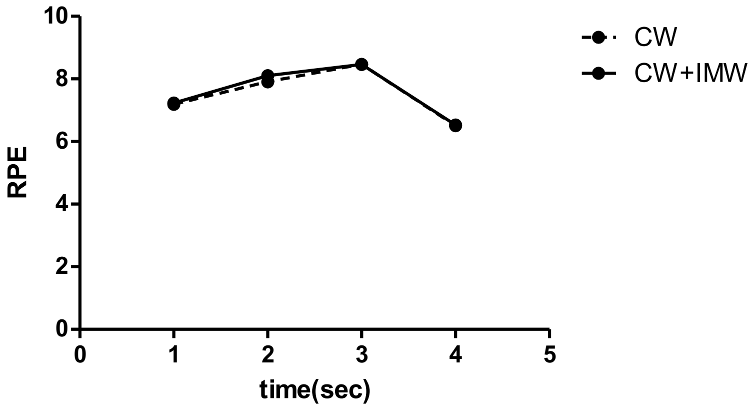


Fig. 3. Rate of perceived exertion (RPE) during the 3 minute all-out test. Mean ± SD of RPE during 3 minutes in the CW+IMW and CW groups. 1 minute (CW+IMW = 7.23±1.39, CW =7.19±1.52). 2 minute (CW+IMW = 8.19±1.41, CW =7.93±1.57). 3 minute (CW+IMW = 8.46±1.36, CW =8.46±1.33).1 minuet after test (CW+IMW = 6.54±1.56, CW =6.50±1.77).

The main findings of this study are that no significant differences in mean CP (p=0.430) and distance (p=0.257) between CW and CW+IMW protocols were observed. Furthermore, there was no significant difference between protocol groups in RPE during the cycling performance test. However, heart rate during cycling in the CW+IMW group tended to be lower than the CW group, and heart rate measured at the third minute of the test was significantly lower in the CW+IMW protocol group.

From a previous study, it was found that IMW can improve exercise performance by enhancing inspiratory muscle function, which contributes to a decrease of dyspnea [6] breathless sensation [4, 7] and attenuates muscle deoxygenation [8]. Moreover, the use of IMW seems to improve performance in sports done in bouts of 15 minutes or less, such as sprinting, rowing and swimming [3, 6, 13]. However, in this study, the cycling performance of the group following the CW+ IMW protocol did not significantly differ from that of the CW protocol group. This result is similar to previous studies [7, 9]. Ohya et. al (2015) studied the effect of 40% (IMW) maximum inspiratory pressure on high intensity intermittent cycling (10 x 5 s with 25-s recovery. They found that the cycling performance of experimental group was not different from the placebo group because the cycling duration was too short to cause sufficient inspiratory muscle fatigue. Therefore, IMW was found to have no effect, and was suggested that further studies examining performance in prolonged sessions are needed. The cycling duration in this study (3 minutes) was longer than previous. In addition, there have been studies that reported inspiratory muscle fatigue after short duration exercises of around 60 seconds to 3 minutes [18-20]. Hence, it was assumed that the exercise protocol used here is sufficiently long to induce inspiratory muscle fatigue. So, one possible explanation for these results is that some participants may have had less cycling experience than others. Low experience participants might have had less control of their cycling position and failed to adjust their cycling cadence appropriately during the high intensity phase, resulting in fatigue of the lower limbs. So, we cannot clearly examine the effects of IMW on performance here, because fatigue in the lower limbs limited cycling performance. Therefore, further investigation should be done in cyclists of similar experience level.

However, there was an interesting response in heart rate during the cycling performance test. Heart rate at the first and second minute of the test, and one minute after the test in the CW+IMW protocol group tended to be lower than the CW protocol group, and heart rate at the third minute of the test was significantly lower in the CW+IMW group. From previous studies, Arend et. al (2015) found that inspiratory muscle warm up can reduce heart rate and increase breathing frequency during submaximal rowing [21]. However, the lowering of heart rate during exercise was not clearly explained. So, the author assumed that the significant heart rate response may have been due to the effect of IMW, which improved respiratory muscle function and reduce lactic acid. The reduction of lactic acid decrease metaboreceptors stimulation and sensory impulse transmitting to the cardiovascular control center which contributed to a decrease in efferent sympathetic nerve activity, resulting in a decreased heart rate during the cycling performance test [22-23]. The effect of inspiratory muscle training on blood lactate was mentioned for a while. Some studies observed a reduction of blood lactate during exercise following inspiratory muscle training [24-25]. Brown et al. (2008) found that the reduction of blood lactate concentration during volitional may be due to a training-induced increase in the oxidative capacity of inspiratory muscles. The adaptation of inspiratory muscles contributes to lowering the blood lactate level by affecting both lactate clearance and efflux from trained inspiratory muscles [26]. But there are no studies clearly explaining the effect of IMW on blood lactate concentration. This area needs further study to support this idea.

Although our study did not find a positive effect of IMW on cycling performance, there was a positive effect seen on participants' physiological response during exercise. Moreover, there is a study that reported no difference in exercise performance between IMW and traditional warm-up groups, but that did find a positive effect on physiological response during exercise, in line with findings of the present study. Chenga et. al. (2013) reported that performance in intermittent high intensity sprints (6 x 10 s with 60-s recovery) were not different between the IMW and control groups, but that the reduction in tissue saturation index (TSI) in legs of the IMW group were significantly less than the placebo and control groups. This suggests that IMW can attenuate muscle deoxygenation during exercise [8]. According to these findings, acute effects of IMW did not impair exercise performance and had a positive effect on physiological response during exercise.

This study had some limitations which have to be clarified in 2 points. First, it lacked the investigation of other physiological parameters such as blood lactate and oxygen uptake. Second, the participants in this study were healthy males with a low level of experience in cycling. So, further investigation should be done with experienced cyclists.

4. Conclusion

The effect of CW+IMW on cycling performance is not significantly different from CW. But heart rate during the cycling performance test following CW+ IMW tended to be lower than the CW protocol group. Hence, further study should be done in experienced cyclists and the study should investigate additional physiological parameters.

Acknowledgements

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