Effects of warm-up intensity on 5 km performance & blood lactate response

Rosalie M. Edmonds, Bradley M. Drewek, Richard J. Kasper, & Rocco J. Repetto

Plymouth State University

Abstract

The 5 km road race has grown increasingly popular and recreational runners are continuously seeking proper warm-up routines for optimal performance. **PURPOSE:** The purpose of the study was to examine the effects of varying warm-up protocols on performance variables during a simulated 5 km race. **METHODS:** Ten male recreational runners ($VO_{2\,max}$: 49.41 ± 6.2 ml/kg/min) participated in a total of three laboratory sessions. The first session consisted of baseline testing where height, weight, body composition, and $VO_{2\,max}$ were evaluated. Following the baseline testing, each subject returned to perform two experimental trials, which included either a high intensity warm-up (HIWU) or moderate intensity warm-up (MIWU). The order of the warm-up protocols were randomized. The HIWU consisted of a 10 min jog at 50% of $vVO_{2\,max}$, followed by 5 min of 30 s intermittent sprints at the individual's $vVO_{2\,max}$. The MIWU protocol consisted of a 15 min jog at 50% of $vVO_{2\,max}$. Following the warm-up, subjects began the 5 km run on a treadmill. Blood lactate [La^-] was taken at each km of the run. Heart rate (HR) was also recorded throughout each trial. **RESULTS:** The mean HR was significantly higher throughout the 5 km following the HIWU ($p < 0.05$). There was no significant difference in mean blood lactate response or performance time between trials ($p > 0.05$). **CONCLUSION:** In conclusion, the variation in intensity between the two warm-up protocols may not have been large enough to elicit a change in performance time. An increase in intensity should increase the metabolic demand, which may better prepare runners for the race.

Introduction

Athletes, at any level, desire to perform at their maximum ability. Whether the goal is to compete with the others, or beat a personal record, physiological performance variables play a role in the outcome of the exercise bout (Kenney, Costill, & Wilmore, 2015). Many sports, including distance running, involve a preparation period before the bout of exercise or competition. As with any form of physical activity or exercise, when the body begins to move, a physiological response is initiated (Kenney et al., 2015). A warm-up period is generally put in place to prepare the individual for the exercise bout that is to come and initiate the body's response to the physical activity (Haff & Triplett, 2016).

Implementing a warm-up before an exercise bout, is beneficial for multiple reasons. When there is a change in the movement intensity, there is an immediate heart rate (HR) response. As intensity increases, HR increases simultaneously (Kenney et al., 2015). This response is the body reacting to the increased demands that are being placed on the muscles. If the body is doing more work, there is a greater demand for energy (Kenney et al., 2015). More adenosine triphosphate (ATP), the molecule used for energy, is in demand (Kenney et al., 2015). The HR response is important for increasing the amount of ATP that is available to the body.

The body creates ATP through two main metabolic pathways: anaerobic and aerobic (Kenney et al., 2015). When exercise is initiated, the body first uses the glycogen stores that are already in the muscle cell for the source of energy (Haff & Triplett, 2016). This is the anaerobic system and oxygen (O_2) is not required for this process (Kenney et al., 2015). When exercise continues for longer than a few minutes, however, the cell runs out of these glycogen stores and O_2 is required for the continuation of ATP production (Kenney et al., 2015).

Hemoglobin is the protein in the blood that carries O_2 to the working muscles (Draoui & Feron, 2011). As the heart is beating faster per minute, blood is circulating through the body at a faster rate (Haff & Triplett, 2016). By initiating the HR response, more O_2 is able to be sent to the working tissue, ultimately resulting in a greater production of ATP, and allowing the individual to sustain their performance throughout the bout of exercise (Kenney et al., 2015).

As the demand for ATP increases, the speed of the metabolic processes also increase (Draoui & Feron, 2011). These processes create byproducts that need to be cleared from the cell in order to prevent acidity (Kenney et al., 2015). As these processes speed up, the byproducts of metabolism begin to accumulate, specifically hydrogen ions (H^+). During the glycolytic process, hydrogen ions (H^+) are formed and lactate is formed. If these H^+ accumulate, the cell can become acidic, and result in a burning feeling that can hinder performance (Draoui & Feron, 2011).

When an individual begins to accumulate H^+ the mitochondria in the cell assists in the clearing process in order to prevent the cell from becoming acidic, and to prevent the painful feeling that often comes from an intense bout of exercise (Bird, Smith, & James, 1998). In order to clear the lactate that is produced as a byproduct of glycolysis, mitochondria takes the H^+ from NADH and the electron transport chain is utilized to produce ATP (Draoui & Feron, 2011). The clearing process is known as the lactate shuttle (Kenney et al., 2015). When the mitochondria can no longer accept the H^+, the mitochondria then will form pyruvate and result in the formation of lactic acid which can hinder performance (Draoui & Feron, 2011). Lactate shuttle is facilitated by a special protein transporter called monocarboxylate transport protein (MCT) which transports lactate out of the cytoplasm of a cell and into other cells and tissues allowing for the clearance of H^+ which inhibit muscle contraction and force development (Wahl et al., 2010).

By implementing a warm-up the processes of cellular metabolism are started to increase efficiency in the exercise bout to follow. If the warm-up is more intense, the HR response will be greater, ultimately resulting in more ATP and a greater performance. In addition the lactate shuttle will be initiated earlier, allowing the clearing process of waste products to begin and be more efficient during the exercise bout to follow (Wahl, Zinner, Zengyuan, Bloch, & Mester, 2010).

Previous research has analyzed the most effective way to warm-up in relation to performance in order to increases the physiological response to exercise to produce the best performance result (Anderson et al., 2014; Bishop, 2003; Bishop et al., 2001; Ciric et al., 2012). A wide range of protocols: static stretching, dynamic, interval sprints, and long and slow paces, have been used in variation to give athletes an answer to the best way to warm-up for optimal performance (Anderson et al., 2014; Bishop, 2003; Bishop et al., 2001; Ciric et al., 2012). In one particular study, greatest improvements in performance were seen after an intermittent warm-up which consisted of 12 min of cycling at 60% $VO_{2\ peak}$ followed by three high intensity phases of 10 s intervals at an intensity of 200% $VO_{2\ peak}$ (Wahl et al., 2010). There was a positive increase in performance as a result the warm-up (Wahl et al., 2010). The research has generally concluded that in competitive athletes, warm-up has shown a significant difference on factors that influence performance: VO_2, $[La^-]$, and HR response (Anderson et al., 2014; Bishop, 2003; Bishop et al., 2001; Ciric et al., 2012).

The 5 km road race has grown increasingly popular over the past ten years (Bush, 2015). With 7.6 million finishers in 2015 alone in the United States, half of these finishers are in the age group of 25 to 44 years old (Bush, 2015). The most effective warm-up for this type of competition is yet to be determined.

A 5 km is a prolonged bout of exercise. Specifically, when preparing for an aerobic activity like a 5 km, having enough O_2 at the muscle cell is vital in order to efficiently produce ATP throughout the entire duration of the race (Haff & Triplett, 2014). Without an adequate warm-up, aerobic metabolism is delayed and the body must rely on anaerobic processes at the beginning of the exercise bout, rather than jump-starting the oxidative metabolism (Bird et al., 1998). Ultimately, a proper warm-up prepares the body for the physical demand that the exercise bout is going to require (Bird et al., 1998). The purpose of the study was to examine the effects of varying dynamic warm-up protocols on performance variables during a 5 km race.

Methods

Subjects

Ten male recreational runners (22.70 ± 2.49 yrs, 82.55 ± 11.22 kg), participated in the study. In order to be considered a recreational runner, each subject consistently ran 5 to 15 miles/week and was not be a member of a collegiate or elite track and field or cross country team. *Table 1* shows the descriptive statistics of the subjects.

Table 1.
Descriptive statistics of the subjects

	M	± *SD*	*n*
Height (cm)	181.76	6.60	10
Weight (kg)	82.55	11.22	10
BodyFat (%)	14.88	4.03	10
Age (yrs)	22.70	2.49	10
$VO_{2\,max}$ (ml/kg/min)	49.41	6.19	10

Baseline Testing

At arrival to the laboratory, the participants filled out the IRB informed consent form and AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire. The subjects then had height (cm), weight (kg) measured and body fat estimated (Tanita BC-418; Arlington Heights, IL) (*Table 1*). Each subject then participated in a $VO_{2\,max}$ test. To determine $VO_{2\,max}$, the participants performed a graded exercise test via the McConnell Protocol and oxygen consumption was measured using indirect calorimetry using the metabolic cart (Parvo Medics

TrueOne 2400; Sandy, UT). The McConnell Protocol was a maximal exercise test. The protocol had the subjects start at 4 mph and increased 1 mph every 3 min until 9 mph. After the subject reached 9 mph, the grade would increase by 2% every 3 min. HR (Polar RCX3; Lake Success, NY) and RPE (Borg, 1982) were measured throughout the baseline testing and during the cooldown.

Following the baseline testing, each subject returned for two trials, with a variation of a warm-up protocol. The order of the warm up protocols (high or moderate intensity) were randomized. The subjects were asked to keep a detailed food log containing everything consumed 3 days prior to each trial. The subjects were asked to maintain any current dietary habits and not vary from this for each trial. Also, the subjects were required to refrain from consuming caffeine 12 hr prior to testing and alcohol 24 hr prior to testing. The subjects were also asked to abstain from strenuous exercise for 48 hr prior to each trial.

Moderate Intensity Warm-up Trial (MIWU)

When the subjects entered the laboratory for the MIWU trial the food log was collected. Prior to exercise, resting HR was recorded, and [La^-] was measured via capillary puncture (Lactate Plus, Sports Resource Group; Waltham, MA). The dynamic stretching protocol consisted of 8 movements designed to prepare the muscles for optimal function and performance in endurance running by elevating core temperature and baseline VO_2 (Wunderlich, 2012). The movements included Toe-and-heel walks, Walking A Skip, Hoping A Skip, B Skip, Heel-to-Glute, Side Shuffle, Grape Vine and Straight-Leg Run. The entire dynamic stretching protocol took no longer than 15 min to complete (Wunderlich, 2012). The participants performed each movement for a total distance of 20 m.

Following the dynamic stretching, the subjects began the MIWU. The MIWU consisted of a 15 minute run at 50% of the individuals' velocity at $VO_{2\,max}$ ($vVO_{2\,max}$) (Billat et al., 2000). The pace was determined using the data collected during the baseline testing. Both warm up protocols took the same amount of time. All variables were recorded.

The subject then had a seated rest for 5 min following the MIWU protocol. Then the subject began a self-paced 5 km on the treadmill (TMX428CP; Newton, KS), and was instructed to run as fast as possible. [La^-] was measured at each km and immediately following the 5 km run via capillary puncture and 5 min post 5 km. Following the 5 km run, the participants cooled down at 3 mph for 5 min or until HR decreased to 120 bpm. HR and RPE were monitored during the entire duration of the trial.

High Intensity Warm-up Trial (HIWU)

When the subjects entered the laboratory for the HIWU trial, the food log was collected. Prior to exercise, resting heart rate was recorded and blood lactate was taken via a capillary puncture. The subjects then completed the same dynamic stretching protocol as in the MIWU trial. Following the dynamic stretching, the subjects began the high intensity warm-up. The high intensity warm-up protocol consisted of a 10 min jog at 50% $vVO_{2\,max}$. Next the subject completed 5 min of an intermittent sprint/jog, alternating 30 s at 100% of $vVO_{2\,max}$ and 30 s at 50% of $vVO_{2\,max}$ (Billat et al., 2000).

The subjects then had a seated rest for 5 min following the HIWU. Following the rest, the subject began a self-paced 5 km on the treadmill and was instructed to run as fast as possible. [La^-] was taken at each km and immediately following the 5 km run via capillary puncture.

Following the 5 km run, the participants cooled down at 3 mph for 5 min or until HR decreased to 120 bpm. HR and RPE were monitored during the entire duration of the trial.

Results

The descriptive statistics for the subjects are shown in *Table 1*. A paired samples t-test was done for the subjects' caloric intake, protein intake, fats, and carbohydrate intake preceding the HIWU vs the MIWU and showed no significant differences ($p > 0.05$).

A 2 x 7 repeated measures ANOVA was done for HR and [La^-] response. A pairwise comparison test showed significant differences at certain points throughout the 5 km (*Figure 1* & *Figure 2)*. The mean HR was significantly greater throughout the 5 km following the HIWU (155.60 ± 3.32 bpm) vs MIWU (152.10 ± 4.13 bpm) ($p < 0.05$). The mean [La^-] was not significantly different following the HIWU (5.37 ± 0.76 mmol/L) vs the MIWU (5.97 ± 0.78 mmol/L) ($p > 0.05$), but there was a significant interaction. Following the HIWU, mean [La^-] was significantly higher pre 5 km and significantly lower at 3 km and 4 km ($p < 0.05$). There was also a significant interaction for HR, at pre and 1 km ($p < 0.05$). Mean HR was significantly higher when recorded pre 5 km and 1 km ($p < 0.05$) (*Table 2, Figure 1,* & *Figure 2*).

A paired samples t-test was done to compare performance. No significant difference was found in performance time between the HIWU (24.76 ± 2.29 min) and MIWU (24.52 ± 2.57 min) ($p > 0.05$) (*Table 2*).

Table 2.
Mean values for [La⁻], HR, and performance time throughout the 5 km.

	HIWU		MIWU	
	M	± *SD*	*M*	± *SD*
[La⁻] (mmol/L)	5.37	0.76	5.97	0.78
HR (bpm)	155.60*	3.32	152.10*	4.13
Performance time (min)	24.76	2.29	24.52	2.57

Note. * Indicates significant difference in the mean (n=10).

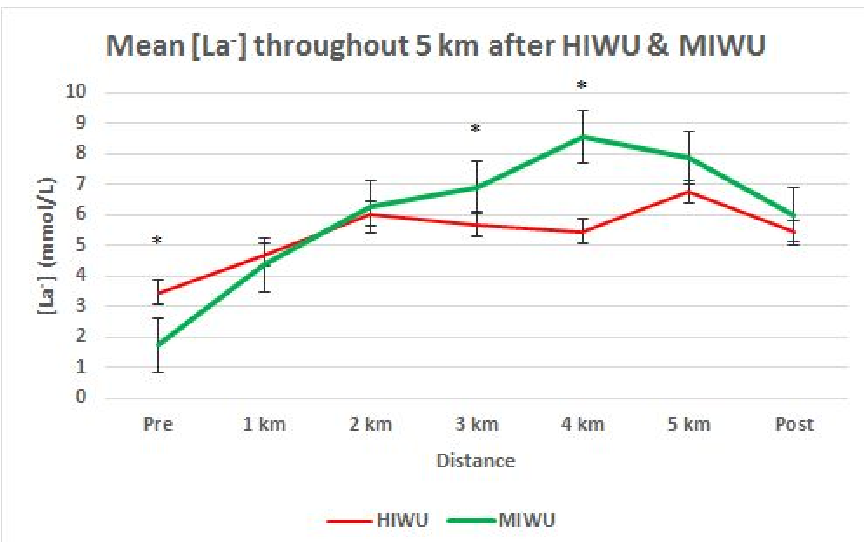

Figure 1. Mean [La⁻] throughout 5 km after HIWU & MIWU. There was no significant difference in mean [La⁻] ($p > 0.05$).
* Indicates significant differences in mean [La⁻] between HIWU & MIWU when recorded at time points: pre, 3 km, and 4 km ($p < 0.05$).

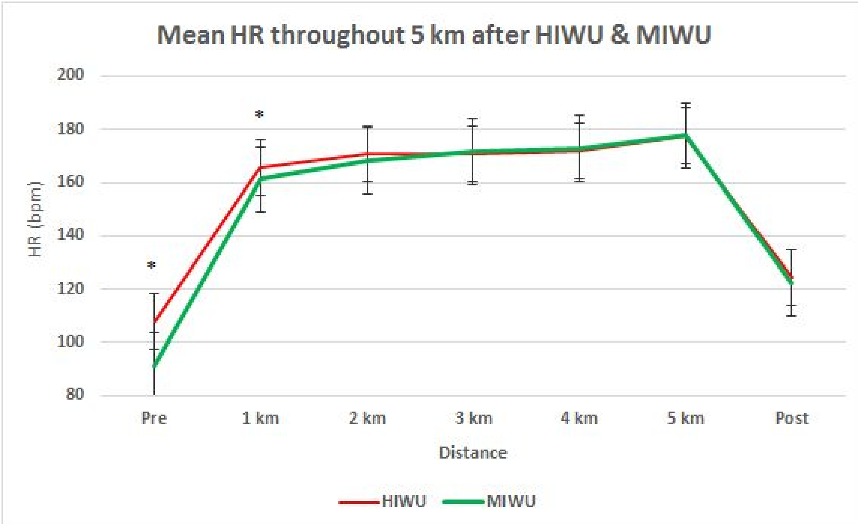

Figure 2. Mean HR throughout 5 km after HIWU & MIWU. There was a significant difference in mean HR ($p < 0.05$).
* Indicates significant differences in mean HR between HIWU & MIWU when recorded at time points: pre, and 1 km ($p < 0.05$)

Discussion

Overall, in this particular study, the warm-up did not impact performance. Mean HR was higher following the HIWU vs the MIWU. Mean [La^-] was not different following either warm-up protocol, however there was a significant difference when measured at the time points pre 5 km, 3 km and 4 km (*Figure 1*). These results show that there was a difference in physiological response between the two warm-up protocols.

The mean [La^-]was not significantly different following either warm-up protocol. However, [La^-] was higher following the HIWU, when measured at pre 5 km. As the 5 km continued, [La^-] following the HIWU was lower than following the MIWU at 3 km and 4 km (*Figure 1)*. Theoretically, this could indicate that the lactate shuttle was working more efficiently.

Mean HR was significantly higher following the HIWU. HR was also significantly higher when measured at the time points pre 5 km and 1 km. This is beneficial for ATP production (Kenney et al., 2015).

The differences associated with performance time and blood lactate response during the 5 km run could have been partially attributed to an insufficient HIWU. If the HIWU was more intense, the response would be greater, to the extent where it may impact performance. Increasing the physiological response would be beneficial because the metabolic process would be initiated even sooner, and the clearing process for [La^-] would be more efficient, allowing the individual to improve performance (Draoui & Feron, 2014).

The major limitation of the HIWU was specifying the intensity to be more individual. When using the McConnell $VO_{2\,max}$ protocol, the highest velocity is 9 mph, and then the test increases in grade, rather than speed. In the study, when using $vVO_{2\,max}$ to determine the sprint speed, most of the participants ran the sprints at 9 mph, although the subjects had differences in their $VO_{2\,max}$ values and presumably different maximal speeds.

Another consideration would be increasing the number of sprints in the HIWU. Previous research has found that a higher intensity than the one that was used in the study has resulted in improved performance (Anderson et al., 2014). In this study, the intensity was purposely lessened, from what was found in previous research, because the subjects chosen were recreational runners, not elite (Anderson et al., 2014). Although that was considered prior to testing, the results suggest that the HIWU used was not intense enough to impact performance. Increasing the intensity of the HIWU would increase the physiological response to exercise and increase the ATP production and lactate shuttle efficiency in order to improve performance

(Wahl et al., 2010).

The 5 min rest also could have impacted the results. In this particular study, in order to reduce variability, the subjects remained seated during the 5 min rest period between the warm-up and the beginning of the 5 km. In a competitive setting, the individuals would likely not be taking a seat before stepping up to the start line. The seated rest also could have decreased the physiological response that the warm-up had initiated resulting in insignificant performance time results.

In the attempt to simulate a 5 km road race, some future considerations should also be noted with regards to ecological validity. The speed should be covered up on the treadmill, as individuals who are actually running a 5 km road race would not be able to see their speed. Rather than the mental pace adjustment that would constantly be taking place in a race, in this study, that adjustment was manual and thus easier to dictate.

In addition, individuals often pace themselves based on the competitors around them (McCormick, Meijen, & Marcora, 2015). With the treadmill pacing, there was not competition for the subjects to determine their starting pace, and subsequent running speeds throughout the race. Competing against someone, in any form of physical activity has shown to improve the individual's motivation, and improve their performance (McCormick et al., 2015). In the laboratory setting, it was not possible to incorporate this important aspect of a 5 km road race. As the study was conducted in a laboratory to minimize unwanted variability, future researchers should consider field based testing.

References

Anderson, P., Landers, G., & Wallman, K. (2014). Effect of warm-up on intermittent sprint performance. *Research in Sports Medicine, 22,* 88-99.

Bird, S. R., Smith, A., James, K. (1998). *Exercise benefits and prescription*. Oxford: University of Oxford Publishing.

Bishop, D. (2003). Potential mechanisms and the effects of passive warm-up on exercise performance. *Sports Medicine, 33,* 439-454.

Bishop, D., Bonetti, D., & Dawson, B. (2001). The effect of three different warm-up intensities on kayak ergometer performance. *Medicine and Science in Sports and Exercise, 6*(33), 1026-1032.

Ciric, I., Stojiljkovic, S., Bubanj, S., Brankovic, N., Stankovic, I., & Stojanovic, J. (2012). Anaerobic threshold determination by direct blood lactate measurement with and without warm-up protocol in female athletes. *Activities in Physical Education & Sport, 2*(1), 101-113.

Draoui, N., & Feron, O. (2011). Lactate shuttles at a glance: from physiological paradigms to anti-cancer treatments. *Disease Models & Mechanisms, 4*(6), 727-732.

Haff, G. G., & Triplett, N. T. (Eds.). (2016). *Essentials of strength training and conditioning* (4th ed.). Champaign, IL: Human Kinetics.

Kenney, W. L., Costill, D. L., & Wilmore, J. H. (2015). *Physiology of sport and exercise* (6th ed.). Champaign, IL: Human Kinetics.

McCormick, A., Meijen, C., & Marcora, S. (2015). Psychological determinants of whole body endurance performance. *Springer Open Choice Sports Medicine, 45*(7), 997-1015.

Randall, C. A., Ross, E. Z., & Maxwell, N. S. (2015). Effect of practical precooling on neuromuscular function and 5-km time trial performance in hot humid conditions among well trained male runners. *Journal of Strength & Conditioning Research, 29*(7), 1925-1936.

Wahl, P., Zinner, C., Zengyuan, Y., Bloch, W., & Mester, J. (2010). Warming-up effects performance and lactate distribution between plasma and red blood cells. *Journal of Sports Science & Medicine, 9*(3), 499-507.

Wunderlich, A. (2012). Dynamic warm-up effect on 5-km performance and running economy in collegiate cross country runners. *Indiana State University Research Journal*, 14-17.