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EFFECTS OF VARIOUS WARM UP PROTOCOLS ON ENDURANCE AND BLOOD LACTATE CONCENTRATION

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Abstract Warm up and stretching activities are typically used by competitive and recreational athletes to enhance physical performance and to prevent sports related injuries. The present study evaluates the effects of various warm-up protocols on endurance, blood lactate concentration and VO_{2max}. 15 healthy male participants were randomly exposed to each of three different warm up protocols with a 2 days' gap in between in a random sequence. Each warm up protocol was preceded by 5 min of jogging, that is, Protocol I (P-I): Static stretching, Protocol II (PII): Moderate to high intensity dynamic exercises, Protocol III (PIII): Dynamic stretching and Control group: only jogging. It was preceded and followed by determination of blood lactate concentration (P-LM5 Analyser), VO_{2max} and treadmill performance test at 65% to 75% heart rate reserve. Results showed a more significant decrease in blood lactate concentration after PII (t=16.91) than > PIII (t=11.72) and > PI (t=12.45); $p < 0.001$, also there was more significant increase in VO_{2max} with PII (t=10.82) than > PIII (t=5.11) and > PI (t=4.13); $p< 0.001$. Similar results were observed for treadmill time to exhaustion [PII (t=4.69)> PIII (t=3.27); ($p<0.05$)> PI (t=1.91)] respectively. It is concluded that dynamic warm up exercises may be a more viable method for enhancing endurance than stretching.
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Key words: warm up, blood lactate, time to exhaustion, VO_{2max}

INTRODUCTION

Musculotendinous injuries are shown to be responsible for a significant proportion of injuries incurred by athletes. The injuries have a high incidence of recurrence. In addition, warm up is considered to be important in preventing muscle injuries by increasing the elasticity of muscles and smoothing muscle contraction [21].

Stretching exercises help to relieve stress as they get the blood flowing - improving circulation while increasing flexibility and relieving muscle tension. Stretching exercises also stimulate receptors in the nervous system that decrease the production of stress hormones. Typically, two different types of warm up protocols were presented: static and dynamic.

Although static stretching has been theorized to enhance performance [16], a number of authors have reported that an acute bout of pre-exercise static stretching may actually reduce anaerobic performance in adults through decreases in force and power [10, 19]. Also it has been shown that long term static stretching increases the range of motion at a particular joint, but it appears that warm up protocols, including prolonged static stretching might have unintended adverse consequences on anaerobic performance in young athletes [27].

Robbins [20] suggested that warm up with dynamic exercise may create an optimal environment for power production by enhancing neuromuscular function. This phenomenon has been referred to as postactivation potentiation (PAP) and is believed to improve power performance. Dynamic stretching consists of function based exercises which use sport specific movements to prepare

the body for movement. Dynamic stretching involves moving parts of body and gradually increases reach, speed of movement or both. It consists of controlled leg and arm swings that take to the limits of range of motion. There are no bounces or jerky movements.

It has been shown [5] that blood lactate concentration is an index of anaerobic metabolism. It reflects the difference between the rate of appearance and the rate of removal of lactate. Astrand et al. [1], Gupta et al [14] and Ghosh et al [12] discussed that intense muscular activity creates an imbalance in the production and removal of lactic acid within the muscle resulting in diffusion of lactate into the blood and increased blood lactate concentration. The diffusion of lactate is observed 3-10 minutes after the cessation of exercise.

Bishop et al [2] recommended that endurance performance be influenced by two important factors in a specific exercise mode: a) maximum capacity to consume O2 (VO_{2max}), b) maximum level for steady rate exercises (OBLA). They have used VO_{2max} as the yard stick to gauge capacity for endurance exercise. Although this measure generally relates to exercise performance, it does not fully explain success, because one does not perform endurance exercise at VO_{2max}. The exercise intensity at the point of OBLA consistently and powerfully predicts endurance exercise performance in men and women.

Previous authors have compared the acute effects of pre-event static stretching and dynamic exercise on anaerobic performance of youths. Whether stretching exercises and dynamic warm up exercises have any effect on blood lactate concentration and VO_{2max} is an intriguing question. In sports even small change in performance can have a drastic effect on the outcome of an event. The purpose of this study was to determine the effects of three different warm up protocols on some endurance performance indices.

MATERIALS AND METHODS

SAMPLES

Fifteen healthy untrained males (age 21.37 ± 0.4 years; height 176.16 ± 1.06 cm, weight 70.48 ± 1.96 kg), were familiarized with the experimental protocol and informed about the possible risk and benefit involved with the study both verbally and in writing before obtaining written consent. Only healthy subjects without any history of pathology or orthopedic limitation were inducted in the study.

Furthermore, VO_{2max} more than or equal to 40 ml/kg/min was determined as minimal aerobic capacity in order for one to be included in the study. The study was approved by Institutional Medical Ethics Committee. The three warm up protocols with concomitant endurance exercises were performed in random order with the 2 days' gap in between to facilitate recovery. Each warm up protocol lasted a total of 12 min of which first 5 min consisted of jogging at a “comfortable pace”. In control group, subjects performed only jogging. The sequence in which all the 3 protocols (PI, PII, PIII) were performed was different for each subject. Subject 1 was assigned to control group on day 1, followed by PI, PII and PIII. Subject 2, after control group readings, was assigned to PII followed by PIII and PI. This sequence was carried on to the next subject and so on. Dependent variables were blood lactate, VO_{2max} and treadmill time to exhaustion.

WARM UP PROTOCOLS

PROTOCOL I – STATIC STRETCHING

Protocol consisted of 5 min of jogging and 7 min of static stretching for the major muscle groups of lower limbs (Table 1). The subjects performed 4 stretches in a slow and deliberate manner. Subjects held each stretch for 20 seconds at a point of mild discomfort, relaxed for 5 seconds and then repeated the same stretch for another 20 seconds before progressing to the other extremity.

PROTOCOL II – DYNAMIC EXERCISES

The protocol consisted of 6 dynamic exercises that progressed from moderate intensity to high intensity (Table 2). The subjects performed each dynamic exercise for one minute and rested about 10 sec.

PROTOCOL III – DYNAMIC STRETCHING

Protocol consisted of dynamic stretching exercises. The subjects performed dynamic stretches in a slow and deliberate manner (Table 3).

Table 1. Static stretching

Muscles	Description
1. Quadriceps	Lie face down on the floor, resting the forehead on the right hand. Bring your left foot up towards buttocks and hold for 20 sec, feel the stretch along the front of the thigh.
2. Hamstrings	Sit on the ground with both legs straight out, bend the left leg and place the sole of the left foot alongside the knee of the right leg. Allow the left leg to lie relaxed on the ground. Bend forward keeping the back straight. Feel the stretch.
3. Adductors	Stand tall with feet approx two shoulder widths apart. Bend the right leg and lower the body, feel the stretch in the left leg.
4. Gastrocnemius	Stand tall with one leg in front of the other, hands flat and at shoulder height against a wall. Ease the back leg further away from the wall, keeping it straight and press the heel firmly to the floor, feel the stretch in the calf of the rear leg.
5. Gluteals	Lie straight on the floor. Bend your knees, bring both knees towards the chest by placing both hands over the knees and hold there for 20 seconds.

Table 2. Dynamic exercises

Warm up Exercise	Description
1. Speed skips	While skipping forward, the subjects accelerated speed of movements and vigorous arm action with both elbows at 900 of flexion.
2. Heel Kicks	While moving forward, the subjects rapidly kicked the heel towards the buttocks while accelerating the speed of movement and quick feel.
3. Toes in, Toes out	While rapidly hopping forward, the subjects turned the toes inwards with the heels turned outwards and then turned the toes outwards with the heels turned inwards. Emphasis was on hip rotation and speed of movement.
4.Trunk twists	The subjects placed both hands behind the head and rapidly hopped forward as they twisted their hips to the right and left. They maintained an upright position with the chest forward as they accelerated trunk rotation.
5. Push-Ups	From a modified push up position with the knees on a mat and the hands near the chest, the subjects performed 3 push-ups at a controlled speed followed by 3 explosive push-ups in which they attempted to lift their hands and body off the mat.
6. High Knee Skip	While skipping forward, the subjects raised the height of each skip, high knee lift, and vigorous arm action with both elbows at 900 of flexion.

EXPERIMENTAL PROTOCOL

Two days prior to the experiment, subjects were familiarized with the experimental setting and protocol. This was done to obtain a pure physiological response as performing for the second time reduces the energy cost and anxiety. Subjects were instructed not to engage in heavy physical activities 24 hours before attending the experimental setting.

On the day of the experiment, the subjects were on the same balanced diet as 48 hours before testing to ensure similar liver and muscle glycogen store. The subjects consumed a similar meal for a minimum of 3 hours prior to the test. On arrival heart rate was recorded with polar heart rate monitor after 15 minutes of rest. Fresh blood sample was collected from the finger tip for pre blood lactate concentration which was analyzed in P-LM5 lactate analyzer (Analox, London). Subjects then performed one of the assigned warm up protocols following 5 minutes of jogging at comfortable pace.

In control group the subjects performed only jogging. After 2 minutes of rest Queen's College step test was conducted. Subject then underwent moderate intensity exercise consisting of motorized treadmill running at an intensity of 65-75% of HR till exhaustion which was continuously monitored by polar heart rate short range telemetry.

Table 3. Dynamic stretching

Exercise	Description
1. Neck flexion / Extension	Tuck your chin into your chest, and then lift your chin upward as far as possible. 6-10 repetitions.
2. Lateral flexion	Lower your left ear towards your left shoulder and then your right ear to right shoulder. 6-10 repetitions.
3. Rotation	Turn your chin laterally toward your left shoulder and then rotate it toward your right shoulder. 6-10 repetitions.
4. Shoulder Circles	Stand tall, feet slightly wider then shoulder width apart, knees slightly bent. Raise your right shoulder towards your right ear, take it backwards, down and then up again to the ear in a smooth manner. Repeat with the other shoulder.
5. Arm Swings	Stand tall, feet slightly wider than shoulder – width apart, knees slightly bent. Keep the back straight.
(i) Over Head/ Down And Back	Swing both arms continuously to an overhead position and then forward, down and backwards. 6-10 repetitions.
(ii) Side/front crossover	Swing both arms out to your sides and then cross them in front of your chest. 6-10 repetitions.
6. Side Bends	Stand tall, with good posture, feet slightly wider than shoulder width apart, knees slightly bent, hands resting on hips. Lift your trunk up & away from your hips and bend smoothly first to one side, then the other, avoiding the tendency to lean either forwards or backwards. Repeat 16 times in a slow rhythm.
7. Hip Circles	With your hand on your hips and feet slightly apart, make circles with your hip in a clockwise direction for 10 repetitions then anticlockwise.
8. Hip twists	Extend your arms out to your sides, and twist your torso and hips to the left shifting your weight on to the left foot, then opposite. 10 repetitions.
9. Leg Swings	Stand sideways against the wall. Put weight on the left leg and right hand on the wall for balance. Swing right leg forward & backward. 10 repetitions on each leg.
10. Lunges	Standing tall both feet together. Keeping back straight lunge forward with the right leg approx 1 to1½ meter. Right thigh should be parallel with the ground and right lower leg vertical. Then repeat with left leg. 10-16 repetitions.
11. Ankle Bounce	Leaning forward with your hands on the wall and all weight on the toes, raise and lower both heels rapidly while maintaining contact with the ball of feet. 12-16 repetitions.
12. Half Squat	Stand tall with hands out in front for balance. Bend at the knees until your thighs are parallel with the floor once at your lowest point, fully straighten your legs to return to your legs to return to your starting position. 16 repetitions.

We took a wide range of HRR because when performed at the same intensity, the task may pose a considerable stress for one person yet fall short of the training threshold for another. The target maximal heart rate was calculated for each subject, using Karvonen's formula [5].

$$\text{Target Heart Rate} = HR_{rest} + \text{required \%} (HR_{max} - HR_{rest})$$
$$\text{Where } HR_{max} = 220 - \text{age}$$

The subject's unwillingness to continue running was considered the point of exhaustion. Total time and distance of the treadmill running were noted at the end. Blood sample was taken 3 minutes post exercise for blood lactate concentration.

STATISTICAL ANALYSIS

All data are presented as the mean ± standard deviation (SD). The data were analyzed for statistical significance by using the statistical package for social sciences (SPSS 14.0) software. Paired student's t' test, one way ANOVA and post hoc multiple Scheffe analysis were used.

RESULTS

Blood lactate - Comparison of baseline values of blood lactate shows non significant differences in all protocols ($p>0.05$). One way ANOVA analysis of post blood lactate values of three different protocols reveals statistically significant difference in blood lactate concentration ($F=10.24$, $p<0.001$), with post hoc scheffe analysis revealing that protocol PII induced lower blood lactate values than protocols PI & PIII (Table 4, Figure 1).

Table 4. ANOVA for Blood Lactate Concentration

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	230.85	3	76.95	10.24	0.001
Within Groups	420.68	56	7.51		
Total	651.53	59			

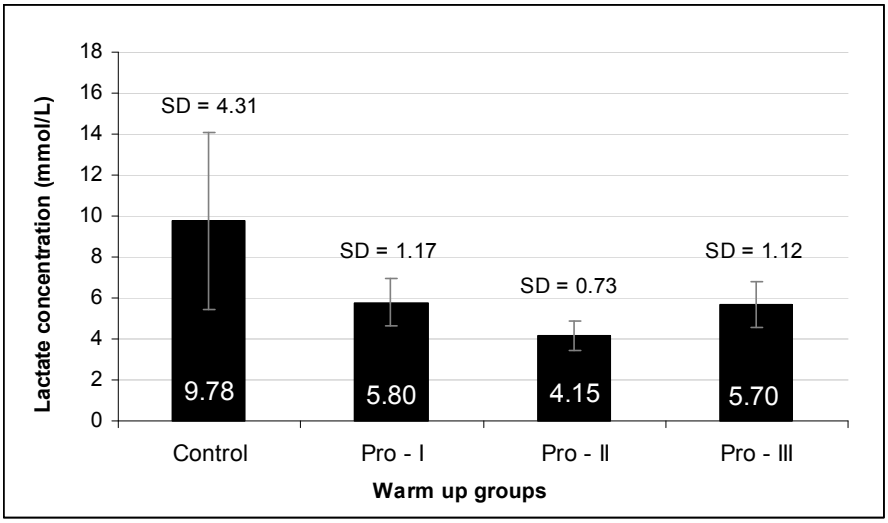

Figure 1. Comparison of post mean values for blood lactate concentration of control and various warm up protocols

VO_{2max} - One way ANOVA analysis of three different protocols reveals statistically significant difference in VO_{2max} ($F=5.18$, $p<0.01$) with post hoc scheffe analysis revealing that protocol PII induced higher VO_{2max} values than protocols PI & PIII (Table 5, Figure 2).

Table 5. ANOVA for VO_{2max}

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	350.39	3	116.80	5.181	0.01
Within Groups	1262.41	56	22.54		
Total	1612.80	59			

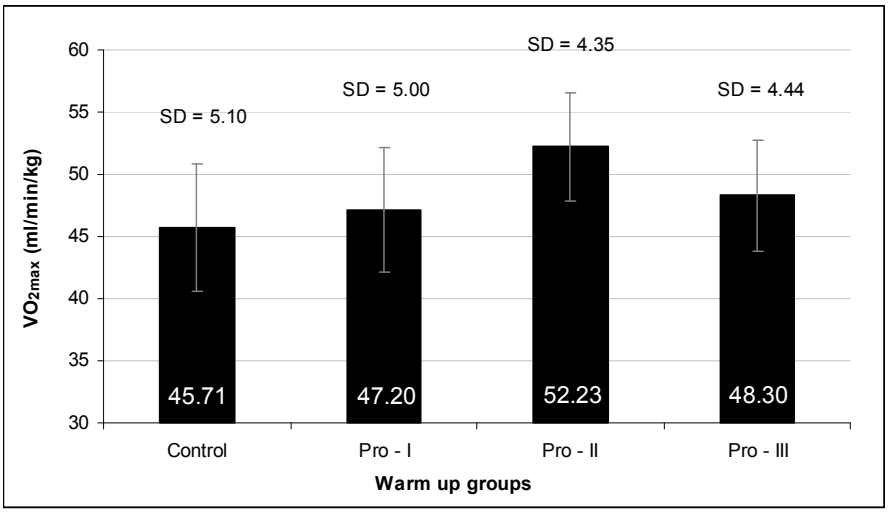

Figure 2. Comparison of mean values of VO_{2max} of control and various warm up protocols

Time to Exhaustion - One way ANOVA analysis reveals statistically significant difference in time to exhaustion ($F=7.45$, $p<0.001$) with post hoc scheffe analysis revealing protocol PII induced increased time to exhaustion in comparison with protocols PI & PIII (Table 6, Figure 3).

Table 6. ANOVA for Time to Exhaustion

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	690.08	3	230.03	7.45	0.001
Within Groups	1728.39	56	30.86		
Total	2418.47	59			

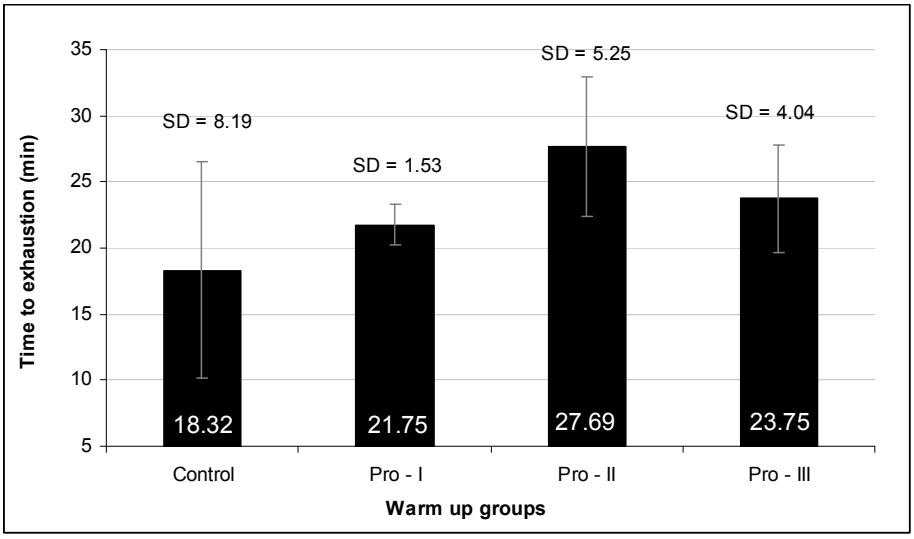

Figure 3. ANOVA for Time to Exhaustion

DISCUSSION

ENDURANCE PERFORMANCE

The results of this study demonstrated that warm up with dynamic exercise induced better endurance indices than warm up with dynamic stretching as well as with static stretching. There was 51.15% increase in treadmill time to exhaustion in dynamic exercise protocol (PII), 29.63% in dynamic stretching protocol (PIII) and 18.72% in static stretching protocol (PI) when compared with control. These results are consistent with Koch et al [18] and Unick et al [29] which stated that there is short term improvement in performance after a bout of dynamic exercises compared with static stretching.

In their article Faigenbaum et al [8] suggested that it may be desirable for children to perform moderate to high intensity dynamic exercises prior to the performance of activities that require a high power output. According to Thompsen et al [28], warm up protocols that include dynamic exercise may be a viable method of enhancing jumping performance in athletic women as compared to stationary cycling and static stretching. It has been shown [6] that the performance on the vertical jump test would benefit from dynamic exercise warm up with weighted vest.

It has been reported [25] that compared with no warm up, there was a significant increase in treadmill time to exhaustion, when running was preceded by a 15 min warm up at either 60 or 70% of VO2max. In their article Burnley et al [7] concluded that priming exercise performed in the moderate and heavy intensity improved cycling performance by ~2-3% despite a mild lactacidosis being present at exercise onset. It has been concluded that dynamic warm up performed with a vest weighted with 2% of body weight may be the most effective warm up protocol for enhancing jumping performance in high school female athletes [9].

In their article Stewart et al [26] compared the effectiveness of warm up in relation to athletic performance. Preparation involving warm up resulted in significantly faster sprint times compared to preparations having no warm up. Warm up was effective at improving immediate sprint performance. It has been reported [24] that competitive and recreational athletes typically perform warm up activities to prepare for more strenuous exercise. These preliminary activities are used to enhance physical performance and to prevent sports-related injuries.

It has been determined by Gray and Nimmo [13] that there is influence of type of warm up on metabolism and performance during high intensity exercise. There is a significant increase in cycling performance when preceded by active warm up. Active warm up tends to result in slightly larger improvements in short term performance than those achieved by passive warm up alone.

Active warm up appears to improve both long term and intermediate performance if it allows the athlete to begin the subsequent task in a relatively non-fatigued state, but with elevated baseline oxygen consumption (VO_2). While Bishop [4] discusses that active warm up improves endurance performance, it may have a detrimental effect on endurance if it causes a significant increase in thermoregulatory strain.

It has been stated [3] that there was impaired 2 min kayak ergometer performance if the subjects performed warm up at their anaerobic threshold, probably because of greater metabolic acidosis. Shellock and Prentice [24] discuss that dynamic stretching protocol shows increased time to exhaustion from static stretching protocol. A possible reason for this phenomenon may be the increase in core temperature during dynamic exercises in comparison to static stretching. Consequently, this may increase the sensitivity of nerve receptors and the speed of nerve impulses, encouraging muscle contractions to be more rapid and forceful.

BLOOD LACTATE CONCENTRATION AND VO_{2MAX}

Dynamic exercise warm up protocol has been shown to have positive effects on blood lactate concentration and VO_{2max}. There was decrease in lactate accumulation by 57.56% in dynamic exercise protocol (PII), 42% in dynamic stretching protocol (PIII) and 40.7% in static stretching protocol (PI) when compared with control. There was significant increase in VO_{2max} by 14.26% in protocol PII, 5.66% in protocol III and 3.25% in protocol PI when compared with control. In their article Gerbino et al [11] found that blood lactate production during constant load, high intensity exercise was less when the O_2 kinetics were speeded by prior exercise.

It has been concluded [22] that lactate production during submaximal exercise is O_2 dependent. Muscle NADH decreases in low intensity exercises but increases during high intensity exercises. The increased NADH consistent with the accelerated lactate production during exercise is due to the limited availability of O_2 in the contracting muscle. It has been demonstrated [23] that blood lactate accumulation and ventilation during graded exercise are dissociated.

The research documented a decrease in NADH with low intensity exercise at 40% VO_{2max} and an increase in NADH with high intensity exercise at 75% and 100% VO_{2max}. It suggests that the availability of O_2 relative to the demand is decreased at high exercise intensities [17]. It has been proposed [15] that the accelerated lactate production during submaximal exercise is due to limited availability of O_2 in the contracting muscle.

CONCLUSIONS AND PRACTICAL APPLICATION

The findings of this study can be summarized as follows: amongst three protocols: static stretching (PI), dynamic exercise protocol (PII), and dynamic stretching protocol (PIII), dynamic exercise protocol is the most effective in increasing aerobic power (VO_{2max}), increasing endurance performance and decreasing blood lactate concentration. Thus, considering the above findings dynamic exercise protocol should be used in order to enhance endurance indices and possibly competition results in endurance sports activities.

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