

Effects of Warm-up Intensity on Anaerobic Performance

by

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The purpose of this study was to investigate the role of warm-up intensity on anaerobic performance. The research material included 18 basketball players with an average age of $24,3 \pm 3,1$ years, body mass and height respectively $86,2 \pm 6,9$ kg and $193,3 \pm 4,5$ cm. All of the players performed anaerobic running test 10 x 30 m with a 20 s rest interval between consecutive sprints. The anaerobic test was conducted twice following two types of warm-up procedures: aerobic and anaerobic. Blood samples were drawn from the fingertip at rest, after the warm-up and in the 4th and 15th min of recovery to evaluate plasma lactate concentration. The results indicate a statistically significant effect (ANOVA, $p < 0,05$) of the type of warm-up procedures on results of the anaerobic 10 x 30 m test as well as particular 30 m sprints ($p < 0,001$). The total post exercise results of the 10 x 30 m test trial after anaerobic warm-up was statistically significant ($p < 0,05$) lowered versus the aerobic warm-up procedures. The intensity of the warm-up significantly ($p < 0,0001$) effected the blood plasma lactate concentration. Statistically analysis showed a significant differences ($p < 0,05$) in post exercise lactate concentration after the two types of warm-up procedures. In conclusion, the results of this study indicate, that warm-up with high intensity performance might be beneficial in anaerobic competition.

Key words: warm-up, anaerobic, aerobic, glycolysis

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Introduction

There is no doubt that warming up brings significant benefits to sports performance. The benefits of increasing body temperature lie in the fact, that the metabolic processes in the cell can proceed at a higher rate, since these processes are temperature dependent (Astrand et al. 2000). For each degree of temperature increase, the metabolic rate of the cell increases by about 13%. Thus in most sport disciplines, and especially those of high intensity competitive effort the athlete attempts to increase body temperature during the warm-up by 2 to 2,5 degrees. At the higher temperature, the exchange of oxygen from the blood to the tissues is also much more rapid (Wilmore et al. 2004). Furthermore the nerve messages travel faster at higher temperatures. The main objective of a warm-up is to elevate core body temperature, yet other important functions include active elongation of muscles, activation of the nervous system, proprioceptors and stabilizers, improvement of kinesthetic awareness and reinforcement of critical motor programs for a specific sport discipline (Foran 2001).

The effects of warming up on sport performance were studied extensively already before World War II (Hill 1927). Hill (1927) stated that physical work capacity is increased following warm-up. The recommendations for warm-up procedures evolved in the past 60-70 years along with advances in exercise physiology and sports training. At first athletes were instructed to warm-up with low intensity exercise for no more than 7-8 min (Hill 1927). Later, before competition more vigorous exercise was recommended, such as running at 10-12 km/h for 15 to 20 min. Recent warm-up prescriptions include 3 phases that follow a specific order, from low level aerobic activity to increase core temperature through joint mobility and dynamic flexibility exercises up to higher intensity sport specific dynamic movements that prepare the athlete for competition (Beachle et al. 2000, Foran 2001). Studies with elite athletes show a 3 to 6% improvement in running and swimming sprint and middle distance performance following a warm-up (Astrand et al. 2000). The benefits of warm-up have been confirmed by research over the past 70-80 years yet there are still many controversies regarding the duration and intensity of warm-up exercise. Early research showed benefits of a warm-up as great as 3 s in a 400 m sprint yet the mechanisms behind these phenomena have not been fully explained, thus the main objective of this research was to evaluate the effects of warm-up intensity on anaerobic performance.

During high intensity exercise the anaerobic mechanism of ATP resynthesis is engaged, which has two distinct pathways. The first one almost instantly replenishes ATP with the breakdown of phosphocreatine. In the second one, the

rate of ATP replenishment is compromised as glycogen is used as the primary substrate for ATP resynthesis. As a consequence of this metabolic pathway lactate is produced. The rate of glycolysis in exercise of varied intensity, such as basketball is controlled by the key enzyme of this pathway - phosphofructokinase (PFK) (Stryer 1995).

PFK is inhibited by a high concentration of ATP, citrate and H^+ ions. It is stimulated by a high level of AMP and its rate is also regulated by the ratio of NADH/NAD⁺ (Semenza 1998).

Under conditions of insufficient oxygen (hypoxia) the signal for transcription of glycolytic enzymatic proteins is hypoxia inducible factor (HIF-1), which is bonded to DNA, and starts the transcription process (Semenza 1998, 1999b).

During physical exercise of high intensity fast twitch fibers type IIa and IIx are recruited, which are characterized by a fast influx of lactate from muscles to blood. The rate of lactate removal from the muscle cell is dependent on training adaptation and is stimulated by adrenaline concentration. A fast removal of lactate from the muscles and further elimination may allow to maintained homeostasis and a better tolerance to high intensity exercise (Billat et al. 2003, Wilmore et al. 2004).

It is a well known fact that the stimulation of aerobic metabolism in ATP resynthesis inhibits the rate of glycolysis (Pasteur's effect).

As pointed out earlier some athletes incorporate high intensity exercises into the warm-up, while others prefer moderate or low intensity exercise before a dynamic, high intensity competition. It seems that the volume and intensity of a warm-up, along with heart rate and lactate concentration, as well as the time interval between the end of warm-up and competition are all important factors influencing performance.

The purpose of this study was to investigate the role of warm-up intensity on anaerobic performance.

Material and methods

The research material included 18 senior, well trained basketball players with an average age of $24,3 \pm 3,1$ years, body mass and height respectively $86,2 \pm 6,9$ kg and $193,3 \pm 4,5$ cm. During the research the athletes were well conditioned since they were in the precompetitive period.

All of the players performed a specific anaerobic running test 10×30 m with a 20 s rest interval between consecutive sprints. The anaerobic test was conducted twice following two types of warm-up procedures, separated by 1 week. The test was performed after 2 days of rest to exclude the influence if fatigue from previous training sessions. During the first trial an aerobic warm-up pro-

cedure preceded the test, which consisted of 15 min running at a steady slow pace with the heart rate between 130 - 140 bpm. The running was followed by 5-7 min of stretching and 3min of passive rest. Before the second test trial an anaerobic type warm-up was incorporated which included 4-5 min of continuous running at a heart rate of 150-160 bpm and 5 x 40 m sprints performed with progressively higher intensity and rest intervals of 90 s. Similar stretching routine followed and 3 min of rest before the start of the test.

Heart rate was monitored (Polar Electro 2000, Fin.) during the entire warm-up and the specific 10 x 30 m sprint test, as well as during the 5 min of recovery. Blood samples were drawn from the finger tip at rest, after the warm-up and in the 4th and 15th min of recovery to evaluate plasma lactate concentration with an enzymatic method (Boehringer Inc. kit)

Running speed of individual 30 m segments and the whole 10 x 30 m time was registered with the use of a laser diode system (LDM300C-Sport, Jenoptik Jena, Germany). The system provides an on-line recoding of the required distance versus-time and velocity-versus-time relationship and of selected individual kinematics variables, making these immediately available for coaches and athletes.

The significance of differences in analyzed variables between the two training protocols was calculated with the use of ANOVA, while differences in particular groups by Tukey's post hoc tests. Statistical significance was set at $p < 0,05$.

Results

The results of ANOVA indicate a statistically significant effect ($F=5,27$, $p < 0,05$) of the type of warm-up procedures on results of the specific anaerobic 10 x 30 m test as well as particular 30 m sprints ($F=5,07$, $p < 0,0001$) (Fig 1). The athletes reached significantly better sprint times in the first 7 trials following the anaerobic warm-up. The results were almost identical in trial 8 what indicates that several high intensity sprints were necessary after the aerobic warm-up to stimulate glycolytic enzymes to the same level as after the high intensity anaerobic warm-up.

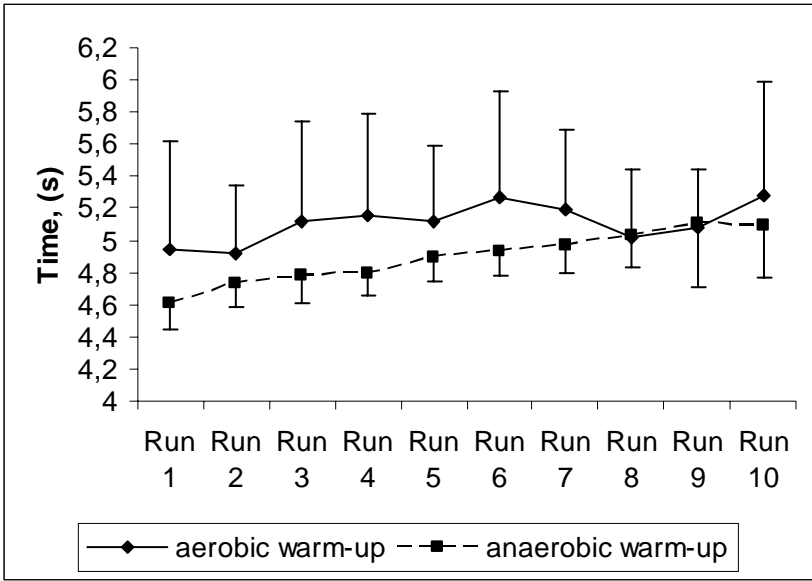
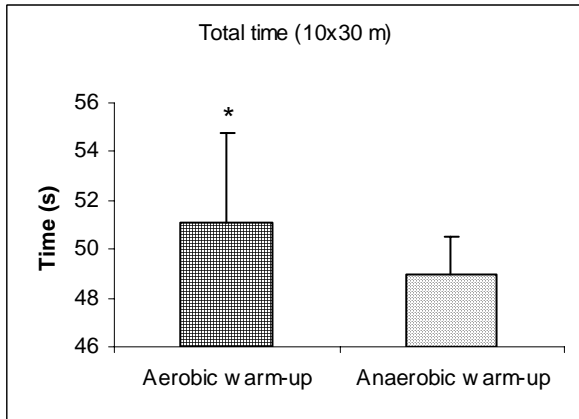


Fig. 1

The average time of each of ten 30m sprints performed after an aerobic and anaerobic warm-up procedures



*significantly different from anaerobic procedures, $p < 0,05$

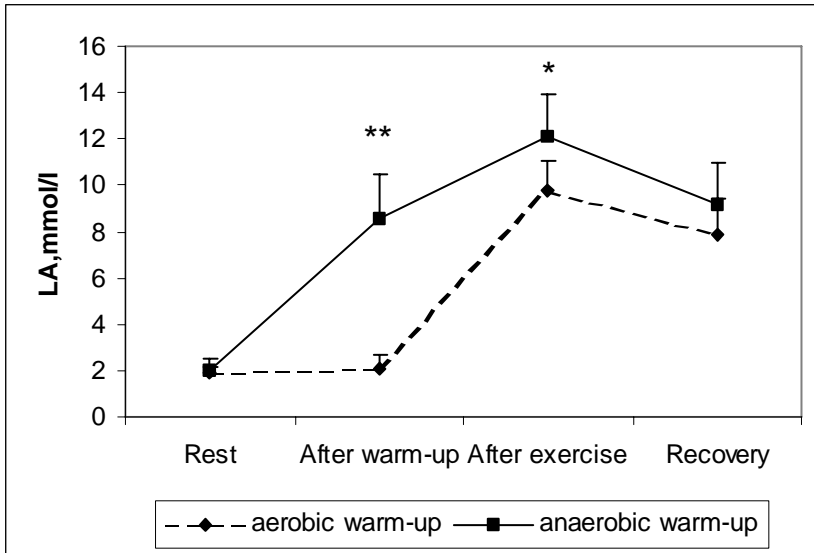
Fig. 2

Total time the results of the 10x30 m test trial performed after the aerobic and anaerobic warm-up procedures

Figure 2 presents the results of the 10 x 30 m test trial performed after the aerobic and anaerobic warm-up procedures. There was a statistically significant

difference in the total time of the test procedure between the two types of warm-ups ($p < 0,05$).

The intensity of the warm-up significantly ($F=1810,5$, $p < 0,0001$) effected the blood plasma lactate concentration. Post hoc analysis showed statistically significant differences ($p < 0,05$) in post exercise lactate concentration after the two types of warm-up procedures (Fig. 3).



*significantly different from the aerobic warm-up procedures, $p < 0,05$

**significantly different from aerobic warm-up procedures, $p < 0,001$

Fig 3

Plasma lactate (LA) concentration at rest, following the warm-up, and in the 4th and 15th min of recovery

Discussion

The results clearly indicate that applying high intensity exercise in to the warm-up stimulates glycolysis and allows for better performance in an anaerobic task that follows. These phenomena can be explained by increase anaerobic enzyme activity what results in a higher metabolic rate. An additional benefit of high intensity exercise incorporated in to the warm-up includes greater arousal of the nervous system through higher level of adrenaline (Hammann et al. 2003). Last but not least short, explosive movements recruit fast twitch muscle fibers which are predominantly used in high intensity anaerobic tasks. Low intensity, aerobic type of warm-up does not prepare an athlete for subsequent

sprint or strength exercise and decreases the performance. Compromised performance is attributed mainly to the inhibition of glycolysis through the stimulation of aerobic enzyme activity following low intensity continues exercise. On the contrary to sprint exercise, low intensity warm-up does not stimulate the CNS adequately and recruits slow twitch muscle fibers (Bunn et al. 1996, Semenza 1999a, Tomlin et al. 2001).

In running exercise of different intensity ATP is replenished through either aerobic or anaerobic processes. Under aerobic conditions the metabolic activity of glycolysis is much lower than during anaerobic, high intensity exercise. Under conditions of oxygen deficit, the level of ATP is maintained through the phosphagen system with the use of phosphocreatine and lactate system with the use of glycogen and glucose (Bishop et al. 2000).

The step that commits to metabolism down the glycolytic path and pyruvate production is phosphofructokinase-1 (PFK-1). PFK-1 has four important regulators: adenine nucleotides, citrate, fructose 2,6-biphosphate and pH. PFK-1 has two allosteric sites for binding regulators of its activity. One of these binds all three adenine nucleotides: ATP, ADP and AMP, with ATP binding resulting in decreased PFK-1 activity and the binding of the other two causing enhanced PFK-activity. Thus PFK-1 has the ability to sense the ATP charge in the cell and respond by altering the flux the glycolytic pathway. Citrate is a key intermediate in the aerobic oxidation of pyruvate and is another allosteric regulator of PFK-1 activity. High citrate concentrations enhance the inhibitory effects of ATP on PFK-1 activity. Thus, like high ATP levels, high citrate levels are a sign that energy needs are being adequately met and the glucose 6-phosphate is better used elsewhere. The final regulator of PFK-1 is fructose 2,6 biphosphate (F2,6-BP), a molecule very closely related to the product of PFK-1, fructose 1,6 biphosphate (F1,6-BP). F2,6-BP is a key factor in the coordination of glycolysis vs gluconeogenesis. The liver must decide when to metabolize the glucose and when more is needed elsewhere. F2,3-BP activates PFK-1 by decreasing the inhibitory effect of ATP and increasing the affinity for fructose 6-phosphate. F2,6-BP is formed by phosphorylation of F6-P. A rise in fructose 6- phosphate levels leads to increased synthesis of F2,6-BP and inhibits its hydrolysis. Thus, higher levels of fructose 6-phosphate leads to more fructose 2,6- BP leads to more fructose 2,6 BP and in turn to higher PFK-1 activity and commitment to glycolysis. Decreased environmental oxygen forces cells and tissues to adopt in multiple ways. In response to hypoxia, a significant number of changes in gene expression occur, resulting in elevated transcription of angiogenic factors, hematopoietic factors and some metabolic enzymes (Lando et al. 2003, Seagroves et al. 2001, Semenza 1998). The switch between the two forms of respiration

utilized by animal cells, aerobic versus anaerobic was first noted by Pasteur in the 19th century. He showed that when the oxygen level decreases the generation of ATP shifts from the oxidative phosphorylation pathway in the mitochondria to the oxygen-independent pathway of glycolysis in the cytoplasm. Although glycolysis is less efficient than oxidative phosphorylation in the generation of ATP in the presence of sufficient glucose, glycolysis can sustain ATP production due to increases in the activity of the glycolytic enzymes (Iyer et al. 1998, Seagroves et al. 2001).

A significant advance in the understanding of the hypoxic response has resulted from the recent cloning of the hypoxia inducible transcription factor HIF-1. HIF-1 binds DNA as a dimer composed of two proteins: a constitutively expressed basic helix-loop-helix (bHLH) protein the aryl hydrocarbon nuclear translocation and an oxygen-response bHLH protein, HIF-1 α . This heterodimer consists of one of the three alpha: HIF-1 α , HIF-2 α , HIF-3 α and beta subunits called ARNT. Under normoxic conditions, HIF-1 is rapidly degraded by the ubiquitin-proteasomal pathway whereas exposure to hypoxia prevents its degradation. This increased protein stability results in the accumulation of nuclear HIF-1 α and coincides with a large and sustained increase in the transcription of genes that contain HIF-1 α binding elements (hypoxia response elements) in their control sequences (Seagraves et al. 2001, Wang et al. 1993).

The role of hypoxia in stimulating the expression of glycolytic enzymes with a concomitant increase in lactic acid production is well described in the literature. In the presence of glucose, cells adapt to the hypoxic environment in part through increased catabolism of glucose and secretion of lactate. Because of the accumulation of lactic acid, a physiological hallmark of hypoxia, tissue acidosis increases. This creates large decreases in intracellular pH, what is prominent in metabolically active tissues (Baker et al. 1998, Green 1994, Gastin 1994, MacRae et al. 1992).

The regulation of oxygen uptake is a combination of both cellular and systemic processes. For example, when oxygen is limited (hypoxia), individual cells decrease oxidative phosphorylation and rely on glycolysis as the primary means of ATP production. To facilitate this switch to glycolysis, cells up-regulate the expression of a select set of genes, such as those encoding glycolytic enzymes and glucose transporters (Messonnier et al. 2001, 2002, Meyer et al. 2001, Phillips et al. 1995). Other hypoxic responses monitor global oxygen levels and effect system wide changes in tissue oxygen availability. For instant, the hypoxic induction of the hormone erythropoietin (Epo) by the kidney stimulates red blood cell production to increase the oxygen carrying of the blood (Spriett et al. 2000, Webster et al. 1988).

In conclusion, the results of this study indicate, that warm-up with high intensity performance might be beneficial in anaerobic competition.

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