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The Affects of a Warm-up and the Recovery Interval Prior to Exercise on Anaerobic Power and Acid-base Balance in Man

by

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The main objective of the paper was to evaluate the influence of warm up and the rest interval separating it from exercise on maximal anaerobic power and acid-base balance (ABB). The research material included 12 students of physical education with an average age, maximal oxygen uptake, body height and mass The students performed 3 exercise trials. During trial I a 30s Wingate test was preceded by a 15 min warm-up performed on a ergocycle with the intensity set at 50% VO_2max and the pedaling frequency equal to 60 rev./min. The rest interval between the end of warm-up and the onset of exercise equaled 5 min. During the second trial the same warm-up procedure was conducted yet the rest interval between the cessation of warm-up and exercise equaled 15 min. On the third occasion the 30 s Wingate test was performed without a warm-up. During the Wingate test the following variables were registered: total external work (W_{TOT}),maximal power (P_{max}), average power (P_{AV}), time of reaching Pmax (TrP_{max}) the index of power decrement (Pdi%). Additionally the following acid –base variables were evaluated in the blood: LA, HCO_3, BE and pH.

The results of ANOVA did not show a significant effect of the 15 min warm-up on all the considered anaerobic power indices: W_{TOT}, $P_{max,}$ P_{AV}, TrP_{max}, while statistically significant effects of the warm-up were obtained in post exercise plasma LA concentration and other acid-base balance variables ($p<0,001$, $F=13,06$), HCO_3 ($p<0,001$, $F= 14,61$), pH ($p<0,01$, $F= 11,49$), BE ($p<0,001$, $F= 14,97$)...

Key words: *warm-up, rest interval, acid-base balance, Wingate test*

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Introduction

It is a well known fact that a warm-up has a positive effect on exercise performance, especially that of high intensity. On the other hand there remains a lot of controversy to warm-up strategy in particular sport disciplines. This phenomenon is thus an often subject of research projects (Bishop 2003, 2003a), Reisman et al. 2005, Skof et al. 2007, Thompsen et al. 2007). Athletes and coaches apply different warm-up procedures, including active and passive forms of increasing body temperature and circulation, general and sport specific exercises for improved neuromuscular coordination. They also very the time and intensity of the warm-up (Atkinson et al. 2005, Burkett et al. 2005, Fradkin et al. 2006). Most warm-up procedures use stretching exercises at the end of it to increase the range of motion and prevent injury (Gremion 2005, Faigenbaum 2006, 2006a, Little et al. 2006, Zakas et al. 2006). An active warm-up is based on physiological adaptive processes of skeletal muscles, cardiovascular and respiratory systems. Additionally a proper warm-up increases work capacity by stimulating specific hormones which regulate substrate and oxygen delivery, as well as increase the contractile properties of muscle (Arnett 2002, Fuglenand et al. 2006, Hajoglou et al. 2005, Vetter 2007). The warm-up also allows to maintain the acid–base balance at an appropriate level by stimulating the buffering capacity (Beedle et al. 2007, Faigenbaum et al. 2005, Koch et al 2003, Mandengue et al. 2005, Pam et al. 2006, Safran 1988).

A passive warm up is based on applying exrenal source of heat to the body, and is most often used during breaks in competition in order to save energy. Recently PNF (proprioceptive neuromuscular facilitation) techniques, which are based isometric contractions and static stretching have been incorporated into the warm-up of different sport disciplines (Wenos et al. 2004).

The volume and intensity of work during the warm-up is of great significance to the metabolic rate during the competitive effort (Saez Saez 2007, Southard et al. 2003). Of great importance to a sprinters effort is the Pasteur's effect, which indicates a necessity of stimulating the rate of glycolysis under hypoxia. On the other hand, one must consider that that the respiratory processes in the mitochondria inhibit the rate of glycolysis. Recently a protein signaling factor has been discovered which stimulates the synthesis of protein – HIF-1 (hypoxia inducible transcription factor) (Seagroves et al. 2001).

In speed-strength competitions, lasting up to 30 s the sport result is primarily dependent on the time of reaching peak power (acceleration) and by its maintenance.

The exercise capacity under such conditions is dependent on the level of high energy substrates (phosphate sand glycogen) and their rate of metabolism. The other factor includes the recruitment of fast twitch muscle fibers. In preparing an athlete for competition especially a sprint, which last a few seconds the time that separates the cessation of the warm-up and the onset of competition is a crucial factor. It seems that a too long rest period between the warm-up and the competition may stimulate aerobic metabolism, what can inhibit the rate of glycolysis, stimulated to the progressive exercise of the warm-up. The main objective of this work was to evaluate the influence of warm up and the rest interval separating it from sprint exercise on maximal anaerobic power and acid-base balance.

Material and methods

Subjects

The research material included 12 students of physical education. Their basic somatic data is presented in table 1.

Table 1

Anthropometric characteristics of the subjects

	VO_2max (ml/kg/min)	Body height (cm)	Body mass (kg)	Age (yr)	BMI (kg/m^2)	Fat (%)
X	58,7	182,1	76,6	19,9	23,1	12,5
SD±	5,9	9,3	9,9	0,6	2,4	3,7

The students participated in their obligatory classes which included 10 hours of physical activities per week. The research project was approved by the Ethics Cometie for Scientific Research at The Academy of Physical Education in Katowice. The first part of the research project included the evaluation of maximal oxygen uptake (VO_2max) during a progressive test on a Monark 874E ergocycle with the use of OXYCON ALPHA gas exchange apparatus (Jaeger). The next step included the calculation of 50% VO_2max for each student what described the intensity of the warm-up. The second part of the research project included the performance of a 30 s Wingate test on three occasions, using the

Monark 874E ergocycle with the application of the MCE v 5 computer program (Poland).

Successive Wingate tests were performed in one week intervals to omit fatigue. During trial I the Wingate test was preceded by a 15 min warm-up on an ergocycle with the intensity set at 50% VO_2max and the pedaling rate of 60 rev/min. The rest interval between the cessation of the warm-up and the onset of exercise equaled 5min. During the second test trial the warm-up was identical but the rest interval was extended to 15 min. In the third test trial the 30s Wingate test was performed without a warm-up.

During the Wingate test the following variables were registered: relative maximal power (Pmax, W/kg b.m.), relative average power (P_{AV}, W/kg b.m.), time of reaching Pmax (TrPmax), total work (W_{TOT}, W/kg b.m.), fatigue index (Pdi%).

Biochemical analysis

Blood samples were drawn from the fingertip. The BioMerieux diagnostic kits and the Shimadzu UV1201 (Japan) spectrophotometer were used for the evaluation of plasma lactate concentration. The following acid-base balance variables were diagnosed (blood pH, (HCO_3^- , mmol/l), (BE, mmol/l) with the use of RapidLab 248 apparatus (Bayer, Germany).

Statistics

The results were presented as mean values and standard deviations. To determine the influence of the warm-up and the rest interval (independent variable) on the physiological and biochemical parameters (dependant variables) the simple analysis of variance was used. The significance of differences between particular dependent variables was determined with the Turkey's pos hoc tests. The level of statistical significance was set at p<0,05.

Results

The results of ANOVA did not show a significant effect of the 15min warm-up at intensity of 50% VO_2max and the rest interval (5 and 15 min) between the cessation of warm-up and the onset of exercise on the level of anaerobic power evaluated by the following variables: maximal power (Pmax, W/kg b.m.), average power (P_{AV}, W/kg b.m.), time of reaching Pmax (TrPmax), total work (W_{TOT}, W/kg b.m.), fatigue index (Pdi% gru,%). (tab. 2,3). The rest interval after the warm-up also did not influence significantly the blood acid –base balance variables (LA, HCO_3, pH and BE) (tab. 5).

On the other hand the results of ANOVA showed a statistically significant effect of the warm-up on post exercise plasma lactate concentration (p<0,001, F=13,06).

Table 2

Wingate anaerobic test values after warm–up [(interval 5 min (trial I) and 15 min (trial II)] and no warm –up protocol (trial III) for: total work (W_{TOT}), relative maximal power (P_{max}) , average power (P_{AV}), time of reaching maximal power (TrPmax), power decrease index (Pd)

Warm-up	W_{TOT} (W/kg b.m.)		P_{max} (W/kg b.m.)		P_{AV} (W/kg)		TrP_{max} (s)		Pdi (%)	
	X	SD	X	SD	X	SD	X	SD	X	SD
Warm-up (trial I-II)	267,21	25,35	11,42	0,87	8,91	0,84	6,82	2,11	22,15	3,33
No warm-up (trial III)	266,04	19,23	11,38	0,89	8,87	0,64	7,03	1,45	22,63	4,97

Table 3

Wingate anaerobic test values after warm – up and 5 min interval (trial I) and 15 min interval (trial II) for: total work (W_{TOT}), relative maximal power (P_{max}) , average power (P_{AV}), time of reaching maximal power (TrPmax), power decrease index (Pd)

Trial	WTOT (J/kg b.m.		Pmax (W/kg b.m..)		PAV (W/kg)		TrPmax (s)		Pdi (%)	
	X	SD	X	SD	X	SD	X	SD	X	SD
Trial I	270,45	23,35	11,47	0,94	9,01	0,78	6,79	1,79	22,17	3,97
Trial II	263,98	27,77	11,36	0,83	8,79	0,92	6,85	2,45	22,14	2,69

Table 4

Lactic acid (LA), bicarbonate (HCO_3^-), base excess (BE) concentration and pH value in serum of subjects pre and post Wingate test, prior to warm–up (trial I-II) and no warm-up (trial III)

Warm-up	Exerc.	LA (mmol/l)		pH		HCO_3^- (mmol/l)		BE (mmol/l)	
		X	SD	X	SD	X	SD	X	SD
(trial I-II)	Pre	1,98	0,83	7,41	0,02	23,90	1,11	-1,01	1,49
	Post	9,47	1,19	7,24	0,04	14,27	1,26	-15,05	2,01
No warm-up (trial III)	Pre	1,62	0,41	7,40	0,02	24,52	0,93	0,11	1,23
	Post	10,89	1,51	7,20	0,04	12,96	1,38	-16,93	2,24

Table 5

Lactic acid (LA), bicarbonate (HCO_3^-), base excess (BE) concentration and pH value in serum of subjects pre and post Wingate test prior to warm-up and after the 5 min (trial I) and 15 min rest interval (trial II)

Trial	Exercise	LA (mmol/l)		pH		HCO_3^- (mmol/l)		BE (mmol/l)	
		X	SD	X	SD	X	SD	X	SD
Trial I	Pre	2,01	0,66	7,41	0,03	23,45	1,05	-1,64	1,31
	Post	9,37	1,28	7,24	0,04	14,25	1,49	-15,13	2,38
Trial II	Pre	1,89	1,00	7,42	0,01	24,35	1,01	-0,38	1,44
	Post	9,57	1,13	7,24	0,03	14,30	1,04	-14,96	1,64

The plasma post exercise lactate concentration was significantly lower in the trial with the application of the warm-up in comparison to the trial without the warm-up procedure (p>0,01). The warm-up had a similar effect on blood HCO_3^- (p<0,001, F=14,61). The post exercise concentration of blood HCO_3 in the trial with the warm-up was significantly lower than without its use (p<0,01). The warm-up also had a significant effect on blood pH (p<0,01, F=11,49). The post-hoc Tukey; s tests revealed a significantly lower drop in blood pH after the trial with the warm-up (p<0,01). As with the other acid –base variables the warm-up also effected blood (BE) (p<0,001, F=14,97). The post exercise base excess was significantly lower in the trial preceded by the warm-up (p<0,01) (tab. 4 and 5, fig. 1,2,3,4).

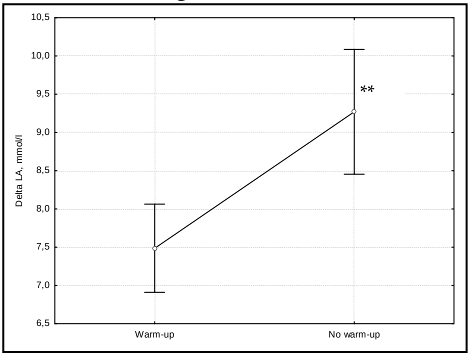

Fig. 1

Post exercise plasma lactate concentration after the 30s Wingate tests performed with and without a warm-up.

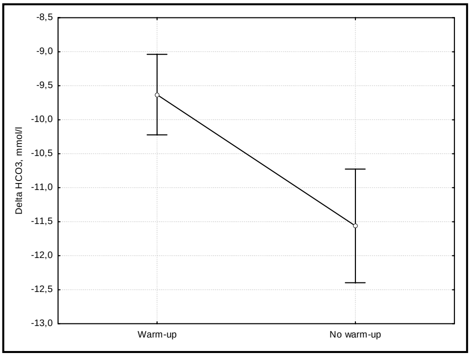

Fig. 2

Post exercise plasma bicarbonate concentration after the 30s Wingate tests performed with and without a warm-up.

** statistically significant difference p<0,001)

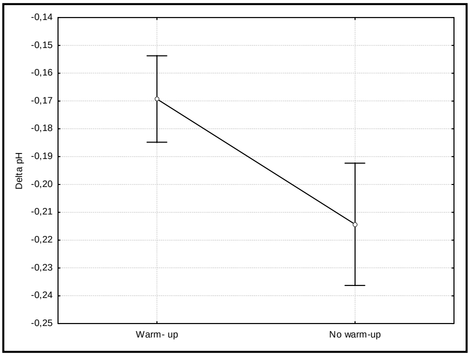

Fig. 3

Plasma changes in pH following the 30s Wingate tests performed with and without a warm-up

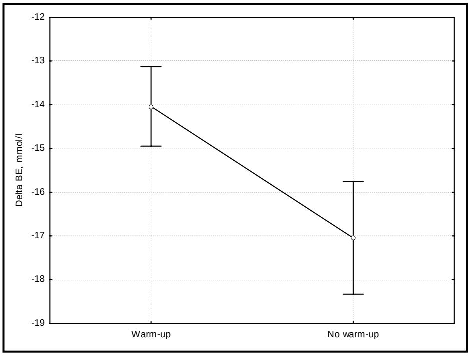

Fig. 4

Plasma changes in base excess (BE) following the 30s Wingate tests performed with and without a warm-up.

Discussion

It is universally accepted, that warm-up exercise should be performed before participation in a period of vigorous physical activity. Despite the seemingly obvious benefit of "priming" the cardio-respiratory and neuromuscular systems before vigorous exercise, the effect of prior exercise on the metabolic and gas exchange response to exercise and its potential impact on performance, has until recently received only modest empirical attention. While increased muscle temperature may improve physical performance in tasks requiring the generation of maximal muscle power, evidence that prolonged exercise performance is similarly improved by warm-up exercise is limited (Evans et al. 2002, Fletcher et al. 2004, Gremion 2005). Scientists have considered the effect of previous exercise on a range of physiological responses to exercise, including those of oxygen uptake (VO_2), glycogenolysis and blood lactate concentration, heart rate, acid-base balance and blood gases (Bouno et al. 1982, Robergs et al. 1990, Robergs et al. 1991). The altered physiological responses noted in these studies suggested that exercise tolerance was changed in some way. Whether this is beneficial or not is likely to depend on many factors, including the intensity and duration of the warm-up exercise, the recovery period separating the prior exercise from the "criterion task" and the nature of this subsequent exercise task itself.

Much less attention has been directed to the rest interval separating the warm-up from the main high intensity task. It seems of great importance in high intensity performances to maintain the increased metabolic rate from the warm-up until competition. Body temperature must not drop, while muscles, tendons as well as the vascular and respiratory systems must remain stimulated (Beedle et al. 2007, Burnley et al. 2005, Sen et al. 1992). If the warm-u metabolism is dominated by aerobic work, the anaerobic glycolysis during the high intensity competition effort will be inhibited. (Pasteur effect).

The development of complex cardiovascular, respiratory and hemopoietic systems in the human being provides a means to efficiently capture and deliver oxygen from the environment to every cell of the body. While a sufficient supply of oxygen is essential for energy production, too much oxygen in the form of free radicals can be detrimental. The regulation of oxygen consumption and its level is a combination of both cellular and systemic processes (Firth at al 1995). 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 selected set of genes, such as those encoding glycolytic enzymes and glucose transporters. Other hypoxic responses monitor global oxygen levels and effect wide changes in tissue oxygen availability. For instance, the hypoxic induction of the hormone erythropoietin (Epo) by the kidney stimulates red blood cell production to increase the oxygen carrying capacity of the blood.

Prior to heavy exercise increased overall VO_2 as a result of vasodilatation in the active muscles, caused by the account accumulation of vasoactive metabolism (MacDonalds et al. 1997). It was proposed that prior heavy exercise increased bulk oxygen delivery to exercising muscle and reduced or eliminated regional perfusion heterogeneities that otherwise existed following the onset of heavy exercise. Further it was proposed that metabolic acidosis might increase oxygen availability by causing a rightward shift in the oxyheamoglobin dissociation curve (Bohr effect) to increase delivery of oxygen to tissues.

A switch between aerobic and anaerobic metabolism during strenuous exertion requires mechanisms to adjust metabolic function and this need is acute in extended exertion in skeletal muscle. It is clear that the transcription hypoxia-inducible factor – HIF-1α is an essential factor in maintenance of ATP levels in cells, to increase glycolytic rate during hypoxia. 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 (Robergs et al. 1991).

In the conducted experiment the 15 min warm-up with a 50% VO_2max intensity did not affect the anaerobic power and capacity of the students. The warm-up did on the other hand influence significantly the acid-base balance variables: LA, HCO_3^-, pH and BE. Gray et al. (2001, 2002), Robergs et al. (1990) observed that a higher intensity of the warm-up is related to lower post exercise plasma lactate concentrations in high intensity sprint type efforts. A lack of a warm-up caused significantly higher post exercise lactate concentrations, due to the domination of aerobic metabolism before the onset of exercise. A stable in relation to acid-base balance muscle cell and blood environment stimulates the rate of anaerobic metabolism initiated by the hypoxia-inducible factor (HIF-1α). An increased rate of anaerobic glycolysis delivers more ATP to the working muscles, necessary for high intensity work.

A lack of statistically significant effects of the warm-up on anaerobic power and capacity does not totally eliminate the positive aspects of this procedure, since a tendency for improved performance was registered. In competitive sports such small margins of improvement in performance may be of great significance.

The rest interval 5 or 15 min) used in this work, between the cessation of warm-up and the onset of high intensity exercise did not influence significantly the considered anaerobic power variables nor the acid-base balance variables. A tendency for increased values of maximal power, average power and total work following the shorter 5 min rest interval.

There were no significant differences in the analyzed post exercise biochemical variables between the 5 and 15 min rest intervals separating the test trials from the warm-up The lowest increase in post exercise lactate concentration occurred after the 5min rest interval, what can be explained by the maintenance of increased rate of glycolysis from the warm-up procedure.

In conclusion it must be indicated that a warm-up preceding a high intensity effort did influence significantly the acid-base balance variables yet it did not affect the anaerobic power indices. The reset interval (5 or 15min) separating the warm-up from the onset of exercise did not affect either the anaerobic power or acid base variables. Further research, with the use of different intensity of the warm-up and different rest interval seem fully justified.

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