ORIGINAL RESEARCH

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BLOOD LACTATE RESPONSE TO 30 S ARM CRANKING AND LEG CYCLING IN ELITE WRESTLERS*

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ABSTRACT

The aim of the present study was to examine post-exercise blood lactate concentration in response to 30 s leg cycling and arm cranking in elite wrestlers. A total of 33 free and Greco-Roman style wrestlers participated in the study. All subjects underwent 30 s leg cycling and 30 s arm cranking. Blood lactate concentrations were determined 3, 5, 7, 9, 13 and 30 min after the exercise. Absolute and relative mean and peak power output during leg cycling (606.4±185.5 W and 8.6±0.5 W • kg^{-1} for mean power and 844.1±166.9 W and 11.3±0.7 W • kg^{-1} for peak power) was significantly greater than during arm cranking (482.9±170.9 W and 6.9±0.5 W • kg^{-1} for mean power and 666.9±242.3 W and 9.7±0.1 W • kg^{-1} for peak power). However, post-exercise blood lactate concentration measured 3-30 min after exercise did not differ following both exercises. Average blood lactate levels (sum of lactate concentration determined 3-30 min after the exercise) was also similar in response to arm cranking (62.5±10.6 mmol • l^{-1}) and leg cycling (61.4±11.5 mmol • l^{-1}). On the other hand, total post-exercise blood lactate expressed per 1 W of the absolute mean power output after arm cranking (0.122±0.025 mmol • l^{-1} • W^{-1}) was significantly greater than after leg cycling (0.099±0.019 mmol • l^{-1} • W^{-1}). Multiple regression analysis revealed that peak post-exercise blood lactate concentration was significantly correlated with relative peak power output during arm cranking and leg cycling (partial correlation coefficient r= 0.61 and r= 0.37 for leg and arm exercise, respectively). We conclude that post-exercise blood lactate concentration following 30 s arm cranking is exaggerated in comparison with leg cycling. Additionally, peak post-exercise blood lactate response to both leg cycling and arm cranking in wrestlers of the present study reflects peak power during upper and lower body supramaximal work.

Key words: supramaximal exercise, upper body, lower body, anaerobic glycolysis

Introduction

It is generally accepted that intensive physical activity results in the production of lactate in the working muscle and its accumulation in the muscle and in the blood (34, 37). Futhermore, lactate production and accumulation in the muscle and post-exercise blood lactate concentration is strongly related to exercise intensity (25).

Due to smaller muscle mass involved in upper vs. lower body muscular work, both maximal power output and post-exercise blood lactate concentration are significantly lower in response to arm vs. leg exercise (28, 31). On the other hand, there are many data indicating that during submaximal arm exercise lactate release from the muscle and arterial lactate concentra-

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tion is significantly greater than during leg exercise when exercise intensity is adjusted to the respective arm or leg maximal oxygen uptake (1, 18). Moreover, it has been noted that arteriovenous oxygen difference during submaximal arm work is by 11-19% lower than during leg exercise indicating lesser oxygen supply to the upper body musculature (17). The above data allow to hypothesize that during small muscle group exercise the contribution of anaerobic processes to overall energetic demands is greater than during large muscle group exercise, probably due to a greater proportion of fast-twitch muscle fibers in the upper body musculature (19, 29).

Post-exercise blood lactate measurements after short-term, exhaustive exercise are often used in sport physiology as an estimate of lactic capacity (for review see 9). Its use is supported by a high correlation observed between maximal blood lactate concentration and short-term running or cycling performance and higher maximal blood lactate concentration in sprint and power athletes compared with endurance sportsmen or untrained subjects (8, 21, 27).

In should be stressed that for many sports (eg. judo, wrestling, kayaking, rowing) arm capacity to perform supramaximal exercise plays an important role in sport achievements (5). However, according to our knowledge there is a paucity of data concerning blood lactate response to short-term arms exercise in elite sportsmen. Taking into account the aforementioned greater reliance of upper body on glycolytic processes it could not be excluded that blood lactate response to supramaximal arm exercise may differ from that observed following leg exercise. It is well known that arm and leg anaerobic power of wrestlers is critical for success because the scoring system for both free and Greco-Roman style promotes the use of quick, explosive maneuvers that can end a match before regulation time (i.e. by a fall or a technical fall). There are numerous data concerning wrestlers arm and leg anaerobic power, however, blood lactate response to supramaximal exercise was not studied (12, 14, 15).

This study was undertaken to examine post-exercise blood lactate concentration in elite freestyle and Greco-Roman wrestlers following 30 s arm cranking and 30 s leg cycling exercise with reference to the relationship between power output and post-exercise blood lactate concentration.

Methods

Subjects

The subjects of the present study were 33 Greco-Roman and freestyle wrestlers of all weight categories - candidates for the European Championships in 1999 and their sparring partners. The study was performed 14 days before competition. The subjects' physical characteristics are given in Table 1. The experimental protocol was approved by the Ethics Commission in the Aca-

Table 1. *Physical characteristics of the subjects (n=33)*

Variable	Mean ± SD
Age (years)	23.0 ± 2.0
Body weight (kg)	75.0 ± 13.5
Body height (cm)	172.9 ± 9.4
BMI	24.8 ± 1.8
Training experience (years)	10.6 ± 2.2

demy of Physical Education. The subjects were informed about multiple blood sampling for lactate determination and all gave their informed consent. The day before coming to the laboratory they refrained from physical activity. All test were performed at least 2 h after a light breakfast (200 kcal). Arm and leg exercise were performed one day apart between 9:00 -12:00 a.m. All subjects were familiar with experimental protocol because their anaerobic power was routinely evaluated at least two times a year. All procedures were approved by coaches to prevent any inconvenience in the training schedule.

Wingate anaerobic tests

The Wingate anaerobic power test was used for the arms and legs during separate tests (16). Resistance of 0.05 kg • kg $^{-1}$ body weight and 0.075 kg • kg^{-1} body weight was used for the arms and legs, respectively, to conform with the protocol used in prior studies of the anaerobic power of wrestlers (13). About 30 s after standarized warm-up (5 min of pedaling or cranking at a self-directed pace against zero resistance) the test was performed. A verbal command was used to start the exercise.

Leg cycling was performed using a mechanically braked Monark 834 ergometer (Sweden). The total number of revolution performed during a 30 s and a single revolution time was counted using electromagnetic gauge and power was calculated using a computerized MCE system, version 4.5 (JBM, Poland). Arm cranking was performed at standing body posture using an electrically braked Angio ergometer (Lode BV, Groningen, The Netherlands). The ergometer was mounted to a special frame fastened to the wall. The center of the ergometer shaft was adjustable to the subjects' shoulder level. Before exercise the subjects' hips were braced using belts connected with firm, steel construction mounted beneath the ergometer. The total number of revolutions performed during the entire 30 s was counted and power was calculated using the Operator Manual Wingate Software, version 1.08 (Lode BV, Groningen, The Netherlands, 1998).

Both during leg cycling and arm cranking mean power was defined as the average power generated during the 30 s interval. During leg cycling peak power was computed from the highest power output registered during a 0.01 s interval. During arm cranking peak power was computed from the highest power output registered during a 0.125 s interval.

Blood lactate determination

Blood for lactate determination was taken from the hyperemic earlobe into heparynized 10 µl capillaries before the warm-up, and 3, 5, 7, 9, 13 and 30 min after cessation of exercise. Lactate was determined immediately after blood withdrawal using commercial Dr Lange kits (Germany). Briefly, after hemolysis of blood lactate was oxidated to pyruvate which formed a red quinonimine red dye with 4-aminophenazone. The coefficent of variation for lactate assays was 4.4%.

An average blood lactate levels following arm cranking and leg cycling was expressed as sum of lactate concentration determined 3-30 min after the exercise.

Data analysis

For comparison of the mean and peak power output during leg and arm exercise paired t-tests were used. The time pattern of blood lactate response to arm and leg exercise was compared using multivariate analysis of variance (MANOVA). Multiple regression analysis was used to evaluate the relationship between peak post-exercise blood lactate and mechanical variables. The value of $p<0.05$ was predetermined as significant.

Results

Peak and mean power output

Both absolute and relative mean power output during arm cranking were markedly lower than during leg cycling (Table 2). Similarly, absolute and relative peak power during arm cranking was significantly lower than during leg cycling.

Post-exercise blood lactate

Both leg cycling and arm cranking induced marked elevation in blood lactate concentration (Table 3). However, no differences were observed between post-exercise blood lactate concentration following arm and leg exercise.

An average blood lactate concentrations after arm cranking was similar to those after leg cycling (Table 4). But average lactate expressed per 1 W of absolute mean power output was significantly higher in response to arm cranking than to leg cycling.

Multiple regression analysis revealed that peak blood lactate following either arm cranking or leg cycling was significantly related to peak power output but was not affected by the mean power output (Table 5).

Discussion

Lower by 31% relative peak power output and by 40% relative mean power output during arm cranking than during leg

Table 2. *Mean and peak power output during 30 s arm cranking and 30 s leg cycling in elite wrestlers (mean ± SD)*

Variable	Arm cranking	Leg cycling
Mean power		
W	482.9 ± 170.9*	606.4 ± 185.5
$W \bullet kg^{-1}$	6.9 ± 0.5*	8.6 ± 0.5
Peak power		
W	666.9 ± 242.3*	844.1 ± 166.9
$W \bullet kg^{-1}$	9.7 ± 0.1*	11.3 ± 0.7

* Indicates significance at p<0.0001 vs respective values during leg cycling

Table 3. *Blood lactate response to 30 s arm cranking and 30 s leg cycling in elite wrestlers (mean ± SD)*

Variable	Blood lactate (mmol x l^{-1})						
	Rest	3 min	5 min	7 min	9 min	13 min	30 min
Arm cranking	0.9±0.1	7.9±2.3*	9.9±2.6*	11.3±2.3*	12.6±1.9*	12.1±2.2*	6.6±1.8*
Leg cycling	0.8±0.1	8.2±2.3*	9.9±2.2*	11.9±2.4*	13.3±2.0*	12.7±2.1*	6.5±1.7*

* Indicates significance at p<0.0001 in comparison with rest.

Table 4. *Post-exercise blood lactate following 30 s arm cranking and 30 s leg cycling (mean ± SD)*

Variable	Avergae post-exercise blood lactate[a] (mmol • l^{-1})	(mmol x $l^{-1} \bullet W^{-1}$)
Leg cycling	61.4 ± 11.5	0.099 ± 0.019
Arm cranking	62.5 ± 10.6	0.122 ± 0.025*

a - Expressed as sum of blood lactate concentration determined 3-30 min after the exercise.
* Indicates significance at p<0.0001.

Table 5. *Multiple linear regression analysis of variables affecting peak post-exercise blood lactate concentration following leg cycling and arm cranking (n=33)*

Variable	Leg Cycling	Arm Cranking
Multiple R	0.650[a]	0.421[b]
R^2	0.423	0.178
Adj. R^2	0.384	0.123
F (df 2,30)	2.30	3.24
Standard error of estimate	15.76	20.03
Intercept	-40.28	53.52
β		
Mean power (W/kg)	-0.40	-0.16
Peak power (W/kg)	0.91	0.52
Partial correlation		
Mean power (W/kg)	-0.32	-0.12
Peak power (W/kg)	0.61[c]	0.37[d]

[a,b,c,d] Indicates statistical significance ([a] $p<0.0003$; [b] $p<0.05$; [c] $p<0.00023$; [d] $p<0.036$).

cycling corroborated the results of other studies (14, 15, 26). However, it should be stressed that the difference between arm and leg relative peak and mean power in the wrestlers of the present study was much less than in young athletes and close to that reported in the American National Team wrestlers (15, 26).

Despite a marked difference in peak and mean power neither post-exercise blood lactate concentration measured 3 - 30 min after exercise nor summarized blood lactate levels differ in response to 30 s arm cranking and leg cycling.

Post-exercise blood lactate concentration reflects lactate production in the working muscles, its transport from muscles into the bloodstream and elimination from the blood. Lactate release from muscles into the bloodstream is related to its concentration in the muscles with a transport hindrance for intramuscular lactate production higher than 4-5 mmol • min $^{-1}$ (20). Assuming much higher power output during leg than during arm exercise and expected greater lactate production during leg exercise it could not be excluded that lactate release into the blood is slower after leg than after arm muscular work (6, 7). However, this was not the case in the present study since no differences in blood lactate response was noted during 30 min post-exercise period.

Post-exercise lactate elimination from the blood after leg high-intensity and moderate exercise is mostly due to its uptake by non-working arm muscles (3, 4, 11). Therefore, taking into account a large non-working muscle mass (legs) during arm exercise blood lactate concentration in response to arm cranking have to be lower than after leg cycling and relatively smaller non-working muscle mass (arms).

The aforementioned facts did not explain the lack of differences in blood lactate response to 30 s arm and leg work in the present study.

It is well known that energetic demands during 30 s leg cycling are covered by both anaerobic and aerobic processes but with prevalence of anaerobic glycolysis (2, 30). In addition, the relative contribution of anaerobic and aerobic energy in overall energetic demands is affected by training status (10). Recent data concerning energy system contribution during 200 - to 1500 m running in highly trained athletes indicated that the crossover to predominantly aerobic energy system supply occurred between 15 and 30 s and the relative contribution of the aerobic metabolism was markedly greater than traditionally thought (32). Assuming a greater fast-twitch fiber percentage in the upper body than in lower body musculature (29) it could not be excluded that the contribution of anaerobic glycolysis to overall energetic demands and resultant lactate production is greater during arm than during leg supramaximal exercise. It seemed feasible since our study revealed that an average post-exercise lactate levels expressed per 1 W of the absolute mean power were significantly (by 25%) higher following 30 s arm than leg supramaximal exercise indirectly indicating greater reliance of arms on anaerobic glycolysis.

Data concerning the relationship between the mean power output during 30 s leg Wingate test and peak blood lactate are not unequivocal. Significant correlation was found between the mean power output and peak post-exercise blood lactate in elite volleyball players (33). In contrast, the lack of significant correlation between these variables was demonstrated in subjects with different fitness level (sedentary to trained) (35). The results concerning the relationship between post-exercise blood lactate and mean power output in elite wrestlers are contradictory. During competitive season significant correlation existed between the mean power output and peak blood lactate following 30 s arm cranking but not leg cycling (22). On the other hand, in another group of wrestlers positive correlation between mean power output during 30 s leg cycling and peak post-exercise blood lactate concentration was observed during competitive season but not during preparatory season (24).

Thus it could not be excluded that the relationship between the mean power output during the Wingate test and peak blood lactate at least in elite wrestlers is probably affected by many factors including training schedule, which may differ due to the coach program as well as to individual differences in training effects as a consequence of athletes' predisposition (35). Therefore, the relative contribution of anaerobic and aerobic energy in overall energetic demands during a 30 s supramaximal exercise may differ affecting the relationship between peak post-exercise blood lactate and power output.

Multiple regression analysis revealed that in the present study peak post-exercise blood lactate concentration in response to either arm cranking or leg cycling was not related to the mean power output ($W \cdot kg^{-1}$) but was under the influence of the peak power output. It is worth noting that significant correlation ($r=0.87$) between peak power and post-exercise blood lactate in the *vastus lateralis* muscle was reported in sprinters and middle-distance runners (16). The contribution of anaerobic glycolysis in peak power develompent has to be carefully recognized since significant elevation in the muscle and blood lactate was reported in sprinters following short-distance (40-110 m) running and in karate athletes in response to 10 s supramaximal leg cycling (13, 23).

In conclusion, the pattern of post-exercise blood lactate concentration 3 - 30 min after leg cycling and arm cranking was similar, despite significantly higher mean and peak power output during leg than arm muscular work. However, summarized post-exercise blood lactate levels expressed per 1 W of absolute mean power following arm exercise was markedly higher than after leg exercise probably indicating greater reliance of the upper body muscle on anaerobic glycolysis during supramaximal exercise. In elite wrestlers of the present study peak blood lactate concentration was not correlated with the mean power output both during 30 s leg cycling and arm cranking. However, significant correlation was found between peak post-exercise blood lactate and relative peak power output.

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