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CHANGES IN HANDGRIP FORCE AND BLOOD LACTATE AS RESPONSE TO SIMULATED CLIMBING COMPETITION

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Abstract. The aim of the study was to estimate post-competition changes in handgrip strength and blood lactate in climbers and relationships of the studied variables with declared climbing ability of the tested athletes. Twenty one male climbers volunteered to take part in the experiment. Each subject took part in simulated lead climbing competition on the artificial wall – (difficulty 7a in French scale). The blood lactate concentration was measured pre-climbing and then 3 min and 30 min post-climbing. Grip force of both hands (dominant and non-dominant) was measured twice – pre-climbing and 1 min post-climbing (semi-final). Maximum heart rate during climbing reached 181.4±7.7 beats per minute. Lactate concentration amounted to 6.35±1.50 mmol/l and 2.28±0.66 mmol/l 3 min and 30 min post-climbing, respectively. Handgrip force related to body mass (averaged for both hands) decreased significantly from 7.39±1.30 N/kg pre-climbing to 6.57±1.05 N/kg 1 min post-climbing. Self reported climbing ability was correlated with lactate concentration and handgrip force, as well. It was demonstrated that athletes reporting higher climbing ability showed better lactate recovery.

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Key words: Sport climbing – Competition – Lactate - Handgrip

Introduction

Rock climbing has become a competitive sport of growing popularity. There is an increasing number of indoor climbing walls. Also sport climbing has been recognized as a competitive sport by the International Olympic Committee [9]. In order to regulate competition climbing to meet Olympic Games requirements the International Federation of Sport Climbing (IFSC) was established in 2007. There has been not much of research done on sport climbing comparing to the other,

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“traditional" sports. Biomechanical and physiological approaches have focused on finger strength [5], aerobic and anaerobic capacity of sportsmen [2,8,9] and their anthropometric characteristics [6,14].

It is known that climbing performance is restricted by growing local fatigue of forearm muscles. Sustained and intermittent isometric contraction of these muscles is necessary for keeping balance and upward propulsion [9,11,13]. The loss of strength of the finger flexors reduces possibility of applying technical skills. The aim of the study was to estimate post-competition changes in handgrip strength and blood lactate in climbers and relationships of the studied variables with declared climbing ability of the tested athletes.

Materials and Methods

Twenty one male climbers volunteered to take part in the experiment. Their age, body mass and height varied between 17 years and 29 years (mean±SD 22.0±3.4, 63 kg and 86 kg (mean±SD 70.6±, 6.0), as well as 171 cm and 187 cm (mean±SD 179.8±4.9), respectively. The climbing ability (CA) of the subject was defined as a climbing grade of the most difficult on-sight ascent ever made. The meaning of on-sight was that an ascent was completed at the first attempt with no falls [5]. The climbing ability, self-reported by subjects, ranged between 17 and 33 (mean 23.0±4.9) in quantitative Australian scale. Each subject took part in simulated lead climbing competition on the artificial wall. Difficulty of the competition route (semi-final) was estimated as 24 in Australian scale (7a French scale). The eight of the best climbers were qualified to the final. The net result was defined as a rank obtained in the final (for those who were classified) or semi-final competition.

The blood lactate concentration was measured pre-climbing (LA_0) and then 3 min (LA_3) and 30 min (LA_{30}) post-climbing (semi-final) using commercial assay kits and photometer (Dr Lange, Germany). In order to estimate lactate recovery the following indicator was defined:

$$\xi = \ln\left(\frac{LA_3}{LA_{30}}\right).$$

Grip force of both hands (dominant and non-dominant) was measured twice – pre-climbing and 1 min post-climbing (semi-final) using hydraulic hand dynamometer. The heart rate during climbing was monitored using Polar 810i (Polar Electro, Finland).

Results

The mean (±SD) heart rate increased from pre-climbing value of 131.0±7.1 beats per minute to its maximal value of 181.4±7.7 beats per min. Lactate concentration amounted to 1.81±0.84 mmol/l pre-climbing, 6.35±1.50 mmol/l and 2.28±0.66 mmol/l 3 min and 30 min post-climbing, respectively. Lactate concentration remained significantly increased ($P<0.001$, Wilcoxon test) 30 min post-climbing comparing to its initial value. As it is shown in Fig. 1, lactate concentration (LA_3) has been correlated with climbing ability (Spearman's $R=0.453$; $P<0.05$).

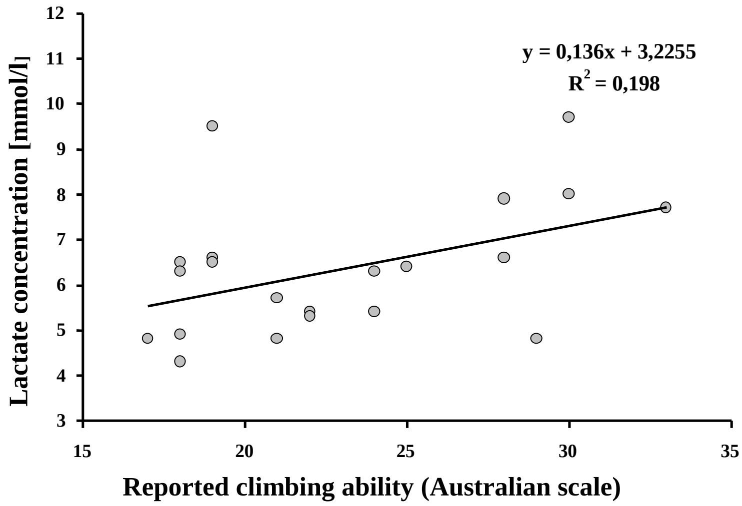

Fig. 1
Relationship between blood lactate concentration measured 3 min post-climbing and the climbing ability self-reported by subjects (n=21)

Climbing ability showed also strong and significant relationship with the lactate recovery indicator ξ (Spearman $R=0.687$, $P<0.001$), as presented in Fig. 2.

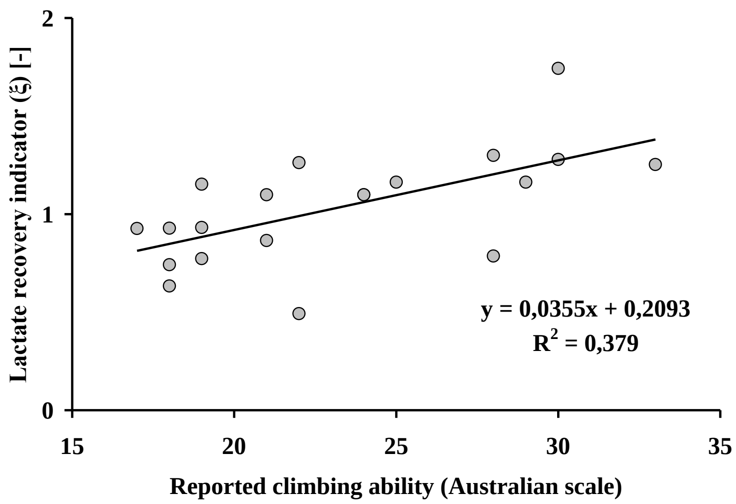

Fig. 2
Relationship between the lactate recovery indicator (ξ) and the climbing ability self-reported by subjects (n=20)

Handgrip force related to body mass (averaged for both hands) decreased significantly ($P<0.001$, Wilcoxon test) from 7.39±1.30 N/kg pre-climbing to 6.57±1.05 N/kg 1 min post-climbing. Pre-climbing handgrip force was correlated with climbing ability ($R=0.560$, $P<0.01$). Similar relationship was observed post-climbing ($R=0.566$, $P<0.01$). Decrease in handgrip force as well as climbing ability were correlated with pre-climbing handgrip value ($R=0.601$, $P<0.01$ and 0.618, $P<0.001$, respectively).

Lactate recovery indicator (ζ) was the only one parameter that was correlated with the result (rank) of the competition (Spearman's $R=-0.763$, $P<0.001$): the better lactate recovery, the better rank achieved.

Comparing finalists and those who were not qualified, the most significant difference was found in relative handgrip force (Table 1). Neither anthropometric nor physiological variables (lactate or heart rate) differed between finalists and non-finalists groups.

Table 1
Mean values (±SD) of the relative handgrip force pre- and post-climbing in finalists (n=8) and non-finalists (n=13)

Group	Relative handgrip force [N/kg]	
	Pre-climbing	Post-climbing
Finalists	8.41±1.28***	7.46±0.94
Non-finalists	6.76±0.85	6.08±0.72

***significantly different from non-finalists (P<0.001)

Discussion

The increasing popularity of climbing as a mode of physical activity or competitive sport raises questions about physiological and anthropometric determinants of climbing performance. Those issues ought to be investigated since mechanisms responsible for climbing abilities are still not well defined and results of studies vary. Hence, presented study aimed at describing changes in handgrip force and blood lactate as response to exertion performed during simulated climbing competition.

Mean heart rate values recorded pre- and post climbing amounted to 131.0 and 181.4 beats per minute, respectively, and were slightly higher than those reported by other authors. Depending on climbing grade, heart rates ranged from 129 beats per minute in Sheel *et al.* [10] studies to 176 beats per minute in Billat *et al.* [1] investigation; the most frequently reported values being about 160 beats per minute [2,7]. During sport climbing climber’s weight is supported intermittently for a considerable period of time with a predominance of isometric contraction of the upper limbs muscles. Because isometric contraction time during climbing can account for more than one third of the total time ascent time [1] arms and forearms are subject to extensive isometric loading [4]. Those loading increases with the route difficulty as more of the climber’s weight is forced onto the arms with less support by the legs causing an increase in heart rate, being possible explanation of reactively high heart rate values observed in this study. Nevertheless the differences stated, there are no doubts that heart rate increases with climbing difficulty and high variability in heart rates is usually attributed to different climbing intensities, experience/skill level [7] route familiarity, technique [17] and physiological stress or anxiety [3,7]. The specific conditions of simulated climbing competition may be another factor that contributed in rise of heart rate and may partly explain relatively high heart rates recorded in this study.

Relative handgrip force is believed to be important factor determining climbing ability.

The values of relative pre-climbing handgrip force recorded in this study (7.39±1.30 N/kg) are comparable to those reported by Watts *et al.* [16] for elite adult male climbers (7.8±0.6 N/kg) and slightly higher than those reported by Mermier *et al.* [6] for adult recreational climbers (6.5±1.4 N/kg). As the results of pre-climbing force are similar, several studies produced equivocal results concerning the magnitude of post-climbing changes in handgrip force. In this study, handgrip force significantly decreased to 6.57±1.05 one minute after climbing and that is comparably close to results attained by Watts *et al.* [13] who found that handgrip strength decreased 22% after lead climbing and continued to be lower than resting values 20 min after the climb. In the same study it was also shown that handgrip endurance was only 57% of resting value immediately after the climb. Although a separate investigation performed by Watts *et al.* [14] failed to reveal any change in handgrip strength it should be rather expected that local fatigue in arm and forearm muscles may result in lower post-climbing grip strength. The results of the present study show strong relationship between handgrip strength and climbing ability. Those findings are not in accordance with the general view that there is no relation between climbing ability and handgrip force assessed with dynamometer because the lack of the specificity of the device and as this measurement is similar only to “pinch” grip of the four grips commonly used in climbing [3]. Correlation between strength and climbing ability seems also to be in contrast to stand of Watts *et al.* [16] who claim that grip strength may not be a necessary attribute of elite climbers. The importance of grip strength to climbing performance is partly supported by results of multiple regression analysis [6] that revealed that the training variables explained 58.9% of the total variance in climbing, whereas the anthropometric and flexibility components explained 0.3% and 1.8% of the total variance, respectively; grip strength to body mass ratio and % body fat being only significant predictors of climbing ability. The usefulness of relative handgrip force was indirectly confirmed in this study as the finalists exhibited significantly higher pre-climb handgrip force compared to climbers who were no qualified to finals; results being 8.4 and 6.7 N/kg respectively. Considering inconsistent results of data presented in literature it is plausible that correlation between grip strength and climbing ability was present due to high variability of climber’s skills and would not be pronounced in very top athletes.

Blood lactate concentration increases with climbing route difficulty and is usually regarded as an indicator of local fatigue. Blood lactate samples taken immediately after climbing range from 2.4 to 6.1 mmol/l [9] or even to 10.2 mmol/l as reported by Gilles *et al.* [3]. Considerable high variability could be attributed to different study protocols or methods applied, variations in style of climbing, climber's experience/skills [3]. In presented study, blood lactate levels were elevated from 1.81 mmol/l pre-climbing to 6.35 mmol/l three minutes after the climbing and were comparable to those reported by Watts *et al.* [13] amounting 1.4 mmol/l pre-climb to 6.4 mmol/l post climb. In present study lactate concentration remained significantly increased 30 minutes post-climbing (2.28 mmol/l), so the result partly supports the statement of Watts *et al.* [14] that it may take up to 30 min for blood lactate to return to pre-exercise levels.

Isometric contractions dominating in climbing performance evoke acute local fatigue causing significant decrease in handgrip and respectively high lactate concentration. In MacLeod *et al.* studies [5], after completing the endurance test simulating climbing grips, participants commented on having a painful burning "pump" in the forearm muscles showing high local fatigue due to high local lactic acid accumulation. Because climbing competitions often involve sections of overhanging terrain, the ability to tolerate and remove lactic acid could be beneficial [3,15]. The results of present study supports that thesis as strong, significant relationships between lactate recovery indicator and climbing ability (R=0.687) or the final rank of the competition (R=-0.763) have been observed.

Although climbing is regarded as an exhaustive event, blood lactate concentrations are lower with climbing than with activities as running or cycling. This is probably because a smaller active mass is producing lactate as much of the mass supported during climbing is provided by forearm muscle [3,10]. It makes the lactate concentration is relatively low compared to other activities and as it could be expected on high accompanying heart rate values. According to Mermier *et al.* [7] it could be due to dilution of venous blood volume, impaired lactate clearance during isometric contraction and uptake of circulating lactate by non-exercising muscles. All abovementioned factors may decide that although high loads that occur in climbing, the local fatigue assessed by selected markers manifests in blood samples to a low degree. That calls for looking for other, supplementary methods that would improve the knowledge of metabolic and cardiovascular responses to climbing activity and would help to discover the determinants of climbing performance.

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