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Research article

Effect of Two Types of Active Recovery on Fatigue and Climbing Performance

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Abstract
Performing intra-session recovery is important in rock climbing due to the multiple efforts that climbers are required to make in competitions, as well as repeated climbing trials that they carry out during training sessions. Active recovery has been shown to be a better option than passive recovery. However, the type of active recovery that should be done and the influence of the type and quantity of muscle mass activated are not clear. The aim of this study was to compare the effects of recovering with easy climbing (CR) or walking (WR) on markers of fatigue and climbing performance. For this purpose, 14 subjects participated in this randomly assigned crossover protocol completing three two-minute climbing trials separated by two minutes of active recovery with the assigned method. Seven days later participants carried out the same protocol with the other recovery method. Blood lactate (La^-), rating of perceived exertion (RPE), and heart rate (HR) were analyzed as markers of fatigue and recovery, while meters climbed (MC) and handgrip force (HF) were analyzed for performance. La- values before the last climbing trial ($p < 0.05$; $d = 0.69$) and Peak La- values ($p < 0.05$; $d = 0.77$) were lower for CR than for WR. Climbers were able to ascend more meters in the set time when following the CR protocol ($p < 0.01$; $d = 0.6$), which shows the important role of the active recovery method carried out on climbing performance. There were no differences in HR, HF or RPE between protocols. A more sport-specific recovery protocol, in addition to moving great muscle mass (e.g. lower limbs), seems to enhance recovery and to facilitate lactate removal. For this reason, CR appears to be a more effective active recovery method than WR in sport rock climbing.

Key words: Blood lactate, rock climbing, handgrip force, active recovery, fatigue, performance.

Introduction

Rock climbing has increased its popularity in recent decades gaining the attraction of both athletes and researchers (Heyman et al., 2009; MacLeod et al., 2007; Magiera et al., 2013; Sheel, 2004; Sherk et al., 2011; Watts, 2004). This sport offers a great variety of disciplines, each of them with specific features that provoke different physiological demands and responses (Draper et al., 2006b).

In this study we will focus on sport indoor rock climbing, which consists of ascending a wall helped by artificial structures with hands and feet being theclimber permanently protected from falling thanks to a succession of pre-installed attachment points for the rope along the climbing route. In this discipline ascents last between one and two minutes (Draper et al., 2006b) and blood lactate concentration can be considered as an indicator of fatigue (Bertuzzi et al., 2007; Billat et al., 1995; Booth et al., 1999; Draper et al., 2006b; España-Romero et al., 2009; Mermier et al., 2000; Sheel, 2003; 2004), which shows its similarity with other short term high intensity efforts where glycolysis provides the main energy source (Draper et al., 2006b).

Forearm muscles strength has also been described as a good indicator of performance (Bertuzzi et al., 2011; Magiera et al., 2013; Deyhle et al., 2015; España-Romero et al., 2009; Gajewski et al., 2009; MacLeod et al., 2007; Mermier et al., 2000; Watts et al., 2000) as its fatigue can result in a decrement of climbing performance.

Watts et al (2000) indicated the necessity of studying the effect of different recovery strategies between climbing ascents due to the multiple routes or efforts on a specific route that climbers are required to perform in competitions, as well as repeated climbing efforts that they carry out during training sessions.

Numerous studies have found improved lactate removal and/or performance with active rather than with passive recovery in different types of exercise (Baldari et al., 2005; Connolly et al., 2003; Corder et al., 2000; Heyman et al., 2009; Martin et al., 1998; Menzies et al., 2010; Monedero and Donne, 2000; Spierer et al., 2004; Wells, 2015; White and Mika et al., 2007). Active recovery has been shown to enhance lactic acid clearance from type II skeletal muscle fibers through facilitating its oxidation by adjacent type I fibers (Baldari et al., 2005). Moreover, other studies (Fujita et al., 2009; McLoughlin et al., 1991) have shown that activating previously inactive muscles can also improve blood lactate removal. Therefore, the type of active recovery carried out can be important since the quantity and type of muscle mass activated may influence the increment in blood flow to different parts of the organism, facilitating metabolites clearance and removal and consequently improving performance.

Previous research has demonstrated that walking and cycling are beneficial modes of active recovery in climbing (Draper et al., 2006b; Heyman et al., 2009; Watts et al., 2000). In the named experiments the exercises chosen to recover from climbing did activate great muscle groups (lower limbs) but not the main producers of lactate (upper limbs, specially forearm muscles), which could accelerate the rate of lactate clearance by adjacent type I fibers in the previously working muscles as well as lactate removal by hitherto-inactive muscles or other organs such as the liver (Gladden, 2000; 2004).

The aim of this study was to determine if activation during active recovery of both great muscle mass as

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well as the principal lactate producing muscles can improve recovery in comparison with activating just great muscle mass. For this purpose, walking –which activates the muscles of the lower limbs- has been compared with easy climbing –which in addition to the lower limbs muscles activates the forearm muscles, which are the main producers of lactate and fatigue in climbing (Watts et al,. 2000; 2008)–. Both central (Rate of perceived exertion) and peripheral (Blood lactate and heart rate) fatigue indicator have been analyzed, as well as their consequences in performance (meters climbed and handgrip force).

Methods

Fourteen male recreational climbers (descriptive data presented in Table 1) with an intermediate-advanced level (Draper et al., 2011) from the climbing school at University of Alcalá volunteered to take part in this study. The criteria for acceptance as a subject included climbing a minimum of 4 hours/week, a climbing experience greater than 2 years and red point climbing ability of minimum 6c, as well as refraining from doing intense exercise the day prior to testing sessions. For the duration of the study subjects were instructed to maintain normal dietary patterns and refrain from using any ergogenic aids or stimulants such as caffeine.

Table 1. Descriptive data from subjects (n=14) expressed as mean (standard deviation).

	Mean (SD)
Age (years)	38.2(6.7)
Climbing frequency (hours per week)	6.9 (2.5)
Body weight (Kg)	72.5 (5.5)
Height (m)	1.77 (.07)
BMI (Body mass index)	23 (1.2)
Fat mass (%)	9.4 (2.7)
Absolute hand grip force (N)	51.5 (7.7)
Relative hand grip force (N/Kg)	.71 (.1)
On sight climbing ability	6c
Red point climbing ability	7a+

Ethical approval was obtained for the study in accordance with the University of Alcalá Ethics Committee regulations and all participants completed an informed consent form after having the procedures verbally explained. Data of all subjects were anonymized. Participants had been familiarized with the climbing route having trained on it on a session that took place one week before the first testing session. This familiarization session consisted of five ascents to the climbing route at a self-regulated speed so at to memorize the necessary movements.

Experimental protocol

For the assessment of influence of the recovery mode, two different active recovery methods were evaluated: Walking recovery (WR) and easy climbing recovery in a 12-meter route graded 4c in the French scale (CR). Both recovery methods were carried out at a self-regulated exercise intensity, as previous studies have indicated that this allows for improved lactate removal (Belcastro and Bonen, 1975; Menzies et al., 2010) as well as an optimal relationship in rock climbing between isometric time (workless and costly) and fatigue due to increased speed and frequency of muscle contraction (Rosponi et al., 2012). All participants completed both WR and CR recovery conditions using a randomly assigned two-way crossover design. There was a separation of seven days between each condition.

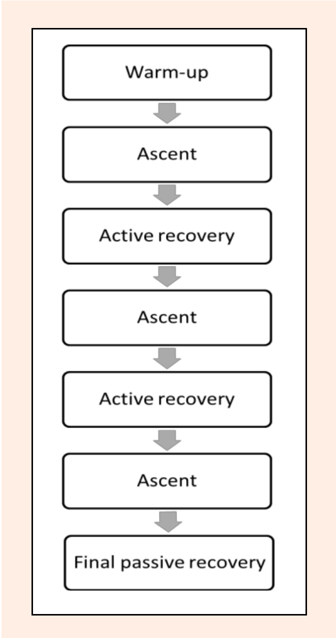

Figure 1. Descriptive scheme of the experimental protocol.

Prior to the climbing protocol, participants followed a ten minute warm-up which consisted of light jogging, articular mobility exercises and one light ascent of the testing route. The climbing protocol was identical for both conditions. Subjects performed three repetitions of two minutes maximal climbing efforts with two minutes of active recovery between them. During these recovery periods WR condition participants walked and CR condition participants climbed a route graded 4c at a subjectively chosen intensity, having been verbally told to perform the recovery exercise at the speed they considered optimal to recover from the previous effort. So as to avoid a competitive attitude between participants during recoveries, distance covered during this phase was not recorded. Active recovery was carried out for 1.5 minutes and the next 30 seconds were left as passive recovery to measure handgrip force and blood lactate (Figure 1) as well as to maintain the ecological validity of the climbing context, as climbers usually need some time before ascending to prepare themselves mentally for the next climbing trial and re-chalk their fingers (Draper et al., 2006b). The duration of the recovery phase was chosen to last 2 minutes so as to imitate a possible situation during training sessions, where climbers usually alternate with their belayers to ascend the routes and therefore rest while the other person is climbing.

After the last 2 minute effort, participants recovered passively seated in a chair while blood lactate was measured until the peak level was found.

Climbing phase

Ascent phase consisted on a 12 meters vertical route with steepness greater than 90º in order to require a higher physical and physiological demand (de Geus et al., 2006; Mermier et al., 1997; Noé et al., 2001). This route, graded 6c on the French scale, was of an inferior level than the maximum of the climbers and its difficulty was mainly physical and not technical to avoid falls or speed loss. Climbing was on top rope –ensuring participants safety with the rope passing through a top anchor between the climber and their belayer so as to diminish the psychological stress (Draper et al., 2010; Hodgson et al., 2009) and to let climbers focus on ascending as fast as possible, and in red point mode –which means that climbers already knew the route, spending less time in static positions (Sanchez et al., 2012).

All subjects started ascending the route at the same point and were said to cover all the meters they could in the 2 minutes climbing phase. When participants reached the top of the route (12 meters) before the end of the time, they were taken down to the floor (with a standardized 10 seconds protocol) and continued the effort until the 2 minutes were completed. This ensured that all participants climbed during 2 minutes in each repetition independently of their ascent speed. At the end of each repetition meters climbed were noted.

Measurements

Height of participants was calculated using a levelled platform scale (Seca, Barcelona, Spain) with an accuracy of 0.001 m. Body weight and body composition were calculated using a Tanita Body Composition Analyzer (TBF, 300, Japan).

A heart rate monitor (Garmin 310xt, Taipei County, Taiwan) was used to determine the exercise intensity during the whole protocol, although only maximal value during each ascent and minimal during the recoveries were noted.

0.5 µl capillary blood samples were taken from the ear lobe (Draper et al., 2006b) for lactate analysis (Lactate Scout, SensLab GmbH, Germany). Samples were collected after warm-up, before each 2 minutes effort and during the final passive recovery in the minutes 1, 3, 5, 7 and so on until maximal lactate peak was reached.

Maximal isometric handgrip force was measured in the non-dominant hand using a manual dynamometer (T.K.K. 5401,Tokyo, Japan). All subjects followed a familiarization phase with the apparatus consisting of three repetitions with each hand during the warm-up. During the protocol, before each 2 minute effort, subjects performed one maximal repetition with the non-dominant hand in a standing position, with the arm parallel to the body and without moving the wrist. This value was noted for later analysis.

The distance participants were able to climb during the 2 minutes ascent phase was measured with a 1 meter precision. Climbers rate of perceived exertion (RPE) was determined using a CR10 scale (Borg, 1998) that was shown to the participants at the end of the whole protocol with each recovery condition.

Statistical analysis

Results are expressed as means ± standard deviations. The normality of distribution of the data was checked with the Kolmogorov-Smirnov test. Data homogeneity was checked with the Levene´s test. The Student’s t-test was used for paired data to determine differences between the parameters calculated in WR and CR, as well as to determine differences between the first measurement and the last one in each protocol (e.g.: distance climbed in ascent 1 and ascent 3). To examine the magnitude of such differences, effects sizes between mean scores with both recovery methods were calculated. Effects sizes of 0.20, 0.50, and 0.80 were considered small, medium, and large, respectively (Cohen, 1988). Pearson´s correlations analysis were used to examine the relationships between handgrip force, distance climbed and blood lactate. The effect size of the correlations was interpreted as small (<0.3), moderate (>0.3 and <0.5), and large (>0.5) according to the scale proposed by Cohen (Cohen, 1988). An alpha level of $p < 0.05$ was set to assess statistical significance of result.

Results

La^- values along the test significantly increased ($p < 0.0001$) in both conditions from 1.36 ± 0.61 to 6.83 ± 0.75 $mmol \cdot l^{-1}$ in the case of WR and from 1.49 ± 0.54 to 6.39 ± 0.55 $mmol \cdot l^{-1}$ in the CR. Differences between methods in La^- did not reach statistical significance until the third trial ($p < 0.05$) with a medium effect size (0.69). La^- peak was significantly higher ($p < 0.05$) in WR (8.22 ± 0.77 $mmol \cdot l^{-1}$) than in CR (7.69 ± 0.80 $mmol \cdot l^{-1}$) with a medium effect size (0.77).

The distance covered by the climbers significantly decreased in both conditions from the first to the last ascent ($p < 0.01$). Differences between both recovery modes in each ascent increased along the protocol, with a significant difference ($p < 0.05$) between WR and CR in ascent 2 (18.71 ± 6.14 and 19.43 ± 6.69 m respectively) but a small effect size (0.2); and a greater difference ($p < 0.01$) in ascent 3 (16.86 ± 7.1 m for WR and 18.57 ± 7.18 m for CR) with a medium effect size (0.6)

Hand grip force values significantly decreased ($p < 0.001$) in both conditions (from 48.75 ± 6.94 to 40.76 ± 6.87 N in WR and from 49.05 ± 6.62 to 40.9 ± 6.23 N in CR). However, there were no differences in values between both recovery modes. There were no differences in RPE between WR and CR (7.71 ± 1.64 and 7.42 ± 1.95 respectively). Heart rate fluctuation did not differ between both types of recovery reaching similar values during ascents and recoveries.

A small positive correlation was found between handgrip force and distance climbed ($r = 0.23$, $p < 0.05$) as well as a small inverse correlation between blood lactate and meters climbers were able to ascend ($r = 0.26$, $p < 0.05$). A moderate significant inverse correlation was found between handgrip force and blood lactate ($r = 0.45$, $p < 0.0001$).

Discussion

The role of lactic acid –and its dissociation in lactate and hydrogen- in fatigue is controversial (Allen et al., 2008;

Gladden, 2004; Westerblad et al., 2002). Lactate, which is a strong anion, is accumulated in skeletal muscle when exercise intensity is above the anaerobic threshold resulting in a decrease in intramuscular pH because of the dissociation of H2O into H+ and OH2 to maintain electroneutrality (Lindinger et al., 2005; White and Wells, 2015). The accumulation of hydrogen ions, and the consequent acidosis environment, can provoke a diminution in performance (Hargreaves et al., 1998) through impairing muscle optimal contraction (Cooke et al., 1988) and through III and IV afferent receptors activation, which can affect muscle activation and motor control (Gladden, 2004; Robergs et al., 2004). However, some studies (Bangsbo et al., 1996) have not found a correlation between lower pH and fatigue, showing than the latter can be caused by many factors (Allen et al., 2008).

Lactate removal can be improved both by stimulating its oxidation by the previously working muscles or by increasing blood flow to other parts of the organism and enhancing its oxidation by hitherto-inactive muscles or other organs such as the liver (Gladden, 2000; 2004).

Some studies have previously analyzed the effect of active recovery with activation of the lower limbs on lactate removal and climbing performance (Draper et al., 2006a; Heyman et al., 2009; Watts et al., 2000). However, in this sport lactate synthesis and fatigue are mainly produced in the upper and not in the lower limbs. For this reason, we sought to study the effect that activating the muscles main producers of lactate during the previous activity –forearm muscles- as well as the great muscle mass of the lower limbs (CR) had in lactate removal and performance in comparison with activating just the lower limbs (WR).

Confirming our hypothesis, significantly lower blood lactate levels in the last ascent and lower lactate peak values have been found for CR in comparison with WR, suggesting that both type and quantity of muscle mass exercised during active recovery influence lactate removal. This results are in accordance with a previous study (Fujita et al., 2009) where it was found that activation of the arms muscles, which suppose a smaller muscle mass than that of the lower limbs, can increase lactate removal in the same manner than those. The fact that differences did not appear until the last stage of the protocol can be explained because of the time lactate needs to perfuse from the muscle fiber to the blood, where it is distributed through the organism.

Blood lactate values found in this study are approximately in accordance with those previously found in rock climbing (Sheel, 2004). It has been exposed that blood lactate levels after rock climbing are lower than those of other activities such as cycling (Sheel et al., 2003; Watts, 2004), maybe because of the smaller muscle mass exercised. These values can easily vary between rock climbing studies due to its dependency on many factors. Climbing routes with the same difficulty can provoke different increments in blood lactate depending on the direction of movement and steepness, being more demanding when ascending vertical routes with an steepness of more than 90º (de Geus et al., 2006). Moreover, the climbing mode strongly affects the physiological demand of the exercise, depending on if the climber is familiarized with the route (Draper et al., 2008) and the type of protection (Draper et al., 2010; Hodgson et al., 2009). Lastly, personal factors such as climbing experience can also influence the physiological responses.

In accordance with the improved lactate removal found with CR, climbing performance (meters climbed in the 2-minute ascend phase) has also been affected by the active recovery method in our study, being significantly higher in CR than in WR. This difference was increased along the protocol, perhaps due to the greater accumulation of fatigue. However, a small inverse correlation has been found in our study between blood lactate levels and meter subjects were able to climb in each ascend, confirming -as previously mentioned- that although this metabolite can be an indicator of fatigue, there are many other factors affecting performance.

Maximal handgrip strength of climbers is generally not higher than that found in sedentary population when presented as absolute values. However, it is much higher when body mass is taken into account (Bertuzzi et al., 2011; España-Romero et al., 2009; Giles et al., 2006; Watts, 2004). Moreover, climbers have been seen able to maintain forceful fingertip force longer than nonclimbers (Vigoroux and Quaine, 2006). Maximal isometric handgrip strength, and consequently forearm muscles strength, has been described to be a good indicator of climbing performance (Baláš et al., 2012), as the contraction of these muscles is necessary to grasp the artificial structures in order to block and visualize the route well as to ascend (De Benito et al., 2011; Gajewski et al., 2009; MacLeod et al., 2007; Nunez Alvarez et al., 2005; Sheel, 2004). The fatigue of this muscle group and the inability to maintain finger and hand contact with the holds has been cited as the primary cause of falls (Watts et al., 2000; 2008), being its importance increased when the route steepness is greater than 90º (Noé et al., 2001), as in the case of our study.

Our results, as other studies have done before (Heyman et al., 2009; Watts et al., 1996), confirm that forearm muscles suffer from fatigue during climbing, having found a very significant decrement in handgrip strength from the beginning to the end of the protocol. No differences in handgrip strength have been found between CR and WR. Previous studies have found a correlation between handgrip decrement, blood lactate and climbing time (Watts et al., 1996). In our study, a moderate correlation has been found between blood lactate values and handgrip strength, suggesting a possible role of low pH on the fatigue of this muscle group through the impairment of its contraction. Contrary to the aforementioned study (Watts et al., 1996), we have found a small correlation between handgrip force and performance, which can be explained by the lack of specificity of this test -due to the greater activation of this muscles during climbing than when using the handgrip ergometer (Watts et al., 2008) - and by the many factors affecting climbing performance (Bertuzzi et al., 2011; Giles et al., 2006; Magiera et al., 2013).

In our study there were no differences in HR or in RPE between both recovery methods. Some studies have found a lower HR for passive recovery than for active recovery (Draper et al., 2006b), which means an increased blood flow and better lactate removal. In this case, maybe because both recovery methods activated the great muscle mass of the lower limbs, the increment in HR was similar. However, HR has been said not to be a good indicator of fatigue in rock climbing as the fatigue is mainly produced at a local level in the forearm muscles (Watts et al., 2000), which do not greatly influence HR. In addition, many factors apart from exercise intensity have been described to affect HR in climbing (Burnik and Jereb, 2007; Mermier et al., 1997).

Conclusion

The results of this study suggest an important role in enhancing lactate removal and preventing fatigue of performing active recovery that includes synchronously light exercise of both great muscle mass -like that of the lower limbs- to increase blood flow facilitating lactate clearance by hitherto-active muscles and organs such as the liver, and exercise of the muscles that have produced the main quantity of lactate during the previous exercise, enhancing lactate metabolism by adjacent oxidative fibers. From a practical point of view, it would be advisable for climbers to perform a sport-specific exercise during active recovery instead of staying static or walking. Easy climbing or walking, while exercising the forearm muscles, could be two more effective strategies that can be easily performed by climbers in any place.

An interesting possibility for future research in this area would be to analyze this mechanism in a more controlled activity (i. e. analytic exercise) than rock climbing, in which fatigue is affected by many factors. Moreover, it would be useful to check if similar results are found in other sports with a predominant activity of the upper limb such as rowing or swimming.

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Key points

- Climbing recovery improved lactate removal in comparison with walking recovery.
- Subjects were able to climb more meters in a determined time when easy climbing instead of walking during recoveries.
- Activating both great muscle mass like that of the lower limbs as well as the main fatigue producing muscles (forearms in climbing) seems more effective for recovering than activating just great muscle mass.

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