Time course changes in hand grip strength performance and hand position sense in climbing

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ABSTRACT

The aim of the present study was to determine the time course changes in hand grip strength performance and hand position sense in novice climbers after one bout of two minutes continuing climbing on an artificial vertical wall. In addition, the rate of perceived fatigue of the participant felt right after the trial was recorded. Sixty five novice climbers aged 20 to 22 years (age 20.50± 0.65 years), were randomly assigned into two training groups with different tests protocols, the Grip strength test group (n=23), versus Joint position sense test group (n=14), and two control groups (n=14 each). The training protocol included one bout of two minutes continuing climbing on an artificial wall for both training groups whereas the control groups did not receive any kind of training during the study. Subjects were pre and post-tested for the selected variables. Statistical analysis showed that the grip strength was significantly decreased only for the training group $F(6,216) = 30.460$, $p < .0005$, partial $\eta 2 = .489$. Similarly, the rate of perceived exertion changed significant $F(2,563, 41,001) = 24.397$, $p < .0005$, partial $\eta 2 = 0.604$, with the training group to be more tired than the control after two minutes continuing climbing. Also, the wrist position sense of training group significantly deteriorated at post-test with $F(3,78)=2,977$, $p<.05$, partial $\eta 2 = .103$. In conclusion, the performance of novice climbers is affected by hand grip strength performance and joint position sense of the hand. In addition it was required almost ten minutes of rest for partial recovery. These variables can be addressed through training design giving attention to those physical abilities. **Keywords:** Indoor climbing; Perceived exertion; Wrist proprioception.

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INTRODUCTION

Rock climbing is an interesting sport activity demanding many physiological abilities of the involving athlete. Climbers' aim is to reach the endpoint of the natural or artificial wall while climbing up, across or down through a pre-oriented route and returning to the base successfully (Mermier et al, 1997; Morrison and Rainer, 2007; Rickly, 2018).

It is a challenging sport that requires not only muscular strength, power and neural adaptation (Giles and Brandenburg, 2016; Grant et al, 1996; Green and Stannard, 2010) but comprehensive technical knowledge to enable the athlete to enjoy it safely (Grant et al, 2001). Also, climbing is one intermittent activity, which consists of single tries on a route and as a result leads in moderate increases in oxygen uptake and lactate production (Mermier et al, 1997; Seifert, Wolf & Schweizer, 2016). The body balance close to the wall and the body transfer for one point to another during body elevation leading the hands grips a continually demanding hand function and possibly a key factor to success the climb. These situations could explain why the hand grip strength measurements recorded higher scores in climbers (Felici, et al, 2001).

More specifically the hand grip strength is increased in trained climbers in comparison to the untrained ones although it has been suggested to focus on optimizing body position to minimize hand grip force at resting stances, setting the hand grip strength an essential effort to achieve the climb. Furthermore, the "proprioception" was described by Sherrington (Lin, 2006; Malliou et al, 2010) as the awareness of body segment positions and orientations, encompasses components as join position sense (JPS), balance ability and force (Malliou et al, 2008; Smith et al, 2013; Stillman and McMeeken, 2002; Riemann and Lephart, 2002).

More specifically, kinaesthesia was defined as joint movement awareness (dynamic activity) (Grob et al, 2002), while JPS evaluates the awareness of a static joint position (Static activity). Thus, the articular joints components (capsule, muscle, tendon, ligaments) mechanoreceptors, despite the dynamic or static formation of joint activity, inform the body to accomplish any kinetic task (Olsson et al, 2004).

Thus, proprioception is even more crucial for climbing because the climbing skills on the vertical wall are composed by complex movements demanding dynamic body control ability (Malliou, 2008; Guney-Deniz and Callaghan, 2018), while with a restricted vision the athlete not only tries to reach the grip point but to correct or to change a static joint position in order to move his body on the wall to continue the climb. In other words joint position sense is another essential effort that climbers have to develop in order to perform successfully the wall climbing.

On the other hand, in order to prepare the beginners to climb on the wall it is necessary to determine the optimal exercise duration and the optimal exercise interval because the beginners usually get tired possibly to continuous hand grip muscle activation when they choose the next grip point and try to move the body weight on the wall resulting the ending of the training session. This problem that was observed in beginners climber classes was the spark to carry out this research.

The aim of the study

Therefore, the aim of the present study was to determine the time course changes in hand grip strength performance and hand position sense in novice climbers after one bout of two minutes continuing climbing on an artificial vertical wall. Secondarily, it was recorded the perceived fatigue that the participants felt right after the trial and over the course of measurements. Despite widespread experimental research in climbing, to our knowledge there is a lack of studies which have explored time course changes in hand grip strength performance and hand position sense in novice climbers, as most of the studies have focused on elite climbers' physiology, especially in rock climbing (Ferrara, Becker, & Seifert, 2018; Ryepko, 2013). What is more, we strongly support that our findings will be important for trainers to plan specific climbing training programs for novice climbers.

METHOD

Participants

Sixty five novice climbers (40 males and 25 females) aged 20 to 22 years were assigned into two training groups with different tests protocol (Grip strength test group GS, n=23, age 20.50± 0.65 years, height 1.75±0.09 m, weight 68.9+9.7 kg versus Joint position sense test group JPS, n=14, age 20.10± 0.45 years, height 1.70±0.09 m, weight 65.9+8.7 kg) and two control groups (Grip strength control group GScontrol and Joint position sense control group JPScontrol, n=14 each, age 20.20±0.59 years, height 1.69±0.06 m, weight 64.6±9.9 kg) which did not receive any kind of training during the study. Subjects were college students who were attending the class of technical climbing for beginners, in Physical education and Sports Sciences Department, in Northern Greece. According to Godin Leisure-Time Exercise Questionnaire (Godin and Shephard, 1985) their usual leisure-time exercise habits was registered as active (92.9%). From the study were excluded those who felt pain, aching, or stiffness in the wrist joint. All groups hadn't been involved in any indoor or outdoor climbing activities before the experimental procedure began. All participants were informed about the nature of the study and signed a written informed consent. The study's protocol was formally approved by the Institutional Ethics Review Board before testing began.

Measures

The evaluation of the maximum isometric strength of the hand and forearm muscle was based on Takei Digital Grip Strength Dynamometer, Model T.K.K.5401. The grip strength of dominant hand was measured at standing position extending the arm next to the body with shoulder adducted and neutrally rotated and elbow in full extension with the palm oriented to the tight. The correct procedures were explained and demonstrated to all subjects, and any questions about the testing were answered. The handgrip dynamometer was adjusted to the size of the participant's hand before testing according to procedures suggested by the manufacturer. Each of them was familiarized with the testing protocol carrying out a sub maximal (75% perceived effort) trial before the actual measurement. The test was preceded by a 5-minutes warm-up exercises included shaking both hands and bending and stretching all fingers (palm up, palm down, ball squeeze, interlace fingers and fingers spread with band). Each subject performed three attempts trying to reach the peak force (100% perceived effort) in the three first seconds with a 60-second rest between measurements. The highest value in kilograms was recorded as the score of the hand grip test.

Perceived fatigue was assessed using a 15-point RPE scale (Borg, 1982), rating the task from 6 (''no exertion at all'') to 20 (''maximal exertion''). The RPE scale measures participants' subjective evaluation of the exercise intensity with adequate reliability and validity (Cleak and Eston, 1992; Bobbert et al, 1986). Verbal anchors are used as follows 6=''no exertion at all'', between 7 and 8=''extremely light'', 9=''very light'', 11=''light'', 13=''somewhat hard'', 15= ''hard (heavy)'', 17=''very hard'', 19=''extremely hard'', and 20=''maximal exertion''. They received a brief explanation of the RPE scale according to the guidelines of Borg (1982) – that is, participants were told how perceived exertion was defined, how the perceptual range was anchored, the nature and use of the scale was explained, the differentiated ratings were explained, that there were no right or wrong answers and, finally, any questions were answered.

Wrist proprioception was assessed through a standardized active position sense method (Hagert, 2010; Karagiannopoulos et al, 2013). The blindfolded subjects were asked to reproduce a predetermined wrist joint angle while were seated on a chair and placing their examined elbows on a table in flexed position. The forearm and wrist were in a neutral position and fingers in a resting flexed position (Karagiannopoulos et al, 2013). The wrist joint assessment was evaluated based on LaStayo and Wheeler technique. The examiner demonstrated to the subject a starting wrist position while was moving passively the wrist to a target angle joint position (20 deg extension and 30 deg of flexion). The subject was asked to register the target angle position for 3 sec while a goniometer was placed palmary to the wrist. Then the subject was asked to move the wrist joint to full flexed position (target point 20 deg extension) or full extended position (target point 30 deg of flexion) and continually to reproduce the previous target wrist angle. The new wrist position angle was recorded with the same goniometry method. Specifically, the goniometer's moving arm was aligned palmary with the third metacarpal while the stationary arm was placed along the distal palmer forearm and its axis was adjacent to the wrist (Karagiannopoulos et al, 2013). The difference between the target and the replicated wrist joint angle were calculated representing a JPS deficit value. The procedure took place twice and the mean value of the two trials was used for data analysis. Particularly, in the present study the tester's intra-tester reliability was established through intra-class correlation coefficient (ICC) high (ICC=0.88).

Procedure

The training protocol included one bout of two minutes continuing climbing on an artificial vertical wall (width 3.5 m, height 7.0 m; rated 5.0 to 5.4) designed by a professional route designer, according to Yosemite Decimal Rating System (American Safe Climbing Association, 2003). The wall which was consisted of laminate panels with a grey grainy texture for friction was placed in a gymnasium-sized laboratory. The climbing route consisted of 25 holds of varying size and shape, all suitable for novice climbers. The frequency of the movements on the wall was auto selected by the climbers.

In particular, the GS test group and the GS control group were pre-tested and post -tested on hand grip strength immediately after the training phase, and on the 1st, 3rd, 5th, 7th and 10ed minute respectively. In addition, GS test group's perceived fatigue was simultaneously assessed on the 1st, 3rd, 5th, 7th, 10th minute and 24, 48 and 72 hours.

Participants of JPS test group and the JPS control group were pretested and post-tested immediately after two minutes continuing climbing and on 1st and 3rd minute respectively. Although the climbing task was new to the participants when they entered the experiment, the climbing route was very easy and readily learned before testing began. All climbers were scheduled in the morning to control for possible diurnal variation in grip strength and proprioception sense. Each participant was tested individually.

Analysis

Means and standard deviations were calculated for all variables. Mixed model repeated measures ANOVA was conducted to determine whether there were statistically significant differences in the detected variables over the course of measurements.

RESULTS

Grip strength test

Mixed model repeated measures ANOVA (2x7, group by time of test) was conducted to determine whether there were statistically significant differences in grip strength over the course of 7 measurements. There were no outliers and the data was normally distributed for each group, as assessed by boxplot and Shapiro-Wilk test ($p > .05$), respectively. The assumption of sphericity was violated, as assessed by Mauchly's test of sphericity, $\chi2(20) = 64.96$, $p = .005$. Therefore, a Greenhouse-Geisser correction was applied ($\varepsilon = 0.58$). Statistical significance was set at $p=0.05$. Specifically, statistical analysis showed significant interaction between the two factors on grip strength, $F(6,216) = 30.460$, $p < .0005$, partial $\eta2 = .489$. Concretely the experimental group elicited statistically significant changes in grip strength over time $F(6,30) = 47.023$, $p < .0005$, partial $\eta2 = .897$, whilst no such significant difference was found for the respective values for the control group $F(6,30) = .023$, $p = .678$, partial $\eta2 = .099$. Post hoc analysis with a Bonferroni adjustment revealed statistically significantly differences on grip strength between all pairwise combinations of measurements of the experimental group with level of significance $p < .0005$, with exception of 1st(pre-test) and 7th(post 10min test) measurement (1.98 (95% CI, 4.50 to -0.52) kilograms, $p = .292$), 4th(post 3min test) and 5th(post 5min test) measurement (-0.57 (95% CI, 0.74 to -1.87) kilograms, $p = 1.000$), 4th(post 3min test) and 6th (post 7min test) measurement (1.98 (95% CI, 0.83 to -4.02) kilograms, $p = .816$), 5th(post 5min test) and 6th (post 7min test) measurement (-1.02 (95% CI, 0.94 to -2.99) kilograms, $p = 1.000$), and 6th(post 7min test) and 7th(post 10min test) measurement (-1.22 (95% CI, 0.17 to -2.61) kilograms, $p = .144$) respectively. As can be seen, the grip strength for the experimental group is significantly decreasing from pre-test to post-test and recording a progressive increase over the time of test, it reaches almost in initial levels at post 10 min test (table 1). Conversely, regarding the control's group performance was observed stabilization from 1st to 7th measurement.

Table 1. Performance changes in Grip Strength test during measurements

	Pretest	Posttest	Post1min	Post 3min	Post 5min	Post 7min	Post 10min
GROUPS	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Strength Grip group	41.76±10.9	30.27±9.4	34.31±9.81	36.98±10.2	37.53±9.57	38.56±10.4	39.78±9.94
Control Group	32.11±7.59	32.24±7.1	31.57±6.39	31.16±6.81	31.26±6.61	32.51±7.38	32.26±7.33

Data presented as means ± standard deviations among two groups

Perceived exertion test

Repeated measures ANOVA was conducted to determine whether there were statistically significant differences in perceived exertion over the course of the 8 measurements. There were no outliers and the data was normally distributed for experimental group, as assessed by boxplot and Shapiro-Wilk test ($p > .05$), respectively. The assumption of sphericity was violated, as assessed by Mauchly's test of sphericity, $\chi2\ (27) = 78.098$, $p = .000$. Therefore, a Greenhouse-Geisser correction was applied ($\varepsilon = 0.366$). The two minutes continuing climbing elicited statistically significant changes in perceived exertion over time, $F(2{,}563, 41{,}001) = 24.397$, $p < .0005$, partial $\eta2 = 0.604$. Post hoc analysis with a Bonferroni adjustment revealed statistically significantly differences on Perceived exertion between all pairwise combinations of measurements with level of significance $p < .05$, with exception of 2ed(post 3min test) and 6th(post 24h test) measurement (2.23 (95% CI, 5.07 to -0.60), $p = .268$), 2ed(post 3min test) and 7th(post 48h test) measurement (3.00 (95% CI, 6.33 to -.33), $p = .110$), 3ed(post 5min test) and 6th (post 24h test) measurement (1.17 (95% CI, 3.56 to -1.20), $p = 1.000$), 3ed(post 5min test) and 7th (post 48h test) measurement (1.94 (95% CI, 4.85 to -.97), $p =.673$), 4th(post 7min test) and 5th(post 10min test) measurement (.588 (95% CI, 1.44 to -.264), $p = .562$), 4th(post 7min test) and 6th(post 24h test) measurement (.059 (95% CI, 2.03 to -2.14), $p = 1.000$), 4th(post 7min test) and 7th(post 48h test) measurement (.706 (95% CI, 3.40 to -1.99), $p = 1.000$), 5th(post 10min test) and 6th(post 24h test) measurement (-.647 (95% CI, 1.59 to -2.89), $p = 1.000$), 5th(post 10min test) and 7th(post 48h test) measurement (.118 (95% CI, 3.00 to -2.76), $p = 1.000$), 5th(post 10min test) and 8th(post 48h test) measurement (1.94 (95% CI, 4.05 to -.173), $p = .095$), 6th(post 24h test) and 7th(post 48h test) measurement (.076 (95% CI, 2.38 to -.85), $p = 1.000$), 7th(post 48h test) and 8th(post 72h test) measurement (1.82 (95% CI, 3.75 to -.107), $p = .077$) respectively. As can be seen perceived exertion decreasing progressively from 14.53 ± 2.50 at post 1min test (1st measurement) to 7.29 ± 2.14 at post 72h test (8th measurement) (Fig. 1).

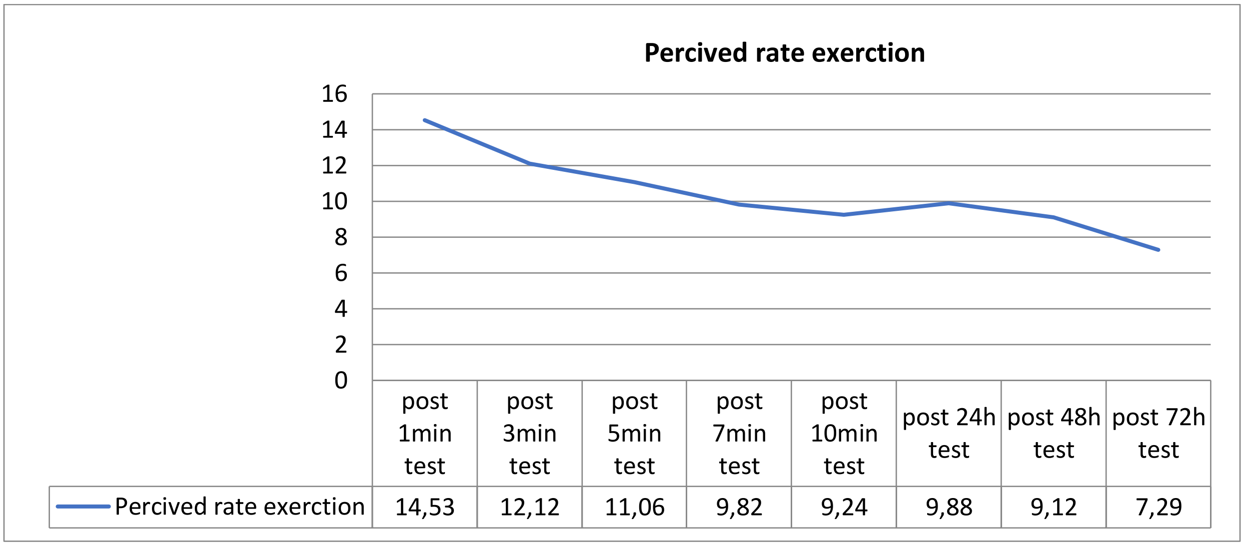

Figure 1. Changes in Perceived Exertion after two minutes continuing climbing (Borg 15-point RPE scale 6-20), over time.

Joint position sense test

Means and standard deviations were calculated for joint position sense variable. Mixed model repeated measures ANOVA (2x4, groups by time of test with planned contrasts on different time points) was conducted to determine whether there were statistically significant differences in joint position sense over the course of 4 measurements. There were no outliers and the data was normally distributed for each group, as assessed by boxplot and Shapiro-Wilk test ($p > .05$), respectively. The assumption of sphericity had not been violated, as assessed by Mauchly's test of sphericity, $\chi2(5) = 6.342$, $p = .275$. Statistical analysis whose significance was set at p=0.05, showed significant interaction between the two factors, on joint position sense F (3,78)=2,977, $p<.05$. partial $\eta2 = .103$. Post hoc analysis with a Bonferroni adjustment revealed statistically significantly differences over the course of measurements on joint position sense of the experimental group. Specifically, it was found difference with level of significance $p < .05$, only between the 1st(pre-test) and 2th (post-test) measurement (.857 (95% CI, .193 to 1.522), $p = .006$) while no were observed the same between all other pairwise combinations of measurements. As can be seen, the joint position sense for the experimental group is significantly differentiated from 3.71±,9 degrees pre-test to 4.57±1,2 degrees at post-test and recording a progressive decrease at 1 minute post-test, which it reaches almost in initial levels (3.78±1,1degrees) at 3 minutes post-test. Conversely, regarding the control's group performance was observed stabilization from 1st to 4th measurement (Table 2).

Table 2. Performance changes degrees in Joint position sense test during measurements

	Pretest	**Posttest**	**Post1min**	**Post 3min**
GROUPS	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Joint position sense group	3,71±,9	4,57±1,2	3,92±1,4	3,78±1,1
Control Group	3,69±,8	3,67±,7	3,71±1,1	3,72±1,2

Data presented as means ± standard deviations among two groups

DISCUSSION

The aim of the present study was to detect possible changes in hand grip strength performance and hand position sense in novice climbers after a 2 min climbing session. The results revealed that hand grip strength performance decreased 29% after the 2min climbing session for novice climbers and continued to be lower than resting performance 10 minutes after the climb. Similarly, the hands position sense presents a statistically significant deviation of 23% from baseline after their trial.

Similar results were found by Watts et al. (1996) where handgrip strength decreased 22% after lead climbing and continued to be lower than resting values 20 minutes after the climb. They also showed that handgrip endurance was only 57% of resting values immediately after climbing. Nevertheless, other studies failed to detect any change in handgrip strength before after) (Watts et al, 2000; Watts et al, 2008; Quaine and Vigouroux, 2004). To our knowledge, there is one study reporting that the activity of the flexor digitorum superficialis and brachioradialis muscles, measured by integrated electromyography, was high during hanging using four fingers of each hand and pull ups to maximum elbow flexion (Koukoubis, 1995). This result was explained by the increased recruitment of motor units during climbing-type activities such as these suggesting that the forearm musculature may be predisposed to developing fatigue. Our study adds more information in the above laboratory measures which provided quantification of muscle activity, but they do not replicate climbing per se. According to the results of the present study it was elucidated a climbing fatigue relation after a short climbing session expressed by hand grip strength performance and position sense deterioration.

The time course changes in hand grip strength performance in climbers found in the present study seem to be explained by the demands of climbing sports. Sport climbing is characterized by longer climb ascent times of 2 to 7 minutes, and route length up to 18 m. These features provide an athletic profile of those who participate in climbing activities pointing out specific physical abilities which have to be developed by the climber always with regard to how demanding is the climbing route. Studies have found that highly accomplished boulderers were also characterized by handgrip and finger strength better than that of nonclimbing controls and superior to that of previously investigated elite climbers (Macdonald and Callender, 2011). The authors concluded that boulderers showed better hand grip strength than elite climbers but both were superior to non-climbers.

The results of the present study are also in line with that study and seem to address partially the multi-variable problem regarding the training design required to prepare a novice rock climber. These data clearly indicate the need of sufficient recovery for novice climbers after a climbing session of even a short duration. Our conclusions are also in agreement with those of Morrison and Rainer (2007) who suggested that the emphasis of training in novice climbers should be on climbing a gradually increased volume and variety of climbing routes to improve fluency and competence of climbing techniques, as opposed to increasing intensity pointing out the need for a development of a long- term athletic training program for novice climbers.

The trainee must keep in mind that beginners face two different challenges while they try to learn the new discipline: to manage the climbing of a demanding and/or unknown route while puzzling out the most efficient technical moves required to minimize the intrinsic risk of falling or injury (Morrison and Rainer, 2007).

Previous studies also examined muscle strength in climbers as hand grip strength and finger strength, and these appear to be higher in elite climbers than recreational and non-climbers (Grant et al, 1996; Grant et al, 2001). However, Watts et al. (1993) reported that grip strength may not be a necessary attribute of elite climbers. Muscular endurance has been assessed in climbers using a bent arm hang, hand grip endurance test, or pull ups, and elite climbers can typically perform longer bent arm hang manoeuvres, hand grip tests, and more pull ups than their non-climbing counterparts (Grant et al, 2001).

Regarding the perceived fatigue that the participants felt right after the trial and during all the testing periods, the results of the present study showed significant deterioration of the rate of the 15point RPE scale. These findings clearly suggest that the novice climbers' subjective evaluation of exercise intensity is time-depended and also dependent on the nature of the climbing task (Hall et al, 2002). For the novice climbers of the present study, one bout of two minutes continuing climbing on an artificial wall was quite enough training stimulus to increase the rate of perceived fatigue and requires almost ten minutes of rest for partial recovery and more than two days for full recovery.

Also, in the present study wrist joint position sense was also evaluated in both groups. Observing the mean values of position sense changes given from the measurement with the goniometer we noticed that they trend downwards for the novice climbers and not for the non-climbers and this trend is dependent on the recovery period. The participants in the novice climbers group showed a slight deterioration of wrist position sense post exercise, after 1min and converged to the baseline levels after the 3rdmin of recovery. To our knowledge there are no previous studies examining upper limb position sense in climbers. Still, there are many studies examining how position sense of upper limbs is affected by eccentric exercise compared to lower limbs. It was concluded that position sense in elbow flexors was disturbed by eccentric exercise to a greater extent that those of the knee flexors (Paschalis et al, 2010). Previous to that study in order to explain difference in position sense between arms and legs the authors were based on the fact that leg muscles are more fatigued in a ''resting'' state compared with arms because of their more intensive use in everyday life activities. Though, fatigue was emerged as the leading factor to a slower shortening speed of the muscle fibre and slower rise of its tension rate. These results have been explained using findings of a previous research on fatigued human adductor pollicis muscle (De Ruiter et al, 1999). As a result of acute fatigue the muscle's capacity to sustain force during stretch was better preserved than the ability to generate isometric force while concentric force production showed the greatest decline. These findings were consistent with slower cross-bridge cycling in fatigued muscles. It seems that the results of our study are in consistent with those previous ones showing isometric force decline and position sense deterioration after a 2min climbing session that requires intermittent isometric contractions of the hand. In our design, the fatigued muscles were the muscles of the forearm and hand and it seems that this fatigue resulted also in less position sense when this was measured in resting state.

These results lead us to conclude that the performance of novice climbers is probably affected by hand grip strength performance and joint position sense of the hand, variables which can be addressed through training design giving attention to those physical abilities. In the same line with our results, another study concluded that most of the variability in climbing performance can be explained by trainable variables, and climbers do not necessarily need to possess specific anthropometric characteristics to be successful in sport rock climbing (Mermier et al, 2010; Goulimaris et al, 2014).

CONCLUSION

The performance of novice climbers is affected by hand grip strength performance and joint position sense of the hand, variables which can be addressed through training design giving attention to those physical abilities. Also, in order to be efficient in incorporating all these new features in their daily training, novice climbers need to have sufficient resting time at least 10 minutes between trials and possibly incorporate.

LIMITATIONS

Despite the fact that our findings will be important for trainers to plan specific climbing training programs for novice climbers, it is necessary to note that the lack of control of dietary and sleep habits, the increased academic commitments of the participants, as the subjects were college students who were attending the class of technical climbing for beginners, in Physical Education and Sports Sciences Department in Northern Greece, as well as the possibility of them being involved in other motor activities, could be the limitations of the present study.

AUTHORS NOTE

The authors have no conflict of interest to declare.

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