COMPARISON OF SELECTED ASPECTS OF STRENGTH AND CONDITIONING AMONG JUNIOR BOULDERERS AND SPEED AND LEAD CLIMBERS

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Abstract:

Background: Comprehensive preparation of climbers for participation in multi-event competitions requires knowledge of the motor characteristics and fitness profiles of successful athletes competing in their individual events. Such knowledge can be used to prepare training programs to prepare for multi-event climbing competitions. The study aimed to compare the fitness profiles of young athletes specializing in different climbing disciplines: lead climbing, speed climbing, and bouldering.

Methods: The study included 13 climbers participating in national and international speed climbing, bouldering, and lead climbing competitions. All athletes were members of the junior national team, aged 17.2±1.9 years. The measurements included: rope climbing power test of the upper limbs, upper limb power test on a campus board, the agonist-to-antagonist ratio of upper body strength, bent arm hang test, core strength test, simple and complex reaction time measurements, Margaria-Kalamen stair climb power test, vertical jump, pull-up shoulder endurance test.

Results: There were no significant differences between the groups. However, for effect sizes, large values of Cohen’s d were reported in the campus board power in which speed climbers reached the highest results and in the pull-up test with stops in which boulderers scored highest. Small-to-medium effect sizes were observed also in the rope climb test and simple reaction time measurements in which speed climbers scored higher than lead climbers and boulderers, and in prone plank in which speed climbers scored lowest.

Conclusions: Speed climbers generated higher power of the lower limbs and had shorter simple reaction times, while boulderers had greater strength in mixed dynamic-static conditions. However, in most strength and conditioning parameters, juniors specializing in different climbing disciplines did not differ significantly.

Introduction

Climbing has been gaining popularity, both as a recreational and competitive sport. The latter became an Olympic sport that entered the Olympic Games agenda in Tokyo 2020, postponed to 2021 due to the COVID-19 pandemic [1]. Competitive climbing involves three events: lead climbing, speed climbing, and bouldering. Each discipline has slightly different physiological requirements for the athletes [2]. In lead climbing, competitors are required to climb as high as possible on a route at least 15 m long, within a time limit of 6 minutes. Since the competitors do not know the route they have to climb with the only possibility of seeing it from the ground before the start of the competition, they have to solve the challenges posed by the arrangement of holds. At the same time, they have to clip the rope into carabiners along the way to protect themselves from the consequences of falling. To meet these challenges, athletes
must have a high level of endurance (particularly for high-intensity efforts) and isometric strength. However, lead climbers are forced to develop high power, speed and strength due to the trend of incorporating spectacular climbing techniques that have proven effective in bouldering, such as jumping between holds. Combined with anaerobic power and speed, these abilities are of critical importance in speed climbing, with its performance criterion of climbing a 10 or 15-metre wall as quickly as possible. Nowadays, because of the high speeds achieved by the best athletes (the current world record on a 15-metre wall is 5.10 seconds), these climbs resemble more running than climbing. As in athletic sprint running, an important factor determining success is how quickly the athlete reacts to the start signal. In essence, the idea of bouldering is to climb a short, barely a few meters long, routes called “problems”. To solve them, a competitor has a time limit of 4 or 5 min (depending on the round), during which he or she can make any number of attempts. The individual problems are varied, requiring a wide range of technical skills, from moving in vertical or even slightly sloping slabs to climbing in large overhangs and even horizontal roofs. The former requires static and dynamic balance skills, while climbing the latter requires whole body strength, power, and power endurance. Since in most competitions, at least one of the problems is of a jumping character, a constant element of bouldering training is improving the rate of force development [3]. All these elements make bouldering the most complex and versatile climbing competition [4].

With the uniqueness of each discipline, climbers usually specialise in one of them or at best two (one of which is lead climbing), usually lead and bouldering. Giving climbing the status of an Olympic sport has brought a new challenge in the form of a combined event. In Tokyo 2020 Summer Olympics, this format included all three climbing disciplines. At the next Olympics in Paris 2024, speed climbing will be a separate event, while lead climbing and bouldering will be combined.

Comprehensive preparation of a climber for participation in multi-event competitions requires knowledge of the motor characteristics and fitness profiles of successful athletes competing in their leading events. Such knowledge can be used to prepare training programs to prepare for multi-event climbing competitions. Therefore, the study aimed to compare the fitness profiles of young athletes specializing in different climbing competitions: lead climbing, speed climbing, and bouldering.

**Material and methods**

Thirteen female climbers participating in national and international speed (n=5), bouldering (n=3), and lead climbing (n=5) competitions volunteered to participate in this study. All athletes were members of the junior national team, aged 17.2±1.9 years. Each athlete had been a medallist in national or international championships and/or Polish or European Cups in one of the climbing disciplines: speed climbing, lead climbing, or bouldering. The climbing skills of the participants expressed by the maximum difficulty of rope climbs were 7b to 8b+ RP style (a style which means climbing routes known from previous unsuccessful attempts to climb in OS style or from doing them with a top rope belay) and 6c to 7c OS (a style that means climbing the route from the first try, without any knowledge, whether from watching another climber doing it or listening to hints about the placement of holds, the most convenient body position, etc.) and by the maximum difficulty of boulder problems 7a+ to 7c. The characteristics of the participants are presented in Table 1.

**Table 1. Physical characteristics of climbers (mean, SD, median)**

<table>
<thead>
<tr>
<th></th>
<th>Whole sample</th>
<th>Lead</th>
<th>Speed</th>
<th>Bouldering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience (yrs)</td>
<td>7.2</td>
<td>2.1</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>17.2</td>
<td>1.9</td>
<td>17.0</td>
<td>16.2</td>
</tr>
<tr>
<td>% FM</td>
<td>11.4</td>
<td>3.4</td>
<td>12.4</td>
<td>11.6</td>
</tr>
<tr>
<td>BMI</td>
<td>19.6</td>
<td>1.4</td>
<td>20.1</td>
<td>19.3</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>56.3</td>
<td>6.3</td>
<td>55.3</td>
<td>54.8</td>
</tr>
<tr>
<td>Height (m)</td>
<td>169.8</td>
<td>5.9</td>
<td>167.5</td>
<td>168.4</td>
</tr>
</tbody>
</table>

The tests were carried out during the national team training camp and spread over the five days of the camp. Each test was planned in such a way that the most physically demanding tests were carried out in the first days of the camp, after a warm-up but before the main training session. The measurements included:
Comparison of selected aspects of strength and conditioning...

Rope-climbing power test of the upper limbs according to the procedure described by Dhahbi et al. [5]: a starting point 70 cm from the ground and an end point above it at a distance of 5 m were marked on a 40 mm diameter gymnastic rope suspended from a solid anchor point. From a straddle sitting position with the rope between their legs and their hands placed on the rope below the starting point, the participants climbed the rope as fast as possible with their upper limbs alone. Time measurement was stopped when the athlete touched the endpoint or the rope above it. For safety reasons, participants were belayed with a rope, handled in such a way that it neither helped nor hindered the performance of the task. In order to verify the execution time, both trials were recorded with a digital camera with full HD resolution at a frame rate of 25 fps whereas time-lapse was analysed using the VirtualDub ver. 1.10.4 software. The following formula was used to determine power:

Power (W) = body mass (kg) x 9.81 rope distance (m) / ET (s)

Where ET = execution time

Climbing-specific anaerobic power of the upper limbs on a campus board: a campus is a popular climbing-specific training tool consisting of wooden rungs screwed to a panel fixed to a wall. There are no standardised parameters for this device which, in terms of angle of inclination, width, height, the distance between slats, size, etc., varies from one climbing gym to another. The campus on which the study was carried out had an overall length of 1945 mm and about 3 degrees of overhang. The distances between the rungs were 243 mm, with a depth of 35 mm. The test consisted of climbing from the first to the last (ninth) rung as quickly as possible by alternately placing the hands between the rungs without skipping any of them. The test started with the participant hanging on the first rung with both hands and straightened arms. On a signal, participants started climbing up to the last rung. The timer was stopped when the participant grasped the rung with the other hand. The formula to determine power was the same as in the rope-climbing power test.

Agonist-to-antagonist ratio of upper body strength [6]: the test used to evaluate arms flexor/extensor strength ratio, using push-up and pull-up exercises. In both trials, participants performed as many repetitions as possible within 15 seconds. The push-up trial was performed on parallel bars placed shoulder-width apart. From the starting position (front support), participants bent their arms until a right angle was reached between the arms and forearms and then returned to the starting position. The athlete started on a signal, which also started the timing. The test result was the number of repetitions completed in the allotted time. The second test was performed on a horizontal bar with a 2.5 cm diameter. From the starting position of fully extended arms, participants were asked to perform a maximum number of pull-ups in the allotted time. A 15-minute break separated both trials.

The bent arm hang test: this test was performed according to the International Rock Climbing Research Association test battery (IRCRA, 2015). The test was performed on a horizontal bar with a 2.5cm diameter. The participant’s task was to hold the bent arm hang position with the chin over the bar. The timer was stopped when the athlete’s chin dropped below the level of the bar.

Core strength: this test was performed according to the International Rock Climbing Research Association test battery (IRCRA, 2015). The participant’s task was to hold as long as possible in a prone plank position on the floor with the elbow angle of 90 degrees and forearms placed underneath the chest, with the pelvis raised off the floor and their body mass distributed on the forearms and toes. The timer was stopped when the contestant was unable to keep the hips in a straight line connecting the shoulders with the feet. The result was recorded in seconds with an accuracy of 1s.

Simple and complex reaction time: simple and complex reaction time was measured using MicroGate’s Witty-SEM device. The device consists of a rack on which 8 light semaphores are arranged in a specific configuration to display colours or characters and have sensors that respond to hand movement. Each semaphore is made up of 5x7 ultra-bright RGB LEDs creating a visible area of 42x60mm. The radio module specifications included a 433-434MHz multi-frequency transceiver radio with FST digital transmission; redundant code with information validation and auto-correction functions; radio frequency: 433.1125 MHz to 434.8125 MHz; radio transmission power: 10mW; signal transmission accuracy: ±0.4ms. In the first test, 7 semaphores displayed capital letters of the alphabet in blue to check the straight reaction time, while the remaining 8 displayed a blue rectangle. The participant’s task was to put his or her hand as quickly as possible to the semaphore with the rectangle. The semaphores displayed the content in a different configuration, but according to the same principle. The test result was the time needed for the participant to complete 19 repetitions in the changing configuration. In the second test (complex reaction time), 7 semaphores displayed different small alphabet letters or numbers in green and the 8th semaphore displayed a small letter ‘a’, also in green. As in the simple reaction test, the athlete’s task was to place his hand on a semaphore with a small letter ‘a’ during 19 repetitions in a changing configuration. The result of the test is the time at which the contestant completed the task.
Margaria-Kalamen stair climb power test. The test was performed on a staircase with a standard step height (175 mm) with a 6 m run-up distance. The athlete run up the stairs placing their feet on the 3rd, 6th, and 9th steps. After 3 trial runs at low speed, there was a 3 min break, and the first trial run in which the participants had to cover the distance between the 3rd and 9th step in the shortest possible time was started. The time of covering the distance was determined by time-lapse analysis of a recording made with a digital camera, recording in full HD resolution at 60 frames per second (to ensure the measurement accuracy of 0.01 sec). Competitors performed 3 trials with 3 minutes rest breaks. The result of the test was the lowest score of the 3 measurements.

Power (Watts) was calculated from the formula: Power = [(Body weight x 9.807) x Height]/ Time

Weight in kg; Height = vertical distance between step 3 and step 9 in meters; Time = seconds

Vertical jump: each participant performed three jumps from a half squat position with a sweep, trying to touch the measuring scale at the highest possible point. Before the series of jumps, the highest point the athlete was able to reach with a straight overhead limb while standing on the ground was measured. Jumps were separated by 30 seconds breaks. The result of the test was the difference between the highest point reached during the jump and the highest point reached while standing on the ground. All attempts were recorded with a digital camera, registering the image in full HD resolution at 25 frames per second, and analysed in a time-lapse mode in the VirtualDub ver. 1.10.4 software.

The pull-up shoulder endurance test (Test No. 8 from the IR克拉 2015 test battery): the participants performed pull-ups with stops on a 2.5 cm diameter horizontal bar. From the starting position of the straight-arm hang, with the arms shoulder-width apart, participants performed pull-ups in a rhythm of:

- flexing the arms to a 90-degree angle at the elbow joints,
- flexing the arms to a position of chin over the bar,
- lowering to a 90-degree position at the elbow joints and returning to the starting position, i.e. the straight-arm hang.

The tempo of each phase was dictated by a metronome tapping out a rhythm at 60 per minute. A cycle of pull-ups at a rate of 15 per minute was performed until the athlete was unable to continue. The result of the test was the number of completed pull-up cycles.

Statistical analysis

Data are expressed as mean±SD and median for all variables. Non-parametric Kruskal-Wallis tests were conducted for all measures to compare the differences across climbing groups. Following Zemkova’s [7] suggestion that “because in sports practice the results of small groups of elite athletes are often analyzed, effect size estimates that are not influenced by sample sizes should be used”, a series of Cohens’s d calculations were made. The Cohen’s d values of effect size were interpreted as follows: < 0.2 = trivial; 0.2 – 0.5 = small; 0.5 – 0.8 = medium; > 0.8 = large [8]. Data analysis was performed using Statistica 13.3 software (TIBCO Software, Inc.).

Results

The results (means, standard deviations, and medians) of all exercise tests for all participants and separately for athletes of different climbing disciplines are shown in Table 2. The comparison of boulderers, speed climbers, and lead climbers did not show statistically significant differences between the tests. Comparisons of individual variables (Kruskal-Wallis rank ANOVA) showed the following results: rope climbing relative power: H[2, 12] = .17, p = .917; campus board relative power: H[2, 13] = 2.9, p = .231; prone plank: H[2, 13] = .22, p = .897; bent arm hang: H[2, 12] = 3.72, p = .156; parallel bars push ups: H[2, 12] = .47, p = .792; pull-ups: H[2, 12] = 1.06, p = .588; pull-ups/pull ups: H[2, 12] = .36, p = .836; squat jump: H[2, 12] = 2.60, p = .273; pull-ups with stops: H[2, 12] = .44, p = .802; Margaria-Kalamen relative power: H[2, 12] = 4.28, p = .118; simple reaction: H[2, 13] = 1.04, p = .594; complex reaction: H[2, 12] = 2.83, p = .243. As previously noted, in view of the small size of individual groups of athletes, effect size measures were also estimated. Indeed, despite p-values suggesting no significance of differences, large effect sizes were reported in four trials: campus board, squat jump, and Margaria-Kalamen in which speed climbers scored higher than lead climbers and boulderers and pull-ups with stops, with boulderers scoring highest. Small-to-medium effect sizes were observed also in rope climb and simple reaction time tests in which speed climbers scored higher than lead climbers and boulderers (d=0.34-0.39), and in the prone plank test in which speed climbers scored lowest (d=0.30). For detailed data see Table 2.
Discussion

The study aimed to characterise selected features of psycho-motor fitness of junior sport climbers. Modern sport climbing comprises three disciplines, placing specific demands on the competitors specialising in them. This translates not only into the performance evaluation criteria of the athletes but also the physiological, motor, or technical requirements they have to meet to be effective in a competition. Introduced with the debut of sport climbing at the Tokyo 2020 Summer Olympics, the combined event has complicated the training process for climbers, who have been confronted with the need to develop new aspects of strength and conditioning that have so far been absent or only vaguely present in their training programs. Even if the combined event does not become a permanent fixture at the Olympic Games in its current form (in 2024, the combination will only include lead climbing and bouldering, while speed climbing will already be a separate competition), it is not out of the question that it appears as a separate climbing specialization, or that athletes will try their hand at different competitions. Kozina et al. [9] point out that “In any case, the success is still relevant in some types of rock climbing, and in Climbing Combined. That is why it is important to build a training process so that the universalisation of athletes required to perform in the Climbing Combined does not interfere with, and may have aided, the success of the athlete's core discipline”. In our research, we included junior climbers, i.e. athletes whose climbing training is still focused on developing a wide range of climbing skills, and whose specialisation in one of the events comes down to personal preferences in terms of participation in competitions and their results. These preferences, however, affect the nature of training, e.g. the time devoted to the development of motor skills and technical aspects linked to performance, the distribution of training emphasis, motivational commitment, etc. Taking this fact into account, we hypothesised that, depending on the preferred competition, the level of some psycho-motor variables of athletes we evaluated would differ. This would make it possible, on the one hand, to identify aspects necessary to develop more versatile athletes (participating in combined events), and on the other hand, to find individuals predisposed to specialising in specific disciplines. However, the results did not reveal statistically significant differences between the athletes, which may suggest that at the junior stage, differences in such aspects of psycho-motor fitness as lower and upper limb power, upper limb muscular endurance, trunk isometric strength, or reaction time are not factors contributing to success in their competition events. Such a conclusion, although legitimate in light of the results of statistical tests, may be premature in view of the fact that the p value is related to sample size. Our research involved a small group of junior climbers, which, although allowing us to include young climbers representing a high sports skill level, limited the sample size to a dozen or so. For this reason, we included effect sizes in our analyses, which in some cases had values indicating significant differences.
between the speed climbers, lead climbers, and boulderers. These were mainly lower limb power measured in the Margaria-Kalamen and the jump squat tests, and, to a lesser extent, rope climb and campus board tests. Lower limb power is an essential component of speed climbing performance, much more critical than in other climbing disciplines. The magnitude of the differences in upper limb power tests was smaller. However, the importance of this factor was also more egalitarian between the competitions. However, only in speed climbing, all repeated moves are performed at the highest possible speed under conditions of overcoming the gravitational force. Although not very high, the better prone plank time performance of boulderers and lead climbers may be related to the greater number of situations that require stabilization of the torso in awkward positions or keeping the body in near-horizontal or even horizontal positions (e.g., climbing overhangs). Similarly, the ability of athletes specialising in bouldering, who performed on average about 2 repetitions more in the pull-up test with static stops, is due to the specifics of the discipline and the preparation for it, in which the repertoire of motor skills needed by the athlete includes the ability to develop static strength. To date, studies comparing the characteristics of athletes in different climbing events have usually been limited to comparing lead and bouldering climbers [3], [10], [11], [12] or included more or less in-depth diagnoses of athletes of specific climbing disciplines [13], [14], [15]. This, to some extent - but only indirectly, made it possible to infer differences in their motor, anthropometric, or physiological profiles. These studies have mainly assessed aspects such as muscular endurance, isometric strength, rate of force development (RFD), and power output of the arms and forearms, usually revealing differences between athletes of both disciplines. In our study, we attempted to compare athletes of all three climbing disciplines at an early stage of specialisation, primarily using tests that can be widely used by coaches (except for apparatus for measuring reaction times). To sum up, the results of the fitness tests carried out among the junior team indicate a relatively equal level of athletes with different preferences in the leading climbing competition. However, the lack of significance of differences may not fully reflect the differences (or rather the lack of them) between the competitions due to the small sample size. Although a consequence of the sampling criteria, the latter is one of the limitations to be considered when interpreting the study results. Another limitation arises from the choice of tests, with not all necessarily having high accuracy. For example, according to Morin et al.[16], the reach jump height may not be a good indicator of maximal limb power. The results of some tests may have been influenced by the conditions of the tests, which were carried out during the team's training camp at a sports centre and had to be included in the training program. Nevertheless, we believe that the obtained results contribute to a better understanding of the characteristics of young climbers who represent the championship level in individual climbing disciplines. However, this does not change the fact that more research is needed, on a more significant number of climbers, and using other tests of general and special fitness, to understand more fully the motor characteristics of climbers who prefer particular climbing events.

Conclusions

1. Regardless of the event in which junior climbers specialize in, they do not differ significantly in terms of upper body strength and power, core strength, lower body strength, and reaction time (simple and complex).
2. However, an effect size analysis suggests that speed climbers generate higher lower limb power values and shorter simple reaction times, while boulderers have greater strength under mixed dynamic-static conditions.
3. As part of the preparation of athletes who are specialists in individual climbing disciplines for the climbing combined event, coaches should aim to develop the motor aspects which seem to distinguish the athletes most from specialists in other disciplines.

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