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D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
G. Funds collection

KINESTHETIC DIFFERENTIATION, KINEMATIC AND DYNAMIC PARAMETERS IN SPORTS CLIMBING COMPETITORS OF VARYING ABILITY LEVELS

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Keywords: strength abilities, kinesthetic differentiation ability, climbing.

Abstract:

Aim of the study: To determine the differences in dynamic and kinematic parameters and kinesthetic differentiation of movement between competitors practicing sports climbing at different levels of advancement.

Material and methods: The research group consisted of 30 men (X = 25.6 years). The respondents were divided according to their level of experience (amateur, intermediate, advanced) into three groups of ten people. Measurements were taken of: relative strength, relative power and climbing speed for the upper and lower limbs using the Myotest accelerometer (Switzerland). To assess kinesthetic differentiation of movement, a two-plate stabilographic scale test (double-plate posturograph) was used.

Results and conclusions: In climbers of greater ability we observed higher values for kinematic and dynamic parameters of the upper limbs. In the evaluation of the same parameters for the lower limbs we observed inverse relationships with climbing ability. Advanced climbers were characterized by lower relative power and relative strength of the lower limbs and also by a lower climbing speed. Compared with the amateurs, the advanced climbers who practice bouldering are characterized by a higher level of kinesthetic differentiation in posturographic tests for the shoulder girdle. The research results did not display any statistically significant differences in the level of abilities for kinesthetic differentiation of movement in measurements involving lower limbs.

The research confirmed that dynamic and kinematic parameters of the upper limbs, including relative strength, relative power and climb speed, are significant determinants of the ability level of a boulderer. In the assessment of the lower limbs, these parameters do not influence ability level in bouldering.

Thanks to the use of an innovative method of examining kinesthetic sensation, we noted that climbers of greater ability are more susceptible to the short-term effect of learning kinesthetic sensation when differentiating active strength (action) in the upper limbs. The double-plate posturograph is a tool which may be used for training and observing changes in terms of these coordination abilities.

In response to the inclusion of climbing in the program for the Olympics as a three event competition, the introduction of training measures influencing relative power and strength parameters of the lower limbs should be considered. Optimizing training based on the development of relative power and speed of the lower limbs in competitors who practice bouldering may improve performance in speed climbing which, in the context of the multi-event competition, is of great importance.
Introduction

Sports climbing is performed up, down or across natural rock formations and on artificial facilities (rock walls). Climbing can be divided into forms practiced professionally and recreationally. As Sonelski and Sadowski [1] observe, the most “sports like” variant of sports climbing is climbing during competitions. Due to their popularity, competitions in climbing on artificial climbing walls are undertaken not only by professional athletes but also by debuting amateurs.

Most often, competition in sports climbing takes place in challenges assessed by time, by degree of difficulty and in “bouldering”. Climbing “by time” (speed climbing) is characterized by barely a few seconds long period of effort with very short contact with the holds [2]. Official records in sports climbing assessed by time have been recorded since the parameters of a standard wall with two identical routes arranged on it were defined. Climbing assessed by degree of difficulty (lead climbing) has different characteristics. This kind of rock climbing takes place on artificial rock walls not in excess of 30 meters high, or on outdoor rock routes reaching up to 100 meters, with an average climbing speed of only 4m/min [3]. The final and very popular form of competition is known as bouldering, which involves climbing on natural or artificial low rock formations without the use of a safety rope. The average duration of climbing a boulder route does not exceed 1 minute [4].

In 2021 sports climbing as a multi-event competition will make its debut at the Summer Olympic Games in three jointly assessed disciplines: lead climbing, speed climbing and bouldering. Thus it is reasonable to expect that, over time, a new form of climber will emerge – the multi-event climber. For the time being, research results indicate that competitors who practice speed climbing and bouldering are characterized by a similar physique. Rokowski and Rgiewelski [5] associate this finding with the fact that, in both competitions, the magnitude of relative finger strength is significant. Elite lead climbers and those who practice bouldering on low rock formations also have similar characteristics in terms of maximum anaerobic power [6].

A climber’s ability level, excluding speed climbing, is determined in relation to the difficulty of the climbing routes they have mastered. The level of difficulty of a given route can be expressed according to various scales. In Poland, there are mainly three types of scales used: Kurtyka, Tatraska (an almost exact replica of the universal UIAA scale) and French. A further complement of scales of difficulty is used in bouldering. The distinction of additional scales in bouldering is related to the specific and somewhat different character of this type of climbing. Bouldering presents both a mental and physical challenge, with the difficulty rating of a route or “problem” dependent upon the level of tactical and technical skills as determined by strength, speed and agility, demanded of climbers [4,5,7].

Research on competitors in a lead climbing challenge showed that sports climbing requires high levels of coordination skills [8]. An important role is played by the differentiation of movement in time and space with simultaneous high levels of muscle tension. The ability to differentiate parameters of movement determines one’s accuracy and economy of spatial movement (the angle of joints), strength (working muscle tension) and time (differentiation of short periods of time) when performing motor activities [9].

The literature shows that rock climbing is a demanding and varied sport where, apart from coordination skills (informational), the role of energetic motor abilities is invaluable. In the case of bouldering; muscle strength and speed, and in the case of lead climbers endurance is also required [3-8,10,11]. It is worth noting that study results indicate that, in terms of climbers’ strength abilities, it is not absolute strength but relative strength which has a decisive influence on performance [12] and determines one’s effectiveness in climbing [10].

Training in sports climbing, apart from the obvious aspects of working on tactics and technique, also involves a constant search for effective strategies to influence the development of coordination, strength and speed abilities.

The present author was interested in an attempt to evaluate differences in levels of relative strength, relative power and climbing speed in measurements for the upper and lower limbs of climbers. There is a puzzling question, whether the expected intergroup differences in the tested parameters for the shoulder girdle (dynamic pulling up) can be seen in the evaluation of the same parameters for the lower limbs (dynamic pushing off)? The second intriguing aspect of the research is the role which kinesthetic differentiation of movement plays in sports climbers. Confirming the role in climbers of this coordination skill, described earlier, can assist in the optimization of training regimes.

Aim of the study

The aim of the study was to determine the differences in dynamic and kinematic parameters and of kinesthetic differentiation of movement in competitors who practice sports climbing at various levels of advancement.

Research questions

Answers to the following questions were sought in the research:
1. To what extent does the ability level of the climbers differ according to the level of kinematic and dy-
Kinesthetic differentiation, kinematic and dynamic indicators and specific selected strength and coordination abilities?

2. How can bodyweight load, both when standing and with front support, differentiate the active strength (action) of lower and upper limbs of competitors of differing ability levels in sports climbing?

3. To what extent are the groups differentiated in terms of rock climbing ability levels susceptible to the short-term effect of learning kinesthetic sensation when differentiating active strength (action) in the lower and upper limbs?

Materials and Methods

Materials

The study was conducted in 2015 in Nowy Targ during the “Boulder WARS III” competition at the “TOP” Climbing Center. The study group consisted of 30 men (\(\bar{x} = 25.6\) years, SD=2.2). The respondents were divided into three groups of ten people each. The criterion for assigning climbers to groups was their ability level according to the rule:

1. The advanced group consisted of respondents who climb at a level above 7C on the Fontainebleau scale.
2. The intermediate group consisted of men who climb at a level from 7A to 7C on the Fontainebleau scale.
3. The amateur group consisted of competitors who climb up to 7A level on the Fontainebleau scale.

Methods

Method for measuring kinematic and dynamic parameters

A Myotest (Switzerland) measuring device was used to evaluate kinematic and dynamic parameters. The apparatus includes a three-dimensional inertial accelerometer capable of measuring vertical acceleration at a sampling frequency of 500 Hz. The device was attached to the climbers using a large (8.5 cm wide) elastic strap with Velcro, as per the manufacturer’s instruction [13]. To determine relative power (W/kg) and relative strength (N/kg) of the lower limbs, as well as climbing speed (cm/s), the test measurement Countermovement Jump (CMJ) was used. The test is to perform, on a sound signal, three vertical jumps on the spot without the use of arm-swing. The measuring device and the test are shown in Figure 1.

Upper limb relative power (W/kg), relative strength (N/kg) and climbing speed(cm/s) were tested with the use of a Pull-Up Bar chin-up test. The starting position was hanging with straight arms from the bar with an overhand grip. On a sound signal, the athlete performed a pull-up with maximum speed. The test was performed twice and the results of two measurements were then averaged.

For measuring the relative power of the limbs (W/kg), relative strength of the limbs (N/kg), climbing speed (cm/s) and jump height in the measurement of lower

Table. 1. Characteristics of the respondents according to climbing ability level

<table>
<thead>
<tr>
<th>Ability Level</th>
<th>n</th>
<th>Age (years)</th>
<th>Body Height (cm)</th>
<th>Body mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(\bar{x})</td>
<td>SD</td>
<td>(\bar{x})</td>
</tr>
<tr>
<td>Advanced</td>
<td>10</td>
<td>24.2</td>
<td>3.3</td>
<td>177</td>
</tr>
<tr>
<td>Intermediate</td>
<td>10</td>
<td>26.9</td>
<td>2.1</td>
<td>175.2</td>
</tr>
<tr>
<td>Amateur</td>
<td>10</td>
<td>25.7</td>
<td>1.1</td>
<td>176</td>
</tr>
</tbody>
</table>

Source: own study
n - Number, \(\bar{x}\) - Mean, SD - Standard Deviation

Source: [13].

Figure 1. The Myotest device shown next to the Swiss Franc coin (Ad), attached to the Velcro strap (Am) and attached at hip level on the left side of the body to record acceleration during vertical jump (C)
limbs (cm) the Myotest device was again used. The measuring device was attached to the belt of the climber (Photo 1, 2).

Method for measuring motor coordination ability – kinesthetic differentiation of movement

Kinesthetic sensation test

For evaluating kinesthetic differentiation of movement a proprietary test was used which utilizes a double-plate stabilographic platform (double-plate posturograph). The posturograph enables independent measurement of changes, in the location of contact points, of the ground reaction forces (passive forces) and the action forces coming from the right and left foot.

Test procedure

In the initial assessment of postural stability the respondents maintained correct standing posture on the posturograph for 30 seconds, putting pressure equally on both lower limbs (the percentage of bodyweight distribution between the limbs should be 50/50). After completing the test, the climber repeated the test while observing on a screen the percentage distribution of pressure onto the base, during which time he was instructed to “learn” a load distribution according to the pattern 70/30. Finally, in a third test, the athletes were instructed to replicate the load distribution of 70/30, applying greater pressure to whichever side they preferred, this time without being able to watch the screen. This test also lasted 30 seconds. The closer the result of the final test was to the target pattern (distribution 70/30) the greater was considered the level of kinesthetic differentiation of movements. The test is presented in Photo 2.

In the next part of the study, the posturograph tests described above were repeated, this time with the participant in a position of front support (Photo 3), with the percentage distribution of the upper limb load first 50/50 and then twice with distribution 70/30 according to preference, first learning then replicating the load pattern. After each measurement, there was a break of about three minutes.

Statistical Analysis

For the number (n) of qualitative variables arranged on a nominal or ordinal scale, percentages (%), measures of position (median, Me) and variability (range) were calculated. The statistical analysis of quantitative variables employed measurements of position, such as the mean
Kinesthetic differentiation, kinematic and dynamic...

The variables were checked for normality of distribution with the Shapiro-Wilk test. In the case of normally distributed variables, one-way ANOVA was used to analyze observations with a single factor (independent variable). In this way, an attempt was made to assess the probability with which particular a factor can be said to account for the differences observed between the group means. The significance of differences was checked with Tukey’s test for post-hoc analysis.

Where the conditions for conducting a classical analysis of variance ANOVA were not met, the alternative Kruskal-Wallis test for one-way analysis of variance by ranks was used. As with the analysis of variance, statistically significant results from the Kruskal-Wallis test tell us only that at least one of the groups differs from another. To check which exact groups differ significantly from one another, the post-hoc Dunn’s Multiple Comparison test with a Bonferroni correction was performed.

The criterion for statistical significance of differences was established at the level $p < 0.05$. Statistical calculations were conducted using the Statistica v.13.0 (StatSoft) program.

Study results

Power, strength and climbing speed in upper limbs

- Pull-Up Bar test

The study results presented in Table 2 show that the advanced climbers displayed the greatest level of power (23.03 W/kg) in the Pull-Up Bar test. They obtained relative power values nearly two times higher than the amateurs ($\bar{x} = 12.6$ W/kg), with these differences proving to be statistically significant ($p < 0.05$). Similar results were observed in the measurement of relative strength (N/kg). One can observe its increase along with the climbers’ level of advancement. The difference in relative strength (N/kg) between the advanced climbers and the amateurs was 26%.

In the participants’ climbing speed measurements (cm/s) too, in the Pull-Up Bar test, it was found that the intermediate and advanced climbers obtained statistically better results than the amateurs (Table 2). The average climbing speed in the groups of higher ability climbers, intermediate (I) and advanced (Ad), was 184.8 cm/s, and was better by 36.4% than that achieved by the amateurs (Am), with 117.7 cm/s.

Surprisingly, no statistically significant differences were found in the measurements of kinematic and dynamic parameters in the Pull-Up Bar test between climbers with higher sports levels.

Power, strength and climbing speed in lower limbs

- Countermovement Jump (CMJ)

The results of measurements of relative strength and power and climbing speed in the Countermovement Jump test (CMJ) are shown in Table 3. The findings show the reverse relationship to that observed in the tests of the upper limbs; the relative power of the respondents’ lower limbs decreases as climbing ability increases. The advanced climbers obtained a lower average rating ($\bar{x} = 41.91$ W/kg) than the amateurs ($\bar{x} = 49.32$ W/kg). In all cases, the differences in favor of the less experienced climbers were not statistically significant.

In the assessment of the groups’ climbing speed, the same direction of differentiation was found, which is to say performance worsened as ability level increased. There were no significant statistical differences in the whole study with the exception of Am/Ad Velocity.

In the context of lower limb performance it is notable that, unexpectedly, the competitors of lower climbing ability obtained better results in the jump test. However, as with the results of both tests of body movement mechanics, the differences were not statistically significant,

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Amateur (Am)</th>
<th>Intermediate (I)</th>
<th>Advanced (Ad)</th>
<th>P-value for multiple comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (W/kg)</td>
<td>12.5</td>
<td>19.3</td>
<td>23.0</td>
<td>Am/I 0.00023*</td>
</tr>
<tr>
<td>Strength (N/kg)</td>
<td>12.3</td>
<td>15</td>
<td>16.7</td>
<td>I/Ad 0.00068 *</td>
</tr>
<tr>
<td>Velocity (cm/s)</td>
<td>117</td>
<td>161</td>
<td>184</td>
<td>Am/Ad 0.000022*</td>
</tr>
</tbody>
</table>

Table 2. Power, strength and climbing speed in upper limb tests of the climbing groups

- Mean, SD- Standard Deviation, *statistically significant difference at $p < 0.05$
Results of posturography examination for lower limbs

At the initial assessment of postural stability, the climbers’ task was to freely maintain a standing body posture on a double-plate platform. The data presented in Figure 2 illustrate that the advanced climbers were characterized by an initial posture closer to a pattern of even load distribution (50/50) on the base. The advanced group: 51.10/48.9 (difference 2.2%), interme-

Source: own study

Figure 2. Percentage load on left and right lower limbs in the posturographic test assuming a 50/50 standard. * - statistically significant differences for $p < 0.05$ Ad

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Amateur (Am)</th>
<th>Intermediate (I)</th>
<th>Advanced (Ad)</th>
<th>P-value for multiple comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (W/kg)</td>
<td>49.32 ± 6.2</td>
<td>46.18 ± 13</td>
<td>41.91 ± 7.9</td>
<td>0.443018 1.0000 0.304076</td>
</tr>
<tr>
<td>Strength? (N/kg)</td>
<td>24.53 ± 2</td>
<td>23.01 ± 1.6</td>
<td>23.4 ± 4</td>
<td>0.474567 0.157645 0.014675</td>
</tr>
<tr>
<td>Velocity? (cm/s)</td>
<td>254.7 ± 18.4</td>
<td>241.6 ± 23.2</td>
<td>220.9 ± 27.7</td>
<td>0.435028 0.137836 0.009018*</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>34.96 ± 5.1</td>
<td>35.12 ± 5.9</td>
<td>36.86 ± 5.5</td>
<td>0.645678 0.765789 0.356786</td>
</tr>
</tbody>
</table>

Source: own study

$x$ - Mean, SD - Standard Deviation, *statistically significant difference at $p<0.05$

Table 3. Power, strength and climbing speed in lower limb tests of the climbing groups
The data presented in Figure 3 show that, when a climber’s task was to maintain a load distribution on the base in a 70/30 pattern, the difference in the measurements of kinesthetic sensation was in favor of athletes of higher ability. The poorest results in this posturographic examination of lower limbs were obtained by the intermediate climbers (65.9/34.1). No statistically significant differences were found between any of the groups.

Results of posturography examination of upper limbs

In the next posturographic test, the climbers’ task was to maintain a front support position on the double-plate platform. The data presented in Figure 4 show that the required 50/50 pattern of pressure on the base with both upper limbs in front support position was most closely followed by the advanced group of climbers: 53.1/46.9 (difference 6.3%), with successively worse results achieved by the intermediate group: 55/45 (difference 10%) and the amateurs: 56.2/43.8 (difference 13.2%). The results align with those of the 50/50 pattern test of lower limbs in terms of the relative performance of the three groups. Noticeably, all groups were closer to the 50/50 pattern in the standing than in the front rest position.

In comparison with the results of load distribution of the lower limbs in a 70/30 pattern, with dominance on the preferred side (Fig. 3), the 70/30 load test in the front rest position yielded better kinesthetic sensation results in all groups (Fig. 5). It can even be said that the competitors who are most advanced in climbing achieved almost perfect accuracy in repeating the required load pattern.

The differences between the results of the amateur and intermediate groups of climbers were not statistically significant. Statistically significant differences between the effects of learning and repeating the memorized pattern of bodyweight distribution on the upper limbs were found between the group of advanced climbers and the other groups.

Discussion

Contemporary sports climbing is a discipline requiring great strength, speed and coordination abilities of those athletes who practice it professionally [5,14,15]. However, the climber’s motor abilities must also be sufficiently high to cope with the difficulty of the climbing route. As may be seen from the introduction of this paper, many studies have shown that motor coordination is a crucial factor which differentiates competitors practicing rock climbing, and which is based upon predispositions conditioning one’s effectiveness in moving quickly, whilst accurately overcoming external factors. One may believe that everything about rock climbing is already known. However, practical experiments have shown that this view may be considered premature. Moreover, sports climbing is already a multi-event discipline, to borrow the term used in athletics, bouldering, lead climbing and speed climbing being events in Olympic sports climbing. During bouldering competitions, competitors climb to the top of a wall which is around 4.0 m high. It is a form of sports climbing which includes a small number of difficult movements. Indeed, for many in the professional climbing community, the term “boulder” can even be considered a single-move crossing of a set rock problem.

In the present study, attention was drawn to the sample included 30 competitors practicing the sport professionally at varying levels of competition. The respondents were divided according to the number 8 Fontainebleau grading (8C) and according to the time spent practicing the sport professionally. It should be noted that competitors specializing in bouldering are given grades in this classification for climbing very short yet extremely difficult routes. The advanced and intermediate groups of climbers both consisted of competitors with a high rank on the Fontainebleau scale (7C), but differentiated in terms of their success in competition. The third group of competitors, who do not practice climbing professionally and were classified at a lower level (7A), were referred to as the amateur group. The rank given for climbing a route is at the same time an indication of high technical and tactical skill in the climbers.

As stated in the adopted study objectives, the observations undertaken were designed to help determine the probability with which the climbers’ level of sporting advancement (independent variable) can be said to be determined by the dependent variables, which included: motor potential in terms of a predisposition to develop strength and power in the upper and lower limbs, climbing speed as well as kinesthetic sensation, as an important component of the motor coordination abilities block (Polish: blok koordynacyjnych zdolności motorycznych (KZM)).

This study has few reference points in the country’s body of scientific research conducted among athletes practicing bouldering. Further, this study is notable because data were collected during laboratory experiments, using the latest measuring equipment. Numerous prior studies were conducted using motor tests with low accuracy and reliability, and as such were not included here for discussion. However, the main difficulty is that it is rare for research to consider the specificity of biological predispositions among championship level competitors specializing in one discipline in mountain climbing.

According to the declaration expressed in the introductory section of this paper, the study author’s focus of research was to determine the importance of strength...
and power levels of the upper and lower limbs of competitors who practice climbing professionally, with particular consideration of their relative values.

The results of the study confirmed already known dependencies between relative strength and the climbers’ ability level [16]. It was also noted that a climber’s body weight greatly affects performance in bouldering. Its role was strongly highlighted in the work of R. Rokowski and T. Regwelski [5], observing that “Relative strength, which is the ratio of absolute strength to body mass, is crucial in achieving best results in the discussed discipline. Hence, world-class champions are characterized by low bodyweight” [5].

In the present study, the bodyweight of the advanced climbers was lower than that of the amateurs by, on average, 1.47 kg. All the respondents were characterized by a relatively low body mass index. Their weight-height indicator (BMI) ranged between 21.6 and 22.5.

As previously highlighted, bouldering specialists are able to perform extremely precise movements with high speed, whilst also engaging high levels of muscle strength [6,17]. It was further noted that climbing speed in bouldering depends mainly upon the potential of relative strength of the competitors’ shoulder girdle [6,17,1]. This may be considered to arise from the specificity of the bouldering discipline. It seems that high strength levels in the muscles of the upper limbs and shoulder girdle are characteristic of champions of sports climbing. This view is confirmed by the results of this study. After all, in most cases, no statistically significant differences in the levels of kinematic and dynamic parameters of the lower limbs were found between the groups of climbers.

No studies have yet addressed the importance of relative power and climbing speed in terms of level of sporting advancement.

Taking into consideration the specificity of climbing training, it seems interesting to answer the question: what are the optimum levels of relative parameters in elite climbers? R. Rokowski and T. Regwelski [5], characterizing lead climbing competitions, stated “climbers of the highest level of advancement reach optimal shoulder strength which enables them to move in hard terrain. Further maximization of the above-mentioned factor does not assist in overcoming harder climbing routes”. It can be assumed that this observation applies also to climbing on lower rock formations.

In previous studies attention has been paid to the great importance of coordination abilities in achieving competitive success in sports climbing. This relationship is emphasized in the work of W. Sonelski and K. Sas-Novosiel斯基 [1]. The authors claimed that economical and effective performance in climbing is associated with maintaining the body’s balance. They also confirmed the assertion of other authors who highlight the great role of kinesthetic differentiation of movement in advanced climbers in the on-sight style [18]. One wonders whether the good results obtained by the advanced climbers in the stabilometric test for the shoulder girdle were the consequence of training focused on these skills, or are they a consequence of many hours spent training “on the wall”?

The importance of kinesthetic sensation to climbers was noted as early as the 1950s in the work of Gill [19]. Considering the specificity of lead climbing and bouldering competitions, the significance of kinesthetic differentiation in elite climbing should be beyond doubt. They share similar techniques of grips and steps and also movement with the basic techniques (e.g. natural, side clings, swivel techniques), special (stabilizing, dynamic, drop knee, etc.) or overhang climbing [5].

Taking into consideration the appearance of publications and manuals which stress the role of stabilization and coordination exercises in the training of sport climbers and alpinists [5,14,20], together with the results of the present study, training measures which improve coordination skills, including kinesthetic sensation, are to be recommended.

In the results of the present research, advanced competitors in bouldering were characterized by lower levels of relative power, relative strength and climbing speed, than the amateurs. Similar findings were presented from studies regarding strength carried out by Krawczyk [15].

Today, many climbers concentrate on development of the shoulder girdle and muscles of the lumbo-pelvic-hip complex, ignoring lower limb training. Conversely, there are authors who concluded that the work of the legs is particularly important. It seems reasonable to believe that it will become normal practice to include in training the development of lower limb power, bearing in mind the requirements of Olympic climbing. Recently, Lavernier et al [21] pointed out the need to focus on relative power training and not only on strength. In their work, with a methodology similar to that of the current study, the authors argue that, in the new Olympic form, the climber’s “dynamics” will play an important role. The muscles of the legs are larger and stronger, and can therefore effectively lighten the load on the muscles of the upper body [14,22]. Moreover, it was noted that the profile of a boulder climber is the most advantageous for the model of practicing the three events of the Olympic competition.

Conclusions

1. The research confirmed that dynamic and kinematic parameters of the upper limbs, including relative strength, relative power and climbing speed, are important determinants of a climber’s ability level in practicing bouldering. The assessment of the lower
limb performance revealed that these parameters do not affect ability level in bouldering.

2. Thanks to the use of an innovative method of examining kinesthetic sensation, we observed that climbers of greater ability are more susceptible to the short-term effect of learning kinesthetic sensation in the differentiation of active force (action) of the upper limbs. A double-plate posturograph can serve as a tool for training and observing changes within these coordination abilities.

3. Training optimization based on the formation of relative power and speed of the lower limbs in climbers practicing bouldering can improve performance in speed climbing which, in the context of multi-event competition, is of great importance.

4. As a result of climbing appearing in the program of the Olympics as a multi-event discipline, consisting of three events, the introduction of training designed to improve the parameters of lower limb relative power and strength should be considered.

References:


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