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Predictive Modeling of the Forecast in the Olympic Discipline "Climbing Combined" Depending on the Results in Various Types of Climbing among Elite Athletes

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ABSTRACT

Purpose: to build a regression model for predicting the possibility of qualified athletes representing various types of climbing getting into the finals of the Olympic discipline "Climbing all-around".

Material: The study involved 87 climbers (men) participating in the 2018 World Cup from 36 countries. To identify the degree of influence of the results in individual disciplines on the result in the all-around, a multiple regression analysis was carried out using the step-by-step method. The dependent variable was the result in the all-around. Independent variables were the rating results in the disciplines “Difficulty”, “Bouldering”, “Speed”. The equations of multiple regression are constructed.

Results: The model of the relationship of the rating in the disciplines "Difficulty", "Bouldering" and "Speed" with the rating in all-around in the form of the multiple regression equation is determined. The regression equation allows you to determine the chances of getting into the final all-around athletes - representatives of certain types of climbing. The specific values of the minimum position in the ranking in individual disciplines for getting into the final in the all-around representatives of different disciplines are revealed.

Conclusions: For a high result in all-around events, athletes specializing in the Difficulty and Bouldering disciplines are more likely. For athletes - representatives of the discipline "Speed", achieving a high result in all-around is a more difficult task.

Keywords: climbing, bouldering, speed climbing, lead climbing, Climbing Combined

1. Introduction

At present, sport climbing is included in the program of the Olympic Games. This is a natural stage of development and will contribute to the expansion of social opportunities for the development of this sport [1]. However, this also creates certain problems [2]. The problems are related to the inclusion in the program of the Olympic Games of 2020 of the only climbing discipline “Climbing Combined” (3,4). This discipline includes three types of climbing: “climbing for difficulty” (“Lead”), climbing for speed (“Speed”) and bouldering (“Bouldering”). Different types of climbing require different motor and functional training. Qualified athletes perform in one form of climbing, sometimes in two forms ("Lead" and "Bouldering"). However, there are no elite athletes who show world-class results in all three disciplines. This is due to the different motor structure of various types of climbing and with different mechanisms of energy supply [3, 4].

2. Literature Review

Speed competitions are held on a standard wall, 15 m high with an inclination angle of 5 °, on which two tracks are placed, each of which has a width of 3 m, climbing holds are wound on both tracks identically. The winner is determined by the best travel time [5, 6].

Lead competitions are held on new tracks unfamiliar to athletes. Athletes must reach the highest possible point on the course. In this case, “lower insurance” is used (the climber fastens the rope in carabiners in braces as the route passes) [6, 7, 8].

Bouldering is a track with a length of 6 to 14 interceptions (competition rules). When passing these trails, the result is affected by the number of attempts to reach the final climbing hold. Climbing occurs on high mats to ensure the safety of athletes [8, 9, 10].

Various types of competitive climbing activities require the inclusion of various energy supply mechanisms and various motor programs [6, 11, 12]. This creates a serious problem in the preparation of athletes for participation in the Olympic discipline "Climbing all-around." Athletes - representatives of individual disciplines have to master competitive disciplines differing in the nature of their motor activity and energy supply mechanisms [3, 13, 14, 15].

Climbing is characterized by specific injuries that require a long recovery [16, 17, 18]. This is especially true for injuries and diseases of fingers, hands, elbows, shoulders [19, 20, 21]. The transition to another type of competitive activity is also a problem from the point of view of increasing the risk of injuries in connection with the performance of non-specific types of activities by qualified athletes [10, 21, 22].

From the point of view of physical training, various types of climbing have different requirements for the development of strength, speed, endurance [5, 6, 22]. This complicates the training process and requires an in-depth analysis of the athlete’s capabilities to build the training process so that the athlete’s universalization does not harm his narrow specialization. At this stage, they are just beginning to get a scientific justification for the training program for climbers, which are common to all types of climbing [11, 13, 15]. This position also applies to the biomechanical structure of movements [10, 23, 24, 25]. The justification of training programs for elite athletes in certain types of climbing in the scientific literature is not enough. Concerning the preparation of climbers in the discipline "Climbing all-around", both scientific developments and the empirical experience of trainers are insufficient.

Training an elite athlete to participate in the Olympic discipline "Climbing Combined" requires a long time based on scientific and practical developments [4]. Long-term training begins with childhood at the stage of

determining specialization in climbing [5, 6]. To participate in the Olympic discipline "Climbing Combined" for athletes who are currently only beginning to prepare for speaking in this discipline, there is not enough time to reach the stage of realization of maximum opportunities in 2020. Therefore, to participate in the Olympic discipline "Climbing Combined" in the national teams at the present stage, athletes are selected who are currently the world leaders in their specialized disciplines [4].

In this regard, for national team coaches and elite athletes, the natural question arises: "What are the chances, for example, of a leading athlete in one of the climbing disciplines to show a decent result for getting into the final of the "Climbing all-around" discipline? "What is the minimum result an athlete should show in his non-core form for getting into the final of the "Climbing Combined"? It is necessary to identify which types of climbing are most preferable for successful performance in the Olympic discipline "All-around". It is also necessary to determine what level an athlete should have in non-specific climbing disciplines for him to reach the final in the "Climbing Combined" discipline.

Thus, at this stage, an accurate statistical determination of the degree of contribution of each type of climbing to success in all-round events is necessary. This is necessary for predicting the success in the Olympic discipline of individual athletes specializing in various types of climbing. These facts are necessary to complete the national teams, which implies the choice of athletes specializing in various types of climbing. To solve this problem, it is necessary to analyze the already existing competition data with the participation of the world's leading athletes.

Traditionally, regression analysis is used for modeling and forecasting, most often the multiple linear regression method. Based on the above provisions, a hypothesis was formulated: an analysis of the current results of performances by elite athletes at world-class competitions in the "Climbing all-around" discipline will create a predictive model for representatives of certain types of climbing regarding the possibilities of getting into the final of the Olympic discipline.

The purpose of the work is to develop a methodology for predicting the possibility of qualified athletes representing various types of climbing getting into the finals of the Olympic discipline "Climbing Combined".

3. Method

3.1. Participants

The study involved 87 climbers (men) who took part in the 2018 World Cup, representing 36 countries of the world.

3.2. Materials

During the study, the data presented in the competition protocols on difficulty, speed, bouldering and all-around were analyzed (places are occupied by the athlete, points are awarded to him to summarize the results) and the time taken for each of them to go through the highway. According to the rules of the competition, points in the discipline "Climbing all-around" are awarded by multiplying the rating (place) of the athlete in each type of climbing [4]. The smaller the figure obtained by multiplying the athlete's rating in individual disciplines, the higher his position in the "Climbing all-around" discipline.

3.3. Procedure

To determine the degree of influence of the results in the disciplines "Bouldering", "Difficulty" and "Speed" on

the all-around result in climbers at the 2018 World Championships (men), a multiple regression analysis was performed using the step-by-step method. The dependent variable was the result in the all-around. Independent variables were the rating results in the disciplines “Difficulty”, “Bouldering”, “Speed”. With the step-by-step method of multiple regression, the considered variables are alternately involved in the analysis. The multiple regression analysis algorithm provided by the SPSS program allows at every step to select the most significant variables according to the degree of influence on the sports result. As a result, only those multiple regression models that contain the most significant coefficients are selected. The remaining variables are placed by the program in the "Excluded Variables" table. In our study, we dwell on the analysis of the selected multiple regression models containing variables with significantly significant coefficients. The model obtained by analyzing the results of the 2018 World Cup can be extrapolated taking into account the error at the 2020 Olympic Games, as it is based on the results of the world's leading athletes.

3.4. Statistical analysis

Multiple regression analysis was applied step by step. The dependent variable was the results in the "Climbing all-around" discipline. The independent variables were the results of the analysis. The data presented in the competition protocols on difficulty, speed, bouldering and all-around were analyzed.

4. Results

The results of the regression analysis of the impact of the rating in individual disciplines in climbing on the Climbing Combined rating showed the possibility of using three models of multiple regression (Table 1). Judging by the values of the coefficients R, R^2 and the biased R^2, all three models are reliable and describe with a high degree of accuracy the effect of the results in the Lead, Bouldering and Speed sections on the result in climbing all-around athletes at the 2018 World Cup. (men) (Tab. 1, 2).

In the third model, the values of R, R^2 and shifted R^2 are close to 1, therefore, one can judge about the high degree of reliability of the regression model of the influence of the results in the disciplines “Lead”, “Bouldering” and “Speed” on the result in Climbing Combined for climbers at the 2018 World Cup (men).

The high degree of reliability of the regression model of the influence of the results in the Lead, Bouldering and Speed discipline on the Climbing Combined result in climbers at the 2018 World Cup (men) is also evidenced by the high significance of all three regression models (Table 2).

The step-by-step method of multiple regression analysis allows you to alternately involve the analyzed indicators in the model. In our study, at the first stage, that is, in the first model, one indicator was involved - the rating in the Bouldering discipline (Table 3). At the second step (model 2), in addition to the rating in the Bouldering discipline, the rating in the Speed discipline was involved in the analysis. In the third step, in the third model, as variables affecting the result (rating) in the all-around event, a rating in the Bouldering discipline, a rating in the Speed discipline, a rating in the Lead discipline (Table 3) were involved.

In addition to the variables reflecting the rating in various disciplines, each model contains a constant that reflects other factors affecting the outcome in the Climbing Combined, regardless of the analyzed rating indicators in individual climbing disciplines (Table 3). Other factors affecting the rating in the Climbing Combined are also reflected in the variance of the residues (Table 3).

The analysis of the reliability of the multiple regression coefficients in the calculated models shows that in the

first, second, and third models all the coefficients and the constant are reliable ($p < 0.05$) (Table 3). Judging by the values of the Beta value for the regression coefficients, in all models, the rating indicator in the Bouldering discipline is most influential on the result in the all-around.

Based on the results of the analysis of the coefficients in the obtained models of multiple regression, to describe the effect of the results in the disciplines “Bouldering”, “Lead” and “Speed” on the result in the all-around in climbers at the 2018 World Cup (men), we chose the third model, since it contains 3 indicators (the largest number of all obtained models) with reliable coefficients and the presence of all 3 coefficients with Beta values of more than 0.4 (Table 3). As a result, the following regression equation was obtained:

$y = -16.014 + 0.485x_1 + 0.515x_2 + 0.388x_3$

Where:

y - rating in Climbing Combined;

x_1 - rating in bouldering;

x_2 - rating in climbing speed;

x_3 - rating in climbing lead

Table 1

Summary table of regression models of the impact of the results in the disciplines of "Lead", "Bouldering", "Speed" on the result in Climbing Combined in climbers at the 2018 World Cup (men) (n = 87)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0,705a	0,497	0,491	18,02
2	0,863b	0,744	0,738	12,92
3	0,908c	0,825	0,819	10,76

Notes:

a. Predictors: (Constant), Boulder, place - rating in the discipline "Bouldering"

b. Predictors: (Constant), Boulder, place - rating in the discipline "Bouldering"; Speed, place - rating in the discipline “Speed”;

c. Predictors: (Constant), Boulder, place - rating in the discipline "Bouldering"; Speed, place - rating in the discipline "Speed";

Lead, place - rating in the discipline "Lead"

Dependent Variable: Climbing Combined, place - rating in the discipline "Climbing Combined"

Table 2

Summary table of regression models of the impact of results in the disciplines of “Lead”, “Bouldering”, “Speed” on the Climbing Combined result for climbers at the 2018 World Cup (men) (n = 87)

Model	ANOVA(d)					
		Sum of		Mean	F	Sig

		Squares	f	Square		.
1	Regression	27261,59		27261,59	83,938	,000a
	Residual	27606,41	5	324,781		
	Total	54868	6			
2	Regression	40842,59		20421,3	122,306	,000b
	Residual	14025,41	4	166,969		
	Total	54868	6			
3	Regression	45258,24		15086,08	130,299	,000c
	Residual	9609,764	3	115,78		
	Total	54868	6			

Notes:

a. Predictors: (Constant), Boulder, place - rating in the discipline "Bouldering"

b. Predictors: (Constant), Boulder, place - rating in the discipline Bouldering"; Speed, place - rating in the discipline "Speed";

c. Predictors: (Constant), Boulder, place - rating in the discipline "Bouldering"; Speed, place - rating in the discipline "Speed";

Lead, place - rating in the discipline "Lead";

d. Dependent Variable: Climbing Combined, place - rating in the discipline "Climbing Combined"

Accordingly, substituting the rating values of athletes in this equation, we can calculate what the minimum result for an athlete in different types of climbing to get into the final in Climbing Combined competitions is. For example, if an athlete consistently falls into the first ten best athletes in climbing lead and bouldering, we can calculate what place he needs to take in climbing speed to get to the all-around final. Having performed the necessary calculations, we obtain the value of 52.8. This means that it is enough for this athlete to be in the ranking for climbing to speed 52 places in order to get into the final "Climbing Combined". This corresponds to the result in climbing at speeds up to 9.29 s according to the 2018 World Cup (Fig. 1). When receiving negative values of the result in the equation for the discipline "Climbing Combined" it is necessary to regard this as a high probability of getting into the finals.

Table 3

Coefficients of multiple regression equations with step-by-step attraction of indicators to determine the effect of results in the disciplines "Lead", "Bouldering", "Speed" on the result in "Climbing Combined" among climbers at the 2018 World Cup (men) (n = 87)

Model	Coefficients (a)					
	Variable	Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	12,6	3,954	-	3,187	0,002
	Boulder, place	0,743	0,082	0,703	9,11	0,000
2	(Constant)	-10,093	3,807	-	-2,651	0,01
	Boulder, place	0,755	0,059	0,714	12,864	0,000
	Speed, place	0,51	0,057	0,497	8,963	0,000
3	(Constant)	-16,014	3,264	-	-4,906	0,000
	Boulder, place	0,485	0,064	0,459	7,588	0,000
	Speed, place	0,515	0,047	0,502	11,004	0,000
	Lead, place	0,388	0,061	0,388	6,42	0,000

Notes: a. Dependent Variable: Climbing Combined, place

Boulder, place - rating in the discipline "Bouldering"

Load, place - rating in the discipline "Lead";

Speed, place - rating in the discipline “Speed”;

Climbing Combined, place - rating in the discipline "Climbing Combined"

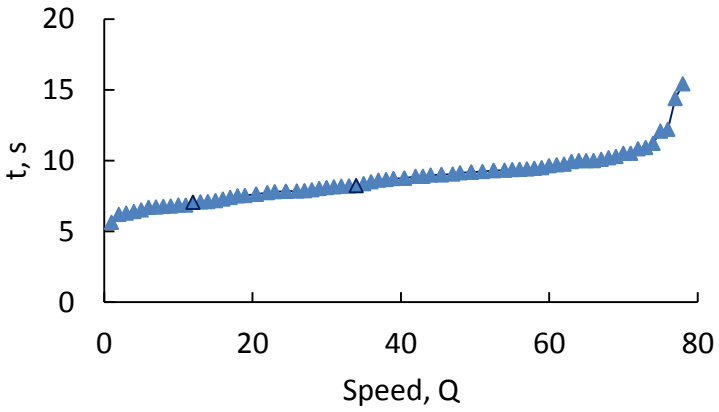

Fig. 1. The relationship of the rating in the climbing discipline “Speed” and the time to overcome the track (n = 80, “false starts” are excluded from the analyzed results):

Speed, place - rating in the discipline “Speed”;

t, s - time to overcome the reference path

If an athlete takes the ranking in lead climbing and bouldering in the ranking up to 20 places, then in the climbing speed to reach the final in the Climbing Combined, the calculated rating value is 35.8. That is, the athlete should not fall below 35 places in climbing speed. This corresponds to a result of up to 8.38 s according to the 2018 World Cup.

Similarly, for athletes specializing in speed climbing, one can determine the minimum rating values for lead climbing and bouldering. If an athlete is one of the ten best athletes in the world in speed climbing (the result is up to 6.9 c), then in order to get to the final in Climbing Combined, he needs to be at least 35 in climbing lead and in bouldering. If an athlete is one of the twenty best athletes in the world in speed climbing (the result is up to 7.6 s), then in order to get to the final in Climbing Combined, he needs to be at least 29 in difficulty climbing and in bouldering.

The relationship between the results in the Lead and Bouldering disciplines on the Climbing Combined result for climbers at the 2018 World Cup (men) is shown in Figure 2. From the figure it can be seen that up to the 60th place in the all-around ranking there is an almost linear relationship between the ratings in the disciplines "Difficulty" and "Bouldering".

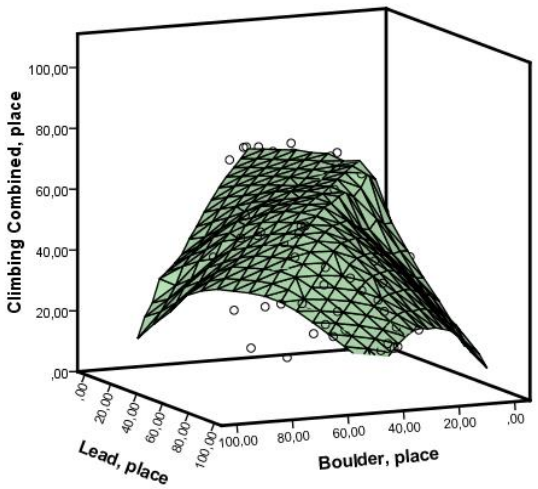

Fig. 2. The relationship of the rating in the climbing disciplines "Difficulty", "Bouldering" and the overall rating in all-around (n = 87):

Climbing Combined, place - rating in the discipline "Climbing Combined";

Lead, place - rating in the discipline "Lead";

Boulder, place - rating in the discipline "Bouldering"

In Figure 3 shows the relationship of the rating in the climbing disciplines "Lead", "Speed" and the overall rating in Climbing Combined. The figure shows that the result in the discipline "Speed" is weakly related to the rating in the discipline "All-around" and the rating in the discipline "Lead". However, the rating in the discipline "Lead" is associated with the rating in the discipline "Climbing Combined". This dependence is especially obvious up to 60th place in the ranking in the discipline "Climbing Combined".

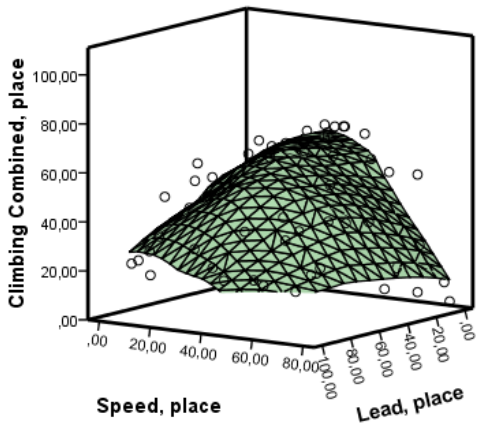

Fig. 3. The relationship of the rating in the climbing disciplines "Difficulty", "Speed" and the overall rating in all-around (n = 87):

Climbing Combined, place - rating in the discipline "Climbing Combined";

Lead, place - rating in the discipline "Lead";

Speed, place - rating in discipline “Speed”

The closest relationship between the results in various climbing disciplines can be traced in the disciplines " Lead" and "Bouldering". When building regression models of this relationship, the linearity regression model showed the greatest reliability (Fig. 4). The high accuracy of this model is confirmed by a value of R^2 equal to 0.63 (Fig. 4). This model shows that athletes who show good results in the Bouldering discipline also show good results in the Lead discipline. This is also confirmed by the results of world-class competitions.

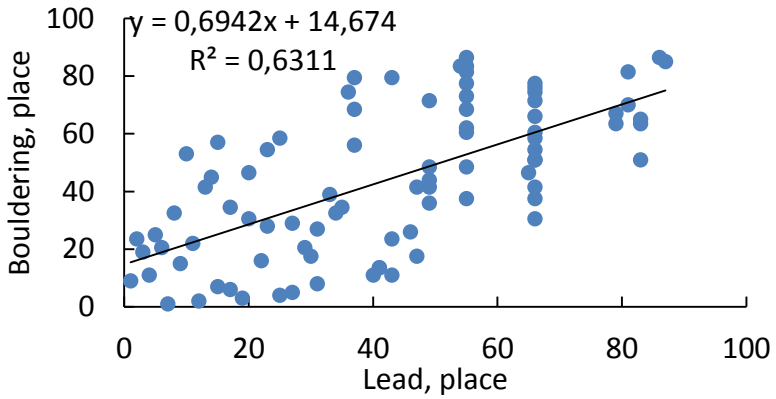

Fig. 4. The relationship of the rating in the discipline of climbing “Lead” and “Bouldering” at the occupied place at the 2018 World Cup (men) (n = 87)

Thus, the results of multiple regression analysis revealed the equation of the relationship of the rating in the disciplines “Difficulty”, “Bouldering” and “Speed” with the rating in “Climbing Combined”. Using this equation, specific values of the minimum position in the ranking in individual disciplines for reaching the final in the all-around

event for athletes specializing in various climbing disciplines were identified.

5. Discussion and Conclusion

The analysis of the results obtained from the point of view of comparing them with the literature data showed that as a result of the study three groups of results were obtained by the degree of their scientific novelty: results that confirm the data of other authors; results that complement and expand the results obtained in the works of other authors and results obtained for the first time. Consider each group of results regarding their scientific novelty.

Kozina et all [6] revealed that different types of climbing have different requirements for the development of components of speed-strength training: high-speed climbing is more conducive to the development of explosive strength and high-speed endurance, and climbing complexity is more conducive to the development of strength abilities and power stamina. In [5, 6], in order to identify hidden relationships between indicators of speed-strength readiness, morphofunctional characteristics and psychophysiological abilities of athletes, a factor analysis was carried out using the main components of indicators for comprehensive testing of athletes. It is shown that for climbers, the most pronounced factors are “Adaptive capabilities of the cardiovascular system, special endurance”, for climbers specializing in distances of difficulty - “Relative strength, stability of reaction rate” and “Strength of the hands and press”, for climbers specializing at speed ranges - “Girth sizes of the arms, mobility of the nervous system” and “Speed of reaction”. The complexity of the manifestation of speed-power qualities in relation to indicators of morphofunctional features and psychophysiological capabilities of mountain sports representatives is shown. From this point of view, the results obtained in our study confirm and expand the data of Kozina et all [6] on the opposite relationships between strength, speed and endurance. In our study, data were obtained on the absence of a relationship between the results in the disciplines of “Lead” and “Speed”, “Bouldering” and “Speed”. Our results confirm that these types of climbing require the development of various physical qualities.

However, the literature data do not provide specific equations to predict the minimum rating in non-specific disciplines for an athlete to qualify for the finals in the Olympic Climbing Combined. Therefore, it can be noted that we obtained these data for the first time and are new.

Thus, in our work, the results of studies of Ryepko [5], Kozina et all [6] (2014) on the presence of the opposite relationship between endurance and speed, manifested in various types of climbing, were confirmed and supplemented.

In our work, we also obtained new data: it is shown that the results in the disciplines “Bouldering” and “Lead” reliably influence the ranking in the Climbing Combined. This relationship is most pronounced up to 60th place in the all-around ranking; the equation of the relationship of the rating in the disciplines "Lead", "Bouldering" and "Speed" with a rating in the all-around is derived: $y = -16.014 + 0.485x_1 + 0.515x_2 + 0.388x_3$, where: y - rating in the Climbing Combined; x_1 - rating in bouldering; x_2 - rating in climbing speed; x_3 - rating in lead climbing. The specific values of the minimum position in the ranking in individual disciplines for athletes specializing in various climbing disciplines for getting into the final in the Climbing Combined 2020 were revealed.

The hypothesis that was posed in this study was fully confirmed. The obtained data on the greatest influence on the result in the Climbing Combined results in the disciplines "Lead" and "Bouldering" and the lack of influence on the result in the Climbing Combined results in the discipline "Speed" can be explained by the following points. The climbing technique in the disciplines “Lead” and “Bouldering” is somewhat similar to each other, but differs from the technique of passing the standard track in the discipline “Speed” [4, 7, 10]. In addition, as shown in [6], the physical

qualities that determine the result in the disciplines “Speed” and “Lead” are antagonists. The main physical quality for success in the discipline “Speed” is speed-power qualities with an emphasis on speed. In the discipline "Lead" the main physical quality is strength endurance. The development of speed-strength qualities is determined by the number of white muscle fibers of type b [11, 12, 26, 27]. The development of endurance, including power, is due to the predominant development of red muscle fibers and white muscle fibers of type *a* [12, 13]. In addition, the antagonism of these qualities is due to the physical laws of the relationship of speed and maximum time to complete work at a given intensity. The same applies to the strength and maximum time to complete the work. This dependence is hyperbolic [6]. Therefore, it is no coincidence that the relationship between the results in the discipline “Difficulty” and in the discipline “Speed” is not reliable: the mechanisms that provide these types of activities do not show a linear relationship with each other, and the hyperbolic relationship is non-linear inverse.

Effectiveness in the discipline "Bouldering" requires the development of explosive force [] 6, 10]. In the disciplines "Difficulty" and "Bouldering" a similar technique, especially this concerns the most difficult stages in the discipline "Difficulty".

These provisions explain why success in the "All-around" discipline is more likely for athletes specializing in the "Difficulty" and "Bouldering" disciplines: these disciplines are similar in motor structure. In order for an athlete to show high results in all-around due to the equal contribution of the results in all three disciplines, strength endurance, explosive strength and speed must be developed equally, but it becomes impossible to achieve maximum success in a separate type of climbing. This is a certain problem in the preparation of climbers for performances in the discipline "Climbing Combined".

The data we obtained made it possible to provide a mathematical justification of the performance characteristics of climbers in various disciplines. This is new data compared with the literature, because it allows us to predict the success of an athlete in the discipline "Climbing Combined", based on an analysis of his results in the disciplines "Speed", "Bouldering", "Lead". It should be noted that the organizers of international climbing competitions based on empirical experience came to similar conclusions, and at the Olympic Games 2024 in France it is supposed to separate the discipline "Speed" from the overall classification in Climbing Combined.

Thus, various types of competitive climbing activities require the inclusion of various energy supply mechanisms and various motor models. This complicates the training process, requires the coaches to deeply analyze the athlete’s abilities to choose the main specialization and the possibilities of increasing the effectiveness in other climbing disciplines.

In the future, further studies are planned physiological and biomechanical analysis of competitive activity in various types of climbing and the construction of in-depth training programs for climbers, taking into account the narrow specialization and the need for universalization of athletes.

Conclusions

1. The model of the relationship of the rating in the disciplines "Difficulty", "Bouldering" and "Speed" with the rating in the all-around event in the form of the multiple regression equation is determined: $y = -16.014 + 0.485x_1 + 0.515x_2 + 0.388x_3$, where: y is the rating in Climbing Combined; x1 - rating in bouldering; x2 - rating in climbing speed; x3 - rating in lead climbing. Using this equation, specific values of the minimum position in the ranking in individual disciplines for athletes specializing in various climbing disciplines for getting into the final in Climbing Combined were identified. When receiving negative *y* values, it should be considered that falling into the final athlete

in Climbing Combined has a high probability.

2. Athletes specializing in the Difficulty and Bouldering disciplines are more likely to achieve high results in the Climbing Combined. For athletes specializing in the discipline "Speed", achieving a high result is a difficult task, since the results in the discipline "Speed" are not related to the results in the disciplines "Lead" and "Bouldering" and do not significantly affect the result in the all-around.

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Conflict of interest

Authors state that there is no conflict of interest.

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