The relationship of leg explosive power with the performance efficiency of ski racers aged 18-20 years old in competitions at various distances

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Abstract

Objective of the study is to investigate the relationship between the explosive leg strength indices of 18-20 years old cross-country skiers with the performance efficiency at the main starts at different distances of cross-country ski races in the sports season 2023-2024.

Methods and structure of the study. Eleven cross-country skiers aged 18-20 years old with qualifications from KMS to MS took part in the research work. The study of explosive leg strength indicators included the performance on a strain gauge platform of jumping exercises from two legs with arm swing with maximum power from a static position at an angle of inclination in the knee joint of 120°. In the course of the study we recorded: the strength of the support reaction, the time of reaching the maximum force, which provided the calculation of the force gradient value (absolute and relative values) characterizing the level of explosive force of leg muscles. The obtained indicators were included in the program of correlation analysis with the results at the main starts of the sports season.

Results and conclusions. It has been established that the efficiency of performances at goal-oriented starts turned out to be significantly dependent on the degree of maximum strength and the time of its achievement, forming the "strength gradient", the level of which differentiates the final result in races with separate starts (individual sprint and individual races, relatively "short" distances) by absolute and with a common start (skiathlon and massstarts, relatively "long" distances) by relative value, depending on body weight.

Keywords: *cross-country skiing, athletes aged 18-20, explosive leg strength, athletic performance, ski racing distances, correlation relationship.*

Introduction. The results of the conducted studies [4, 5] showed that the effectiveness of competitive activity for both adults and young athletes significantly depends on the formation of the main components of physical fitness, among which the level of development of explosive leg strength is of great importance, the differentiated significance of the structural components of which is determined by the requirements of the specifics of training and competitive activities [6, 7].

One of the possible directions for improving the training process is the study of correlation relationships and the establishment of the significance of indicators reflecting the influence of explosive leg strength on the achievement of a high sports result, taking into account the specifics of muscle activity. In this regard, for scientifically based management of the training of young athletes, specialists need to have information not only about the level of development of the structural components of explosive leg strength, but also about the degree of relationship of the selected indicators with the sports result at various distances of cross-country skiing [6, 8].

Objective of the study was to evaluate the relationship between the explosive leg strength of ski racers aged 18-20 years and the effectiveness of per-

formance at the main starts at various ski racing distances of the 2023-2024 sports season.

Methods and structure of the study. The set goal was achieved through the use of the following research methods: pedagogical (collection, processing and analysis of competition activity documentation); ergometric methods (performing jumping exercises on the PD-2, VISTI strain gauge platform); mathematical and statistical methods [3].

To assess the level of development of explosive leg strength, cross-country skiers were asked to undergo testing on a strain gauge platform in accordance with the developed test procedures [1]. The test procedure consisted of performing jumping exercises from two legs (with arm swings) from a static position corresponding to the beginning of the push-off in an alternating two-step stroke (knee joint angle 120°), while recording and calculating the following indicators included in the nomenclature of the 2022 Olympian model characteristics [2]: maximum strength, time to reach maximum strength, "force gradient" (absolute and relative values).

During the 2023-2024 sports season. 11 athletes of the Russian junior national cross-country skiing team aged 18 to 20 years, with qualifications from CMS to MS, were observed. To achieve the stated goal and the tasks of the study, the magnitude (closeness of the relationship) and direction ("+/-") of the correlation coefficients were considered through the dynamics of the relationship "selected indicator" – "goal-setting significance of the competition".

That is why, in order to identify the relationship between the indicators of explosive leg strength and sports results, the dynamics of the correlation coefficients of maximum leg strength (support reaction force), time to reach maximum strength, strength gradient with the results of performance at various distances of individual sprint (qualifying races), individual races, skiathlon and mass starts were studied at the following stages of the 2023-2024 annual cycle: at the end of the snowless stage of the preparatory period, including the All-Russian Competitions (VS) and the Summer Championship of Russia (SCR, September), the middle and the end of the competitive period, including the II All-Russian Spartakiad of the strongest athletes of Russia (VUSSR, February), the Russian Championship for athletes aged 19-20 (PR19-20, mid-February), the Russian Championship aged 21-23 (PR21-23, end of February), the Russian Championship (CR, mid-March), the Final Russian Cup (RKF, April) and Russian Championship 19-20 years (PR19-20, mid-April). The dates of the goal-setting starts (February, March) are associated with reaching the peak level (February, March) at the main starts of the season (VUSSR, PR19-20, PR21-23, CR), as well as the LCR races (September) at the end of the snowless stage of the preparatory period and the RKF and PR19-20 years (April) at the end of the competitive period.

Results and conclusions. The following recorded and calculated indicators were used to conduct the correlation analysis: maximum leg strength (Fmax), time to reach maximum strength (tmax), absolute and relative values of the force gradient (Jabs. and Jrel., respectively) and sports results at the main starts of the season. The average group data of the studied indicators of explosive leg strength (at the end of the snowless stage of the preparatory period, CP) and average speed at various distances, taking into account the specifics of muscle activity by types of races and

Table 1. The level of explosive strength of the leg muscles in the checkpoint and average speed in 18-20 year old cross-country skiers at various distances of the main starts of the 2023-2024 season (average group data, n=11)

The indicator under study	Level achieved
EXPLOSIVE POWER OF THE LEGS	
Maximum leg strength (Fmax), kg	172,6±17,8
Time to reach maximum leg strength (tmax), s	0,209±0,002
Absolute value of the gradient of the leg force (Jabs), kg/s	826,6±90,7
Relative value of the gradient of leg strength (Jrel.), kg/s/kg	11,50±0,86
SPORTS PERFORMANCE (speed of overcoming the distance)	
Individual sprint (qualifying race), m/s	7,166±0,187
Individual race (races with separate start), m/s	6,646±0,162
Skiathlon (race with changing movement styles), m/s	6,267±0,186
Mass Start (races with a general start), m/s	5,982±0,105

the dynamics of the correlation coefficients are presented in Tables 1 and 2.

To achieve this goal, we will analyze the dynamics of the correlation coefficients for each of the selected indicators. The dynamics of the relationship between the maximum leg strength indicator (F_{max}), which is a characteristic of both the absolute strength itself and the strength component of the strength gradient, is characterized by a unidirectional change in the tightness (strength) of the relationship in the range from 0.297 to 0.586 in individual sprint, from 0.252 to 0.724 in individual races, from 0.467 to 0.565 in skiathlon and from 0.353 to 0.725 in mass start (see Table 2).

The peak level of correlation coefficients (Rtk), assessed by direction ("+/-" and strength of the relationship), is achieved with the "+" sign in sprint races at the All-Union Soviet Union competitions (Rtk=0.586, February) and the winter Russian Championship (Rtk=0.490, March), in individual races at the race in the Russian Championship (Rtk=0.724, April) and the Russian Championship for 19-20 years (Rtk=0.714, February), in skiathlon the highest level is set at the Russian Championship race (Rtk=0.565, March) and in mass start at the race in the Russian Championship (Rtk=0.725, April) and the Russian Championship for 21-23 years (Rtk=0.588, March) and the lowest in the 50 km race at the Russian Championship for 19-20 years (Rtk=0.353, April). In general, the positive direction of the relationship is maintained for peak values at the "medium-strong" level and the lowest values at the "moderate-weak" level throughout the entire period of the main starts.

The dynamics of the relationship between the indicator and the time to reach maximum leg strength (tmax), on the one hand, reflecting the speed of the push-off, and on the other hand, the level of the speed component of the strength gradient, is characterized by a unidirectional (by the "-" sign) change in the tightness of the relationship in the range from -0.177 to -0.743 in the individual sprint, from -0.304 to -0.642 in individual races, from -0.254 to -0.382 in the skiathlon and from -0.204 to -0.351 in the mass start (see Table 2).

In this case, the peak level of the correlation coefficients is achieved at the main starts of the sports season: in sprint races at the competitions of the win-

Table 2. The level of correlation coefficients of the indicators of explosive leg strength with the performance efficiency at various distances of the main starts in the 2023-2024 sports season

The type of competitive activity under study	The studied indicator of explosive leg strength			
	Fmax	tmax	Jabs.	Jotn.
INDIVIDUAL SPRINT				
1.97 KL, 09/16/2023 – LCR, Arkhangelsk region	0,343	-0,264	0,345	0,244
1.70 KL, 02/09/2024 – VUSSR, Tyumen	0,586*	-0,580*	0,620*	0,561*
1.71 KL, 02/21/2024 – PR19-20, K-Chepetsk	0,363	-0,233	0,430	0,343
1,39 KL, 02/28/2024 – PR21-23, Syktyvkar	0,380	-0,177	0,519	0,390
1.52 St., 03/16/2024 – Czech Republic, Arkhangelsk region.	0,490	-0,743*	0,555*	0,426
1.50 SV, 04/02/2024 – FKR, Kirovsk	0,297	-0,323	0,308	0,381
INDIVIDUAL RACE				
September 20, 09/15/2023 – LHR, Arkhangelsk region	0,252	-0,305	0,265	0,539
CLASS 20, 09/18/2023 – LHR, Arkhangelsk region.	0,516	-0,561*	0,518	0,373
10 SV, 12.02.2024 – VSSSR, Tyumen	0,637*	-0,420	0,639*	0,434
10 SV, 02/22/2024 – PR19-20, K-Chepetsk	0,714*	-0,642*	0,737*	0,609*
10 SV, 02/29/2024 – PR21-23, Syktyvkar	0,529	-0,321	0,667*	0,545*
CLASS 10, 03/19/2024 – Czech Republic, Arkhangelsk region.	0,556*	-0,318	0,564*	0,484
15 SV, 04/03/2024 – FKR, Kirovsk	0,724*	-0,304	0,646*	0,416
KL 15, 04/05/2024 – FKR, Kirovsk	0,488	-0,314	0,498	0,358
SKIATHLON (race with a change of course)				
20 02/17/2024 – VSSSR, Tyumen	0,467	-0,254	0,370	0,421
20 03/17/2024 – The Czech Republic, Arkhangelsk region.	0,565*	-0,382	0,462	0,463
MASS START (race with a shared start)				
20 KL, 02/25/2024 – PR19-20, K-Chepetsk	0,436	-0,244	0,295	0,362
20 KL, 03.03.2024 – PR21-23, Syktyvkar	0,588*	-0,280	0,385	0,475
10 SV, 04/07/2024 – FKR, Kirovsk	0,725*	-0,351	0,697*	0,656*
50 KL, 04/12/2024 – PR19-20, Monchegorsk	0,353	-0,204	0,446	0,406

** – correlation coefficients corresponding to the significance level of p<0.05.*

ter Russian Championship (Rtk=-0.743) and the All-Union Soviet Union (Rtk=-0.580), in individual races the highest level is at the PR19-20 race (Rtk=-0.642) and in the summer Russian Championship race (Rtk=-0.561, when moving in the classic style), in skiathlon the highest level is achieved in the Russian Championship race (Rtk=-0.382) and in the mass start in the FKR race (Rtk=-0.351) and PR21-23 (Rtk=-0.280) and the lowest is set in the 50 km race at PR19-20 (Rtk=-0.204, April).

In general, the dynamics presented in the table. 2 reflects the tendency of the highest correlation relationship of the indicator of the time to reach maximum strength with sprint races and individual races in the entire studied range from 10 to 20 km and a decrease in significance (tmax) in distance races depending on the duration of muscle activity.

The dynamics of the correlation coefficients of the indicator of the absolute value of the strength gradient (Jabs.) is characterized by a unidirectional change in the sign ("+") of the relationship in the range from 0.308 to 0.620 in individual sprint, from 0.265 to 0.737 in individual races, from 0.370 to 0.462 in skiathlon and from 0.295 to 0.697 in mass start (see Table 2). The peak level of the correlation coefficients is reached at the main starts: in sprint races at the All-Union Soviet Union competitions (Rtk=0.620) and the winter Russian Championship (Rtk=0.555, March), in individual races at the race for the PR19-20 years (Rtk=0.737, February), PR21-23 (Rtk=0.667, February) and the All-Union Soviet Union (Rtk=0.639, February), in skiathlon the highest level is set at the Russian Championship race (Rtk=0.462, March) and in the mass start at the Russian Federation of Cross-Country Skiing (Rtk=0.697, April) and the lowest in the race for the PR19-20 years (Rtk=0.295), reflecting a decrease in the significance of the strength gradient indicator (Jabs.) in relatively long races with a mass start (skiathlon and mass start in a 50 km race).

The dynamics of the correlation coefficients of the relative magnitude of the force gradient (Jrel.) is characterized by a unidirectional change in the sign ("+") of the relationship in the range from 0.244 to 0.561 in the individual sprint, from 0.358 to 0.609 in individual races, from 0.421 to 0.463 in the skiathlon and from 0.362 to 0.656 in the mass start (see Table 2).

The peak level of the correlation coefficients is reached at the main starts: in sprint races at the All-Union Soviet Union competitions (Rtk=0.561, early February) and the winter Russian Championship (Rtk=0.426, March), in individual races the highest level is reached at the race for the PR19-20 years (Rtk=0.609, February), PR21-23 (Rtk=0.545, February) and the winter Russian Championship (Rtk=0.484, March), in skiathlon the highest level is set at the Russian Championship race (Rtk=0.463, March) and in the mass start at the Russian Championship race (Rtk=0.656, April) and the lowest in the race for the PR19-20 years (Rtk=0.362, February), reflecting, on the one hand, the tendency to equalize the peak level of the correlation coefficients in the entire range of competitive activity (from sprint to marathon), and on the other hand, the absolute values of the correlation coefficients are inferior to the indicators that are directly dependent on body weight.

Conclusions. The results of the analysis made it possible to establish that a characteristic feature of the dynamics of the correlation relationships between the indicators of explosive leg strength and the results in races at the main starts is the differentiated significance of the ratio of maximum strength and push-off speed, which form a strength gradient that prevails in races with a separate start (individual sprint and individual races) in relation to races with a common start (skiathlon and mass starts), in which the final result is largely determined by the influence of endurance qualities associated with the development of body weight.

The results of the study allowed us to formulate the main patterns of manifestation of indicators of explosive leg strength depending on the specifics of the competitive activity of athletes aged 18-20:

- in individual sprint races, the effectiveness of competitive activity (average distance speed in the race) is determined by the balance of the development of the strength and speed components of the strength gradient with the dominant significance of absolute values in relation to relative ones, having a correlation relationship with the result at a level of at least "average" - "strong";

- in individual races, the success of the performance is determined, first of all, by the development of the strength component of the explosive leg strength (the maximum strength and strength gradient), reflecting the influence of the incompleteness of the process of formation of strength qualities that depend on body weight, which determines the high relationship with the absolute value of the strength gradient;

- in skiathlon, the success of the performance is determined, first of all, by the priority development of

the power component (maximum strength) in relation to the speed component (push-off time) of the force gradient, with an emerging tendency for the correlation coefficients of the relative value to prevail in relation to the absolute force gradient;

- in mass start (races with a mass start), the success of the performance is determined by the priority development of the power component (maximum strength) of the force gradient in relation to the speed, with a balanced significance (by the value of the correlation coefficients) of the absolute and relative values of the force gradient, which may be associated with the specifics of competitive activity, which imposes increased requirements both for maintaining mid-distance speed and finishing acceleration.

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References

1. Golovachev A.I., Kolyhmatov V.I. and Shirokova S.V. (2018). Sovremennye metodicheskie podkhody kontrolya fizicheskoy podgotovlennosti v lyzhnyh gonkah. Vestnik sportivnoy nauki, no. 5, pp. 11-17.
2. Golovachev A.I., Kolyhmatov V.I. and Shirokova S.V. (2019). Modelnye pokazateli fizicheskoy podgotovlennosti lyzhnic-gonshchic vysokoy kvalifikacii pri podgotovke k XXIV zimnim Olimpiyskim igram 2022 goda v Pekine (Kitaj). Chelovek. Sport. Medicina, no. 19(2), pp. 81-87.
3. Deryabin V.E. (2008). Kurs lekciy po mnogomernoy biometrii dlya antropologov. Moskva, p. 328.
4. Novikova N.B., Ivanova I.G., Kotelevskaya N.B. and Golovachev A.I. (2022), Sravnitelnyy analiz rezultativnosti silneyshih lyzhnikov-gonshhikov v yunosheskom i vzroslom vozraste, Teoriya i praktika fizicheskoy kultury, no. 3, pp. 97-99.
5. Carlsson, M., Carlsson, T., Hammarström, D., Malm, C. and Tonkonogi, M. (2014), Prediction of race performance of elite cross-country skiers by lean mass, International journal of sports physiology and performance, no. *9*(6), pp. 1040-1045.
6. Losnegard, T., and Hallén, J. (2014), Physiological differences between sprint-and distance-specialized cross-country skiers. International journal of sports physiology and performance, no. *9* (1), pp. 25-31.
7. Sandbakk, Ø. and Holmberg, H.C. (2014), A reappraisal of success factors for Olympic cross-country skiing, International journal of sports physiology and performance, no. *9* (1), pp. 117-121.
8. Sandbakk, Ø., Solli, G.S., Talsnes, R.K. and Holmberg, H.C. (2021), Preparing for the Nordic skiing events at the Beijing Olympics in 2022: evidence-based recommendations and unanswered questions. Journal of Science in Sport and Exercise, no. *3*(3), pp. 257-269.