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Optimizing the Ski Network Density in the Competition Areas for Ski Orienteering

Anna A. Khudik*, Alexander Yu. Bliznevskiy, Sergey V. Khudik, Valentina S. Bliznevskaya and Alexander A. Zlobin
Siberian Federal University
Krasnoyarsk, Russian Federation

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Abstract. The purpose of any competition is to identify the strongest athletes in a certain sport, and in a complex sport, i.e. sports orienteering, the winning factor is an optimal combination of physical endurance, technical skills and maximum self-realization of athletes. Today more than ever, the spectacularity and attractiveness of sports increases comprehensive involvement in sports. This points to the special responsibility of the competition organizers in the preparation of starts, which also applies to the ski orienteering disciplines. In comparison to cross-country skiing and biathlon, it is necessary to prepare not just a standard ski track and the start-finish arena, but a whole network of such tracks, combining trails of different grades. This study analyses the prepared terrains with a ski tracks network for competitions in the individual disciplines of ski orienteering in a given direction. The authors have determined the correlation between the density of the ski tracks networks and the final Russian ranking of the strongest Russian athletes. As a result, the optimal ski network density coefficients (SND) in the competition area were calculated for the category of men/women (SND 32.04 + 1.37), and for the category of male and female juniors under 21 years old (SND 32.15 + 1.87). The SND coefficient introduced in the article is the total length of tracks of all classes per 1 km^2 of the competition area rounded to the nearest hundredth. It is a relevant characteristic of the competition area, as the organizers may sometimes make either a simpler track network or over-fill it with tracks and turn it literally into a ski trails web. Both choices have a negative impact on the objectivity of the athletes' results.

Keywords: density of ski network, technical complexity, orienteering, gradation of ski tracks, optimization of competitive speed, spectacularity of competitions.

Research area: Social Structure, Social Institutions and Processes; Sport.

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* Corresponding author E-mail address: anich_ski-o@mail.ru

Оптимизация плотности лыжной сети в районах соревнований для проведения лыжных дисциплин спортивного ориентирования

А.А. Худик, А.Ю. Близневский, С.В. Худик, В.С. Близневская, А.А. Злобин
Сибирский федеральный университет
Российская Федерация, Красноярск

Аннотация. Цель любых соревнований – выявление сильнейших спортсменов в виде спорта, а в комплексном виде – спортивном ориентировании – это оптимальное сочетание физического и технического мастерства при максимальной самореализации спортсменов. Сегодня как никогда актуальна зрелищность и привлекательность видов спорта для повышения массовости занятий. Это указывает на особую ответственность организаторов при подготовке стартов, что относится и к лыжным дисциплинам спортивного ориентирования. Ведь в сравнении с лыжными гонками и биатлоном помимо арены старта-финиша нужно подготовить не просто стандартную лыжную трассу, а целую сеть таких трасс, сочетающую лыжни разной градации. В данном исследовании представлен анализ подготовленных местностей с лыжной сетью для соревновательных трасс по индивидуальным дисциплинам лыжного ориентирования в заданном направлении и определена корреляционная связь между плотностью лыжной сети на них с итоговым российским рангом сильнейших спортсменов России. В результате были установлены оптимальные коэффициенты плотности лыжной сети (ПЛС) в районе соревнований для категории мужчины/женщины – ПЛС 32,04 $\pm$ 1,37, для категории юниоры до 21 года/юниорки до 21 года – ПЛС 32,15 $\pm$ 1,87. Введенный в исследовании коэффициент ПЛС – это суммарная длина лыжней всех классов на 1 км^2 района соревнований с точностью до сотых долей. Он является актуальной характеристикой района проведения соревнований, так как организаторы могут сделать как более простую сеть лыжней, так и явно перенасытить ее и превратить буквально в «лыжную паутину». И то и другое негативно сказывается на объективности результатов спортсменов.

Ключевые слова: плотность лыжной сети, техническая сложность, спортивное ориентирование, градация лыжных трасс, оптимизация соревновательной скорости, зрелищность соревнований.

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Statement of the Problem

While Russian sportsmen have almost not taken part in international competitions in the last three years, the role of domestic sporting events has been increasing (Lubysheva, 2024). And here there is a tendency to strengthen the role of not only the sports included in the Olympic Games programmes, but also the so-called non-Olympic sports with international recognition, which enjoyed world and European championships and competitions before the isolation (Budtsyn et al., 2022; Grigoriev, 2023). Sport orienteering also falls into this category (Bliznevsky et al., 2022). At the current moment it is safe to say that it is a mass sport in Russia. It has 73 accredited regional federations in the country, with 206,743 participants according to the 1-FC reports of the Ministry of Sport of Russia for 2023. In the All-Russian register of sports there are 30 disciplines of this sport in three categories – cross-country (14 disciplines), skiing (12 disciplines) and cycling (6 disciplines). However, the most difficult to organise are the competitions in ski disciplines (Bliznevskaya, 2006; Khudik et al., 2023). In cross-country and cycling disciplines, a natural area of forest or even urban territory is used, the course is planned in the already existing terrain, and control points (CPs) are set at different convenient areas. But for ski orienteering disciplines it is necessary to prepare not just one ski track but a branched network of tracks (Bliznevsky, 2004), which increases their total length to 80–200 km in comparison with, for example, biathlon or cross-country skiing (Butin, 2000) where ski tracks are up to 10–20 km.

In addition, the specificity of competitions consists in ski racing on tracks of different gradation implying simultaneous complex thinking activity (Korsakov, Korsakova, 1993; Lapp, 1993; Matyugin, Chakaberia, 1993; Khudik et al., 2019). It is associated with independent selection of a movement direction in the ski network and then error-free going. The variants chosen by an athlete for movement may turn out to be losing which will not allow an athlete with a high level of specialised ski training to compete with the leaders. Therefore, the task of planning a way is the most important tactical decision of an orienteering skier in a competitive environment (Khudik et al., 2015). In contrast, the task of the organisers is, on the one hand, to complicate and diversify the technical component in the choice of movement options and, on the other hand, to create conditions for increasing the speed of athletes on the course. It is not always possible to maintain this balance, as a ski network too replete with tracks in the competition area naturally reduces the speed of athletes, while too weak on the contrary, simplifies the process of orienteering and reduces the role of technical skill of the orienteering skier. Due to these circumstances, the purpose of this study was to find the optimal degree of ski network density for competitions in ski orienteering disciplines and to obtain the most objective protocol of competition results.

Theoretical framework and methods

In order to determine the optimal degree of ski tracks density in the competition area, we took the competition areas of individual courses in a given direction of the championships, areas of different stages of the Cup and championships of Russia, as well as the All-Russian competitions of 2023–2024 competition season, to analyse the quality of networks and measure the length of the ski runs. In total, there are 8 sport orienteering disciplines in the All-Russian register of sports (Khudik et al., 2023).

Two age categories of athletes were chosen for the study: men/women and male/female juniors under 21. These age categories apply to athletes aged 18–25. The fall into the category of students who have the right to compete in student sport events at regional, All-Russian and international levels (Bolotin et al., 2009). In general, the tradition of ski orienteering in the student environment dates back to the late 1960s and has intensified since the opening of such sections in universities in the USSR and then Russia (Hudik et al., 2019). The magnification of this process came in late 2008, when the issue of holding All-Russian Universiades in summer and winter sports was being discussed at the federal level with the aim to better develop the student sports movement in the country. As a result, the Ministry of Sport and Tourism of Russia coupled with the Ministry of Education and Science of Russia issued Order No. 63/89 of 02 February 2010 to hold the First All-Russian Winter Universiade in 2010, including ski orienteering disciplines. Later on and up to the present day, this sport has constantly been present in the programme of the All-Russian Winter Universiades held in the country biennially (Bliznevskaya et al., 2019). So, in 2024 during the Universiade students from 27 universities of the Russian Federation took part in ski orienteering competitions.

At the next stage of the study, we carried out an analysis of the correlation between the results in each start of athletes of the two age categories and the results of the final ranking of the strongest athletes in 2023–2024. Based on the results obtained, we determined the optimal range of the technical density coefficient concerning the ski network of the competition area, which would allow athletes to maximally demonstrate the level of sportsmanship in ski orienteering competitions.

Results and Their Discussion

The requirements for the preparation of the competition area and data about winners' times for the investigated sports disciplines shown in Table 1 indicate a wide range of distances in the ski disciplines, from the shortest 2.5–4.5 km with an estimated winner's time of 15–30 min, to the longest 30–40 km with an estimated winners' time of 150–180 min, hence the requirements for the preparation of the competition area. According to the Unified calendar plan of sports events of the Russian Federation, every Russian championship or competition in sports orienteering (ski disciplines) includes from two to five sports disciplines in the annual programmes of each sporting event.

The competition rules of the sport (Rules of Orienteering, 2017) describe the density of the track network in the competition area for the ski orienteering disciplines, i.e. the total length of tracks of all classes per 1 square kilometre of the competition area. Thus, the network of tracks is divided into the following categories: dense – more than 20 km of tracks per 1 square kilometre of the terrain, medium density – from 10 to 20 km of tracks per 1 square kilometre of the terrain, weak density – less than 10 km of tracks per 1 square kilometre of the terrain.

The class of a ski track is a characteristic of a ski trail that depends on its width and preparation technology. The speed of movement and the choice of a certain ski run depend on the class. A standard track is a very fast skate skiing track of a ski or biathlon centre, as a rule prepared by a snowcat, with a width of more than 3 m; a sprint track is a fast skate skiing track made by a snowmobile, with a width of 1.5–3m; a fast track is a good track prepared by a snowmobile of the Buran type, with a width of no more than 1.5 m. Obviously it is

Table 1. Recommended area of the competition spots and course parameters of individual ski disciplines in orienteering, included in the All-Russian Register of Sports (data as of July 1, 2024)

	Title of sports discipline	Recommended terrain area for training (km^2)	Recommended maximum time for winners (min)	
			men/women	male/female athletes under 21 y.o.
1	Sprint ski race	3	15–30/15–30	15–30/15–30
2	Classic ski race	4	40–60/40–60	40–60/40–60
3	Long ski race	8	95–120/80–110	75–110/65–90
4	Multi-day ski race	8	65–90/65–80	60–75/60–75
5	Long ski race – common start	6	80–95/75–90	75–85/70–80
6	Ski race – combination	6	45–80/45–80	40–70/40–70
7	Classic ski race – com-mon start	4	40–60/40–60	40–60/40–60
8	Marathon ski race	12	150–180/120–140	–

not suitable for full skate skiing. There is one more class of track – slow. It is a rough, in some places not cleared from low vegetation, single snowmobile track, or a track made by passerby, with a width 08–1.0 metres, or a skier's track (Aleshin et al., 2009; Bliznevskaya, 2004).

There are no strict regulations for different types of tracks in the rules, as every terrain chosen for ski orienteering is unique and it is impossible to set absolutely precise standards on the terrain without disturbing the natural landscape. But typically the organisers manage to adhere to the following regulations: regular tracks account for 3–10 % of all the tracks, sprint tracks occupy 5–15 %, fast tracks – 50–80 %, slow tracks – 0.3–0.5 %. When the areas are prepared for future competitions this distribution is carried out as follows. Fast tracks are prepared and added to the existing competition arena (ski or biathlon stadium), as well as to already existing regular and sprint tracks, based on the conditions of the terrain. Short cross-country junctional ski tracks are laid between the sections of the regular and sprint tracks. When technically necessary, small sections of slow track may be laid during the planning of the orienteering course itself in order to create an alternative choice of movement options. As a result, the organisers can either make a simpler track network or clearly overfill it with tracks and turn it into a ski "web". Both solutions have a negative impact on the objectivity of the athletes' results. Due to this in the study we introduced the coefficient of ski network density in the competition area (SND), namely the total length of tracks of all classes per 1 square kilometre of the competition area rounded to the nearest hundredth of a fraction. Table 2 and Table 3 show the SND coefficients obtained with accurate measurements for the locations of the competitions in ski disciplines which we specially analysed.

It turned out that all prepared areas had a dense ski network according to the gradation of the category of ski network density specified in the rules of competitions of the sports orienteering. This is reasonable, as the competitions of the All-Russian level are intended for athletes of sports qualification not lower than masters of sports. But the degree of this denseness, i.e. the coefficient of SND, happened out to be different, even for separate disciplines of the same competition area. After all, only a part of the prepared large area of terrain is used for different distances.

A comparative analysis of the results of the final ranking for 2023–2024 season with the results of the protocols in the individual races listed in Table 2 allowed us to determine, by means of the coefficient of correlation, the closest correlation between ranking and nine courses out of the fourteen studied in the general male/female age category. There were found no significant differences between men and women. Thus, the obtained correlation coefficients in the range of $r = 0.911–0.786$ indicate a close positive relationship between the taken indicators and the places taken by the athletes. As a result, the optimal average coefficient of ski network density for the category of men/women was determined: SND 32.04 + 1.37.

Despite the insignificant differences in the SND coefficient concerning the remaining five competition races in Table 2, the protocols of their results still show an average connection with the result of the final ranking of the season (5 %, $p < 0.01$). For one competitive distance the SND exceeds the average value and equals 36.14, and for the remaining four races SND is below the calculated optimal value, ranging from 30.04 to 28.84.

Similar results were obtained for another age category of athletes – juniors (males and females up to 21 years old) (Table 3), where there were also found no noteworthy differences between males and females. Of the eleven competition distance protocols examined, eight showed a strong correlation with the final junior ranks for 2023–2024 season, with correlation coefficients in the range of $r = 0.925–0.796$. The remaining three had a medium correlation range of $r = 0.623–0.580$. The optimal coefficient of ski network density for the competitions of the sports season for the category of juniors under 21 years old is SND 32.15 + 1.87, i.e. practically comparable with the indicator for older ski orienteering athletes (SND 32.04 + 1.37).

Table 2. Correlation dependence of sports results of athletes at individual competitions of the All-Russian level on their final rank position in the age category men (n = 25), women (n = 25) during 2023–2024 sports season

	Title of sports discipline	Level of competition, place and time	Ski network density factor (SND)	Correlation coefficient, r (n = 50)
1	Sprint ski race	Championship of Russia, Perm Krai 13–19.12.2023	36.14	0.634
2	Long ski race	Championship of Russia, Perm Krai 13–19.12.2023	33.41	0.892
3	Multi-day ski race	Championship of Russia, Perm Krai 13–19.12.2023	32.68	0.911
4	Classic ski race	SkiO Cup of Russia, Chely-abinsk Oblast 11–15.01.2024	30.68	0.814
5	Sprint ski race	SkiO Cup of Russia, Chely-abinsk Oblast 11–15.01.2024	31.54	0.786
6	Marathon ski race	SkiO Cup of Russia, Chely-abinsk Oblast 11–15.01.2024	30.04	0.623
7	Ski race – combination	Championship of Russia, Chelyabinsk Oblast 16–19.01.2024	31.45	0.853
8	Sprint ski race	All-Russian Competition, Krasnoyarsk Krai 13–18.02.2024	31.98	0.788
9	Multi-day ski race	All-Russian Compe-tition, Krasnoyarsk Krai 13–18.02.2024	29.88	0.587
10	Classic ski race	All-Russian Compe-tition, Krasnoyarsk Krai 13–18.02.2024	33.02	0.825
11	Classic ski race	Championship of Russia, Irkutsk Ob-last 05–11.03.2024	32.08	0.792
12	Long ski race	Championship of Russia, Irkutsk Ob-last 05–11.03.2024	31.50	0.863
13	Classic ski race – common start	Championship of Russia, the Altai Re-public 14–18.03.2024	29.12	0.612
14	Marathon ski race	Championship of Russia, the Altai Re-public 14–18.03.2024	28.84	0.596

Table 3. Correlation dependence of athletes' sports results at individual competitions of the All-Russian level on their final rank position in the age category male/female under 21 years old (n = 25) during 2023–2024 sports season

	Title of sports discipline	Level of competition, place and time	Ski network density factor (SND)	Correlation coefficient, r (n = 50)
1	Sprint ski race	Championship of Russia, Perm Krai 13–19.12.2023	36.14	0.623
2	Long ski race	Championship of Russia, Perm Krai 13–19.12.2023	33.41	0.925
3	Multi-day ski race	Championship of Russia, Perm Krai 13–19.12.2023	32.68	0.886
4	Ski race – combination	Championship of Russia, Chelyabinsk Oblast 16–19.01.2024	31.45	0.874

Table 3 Continued

	Title of sports discipline	Level of competition, place and time	Ski network density factor (SND)	Correlation coefficient, r (n = 50)
5	Ski race – combination	Competition of Russia, Tomsk Oblast 08–12.02.2024	32.04	0.848
6	Sprint ski race	Competition of Rus-sia, the Bas-hkortostan Republic 20–26.02.2024	30.77	0.854
7	Long ski race	Competition of Rus-sia, the Bas-hkortostan Republic 20–26.02.2024	30.28	0.816
8	Classic ski race – com-mon start	Competition of Rus-sia, the Bas-hkortostan Republic 20–26.02.2024	28.54	0.580
9	Classic ski race	Championship of Russia, Irkutsk Ob-last 05–11.03.2024	32.08	0.796
10	Long ski race	Championship of Russia, Irkutsk Oblast 05–11.03.2024	31.50	0.862
11	Classic ski race – com-mon start	Championship of Russia, the Altai Republic 14–18.03.2024	29.12	0.618

Conclusion

The obtained results of the analysis of prepared terrains with a ski network for competition courses in individual disciplines of ski orienteering led to discovery of the correlation between the density of the ski network with the final Russian rank of the strongest Russian athletes. As a consequence, the optimal coefficients of ski network density in the competition area were calculated for the category of men/women – SND 32.04 + 1.37, and for the category of juniors, male and feamles under 21 years old, – SND 32.15 + 1.87. These findings will have a positive effect on the objectivity of the results of competitive performance in ski orienteering disciplines. The SND coefficient introduced in the study is the total length of tracks of all classes per 1 km^2 of the competition area rounded to the nearest hundredth. It is a relevant characteristic of the competition area, as the organisers may make either a simpler network of tracks or over-fill it with tracks and turn it literally into a ski "web". Both solutions have a negative impact on the objectivity of the athletes' results.

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