

SIMULATION OF REALIZATION OF SKI-RACERS' FUNCTIONAL POTENTIALS IN PASSING SKI TRAILS OF DIFFERENT COMPLEXITY

Khmelnyska J.K.

National University of Physical Education and Sport of Ukraine

Abstract. *Purpose:* to substantiate model characteristics of functional fitness components of elite ski-racers, depending on competitions' conditions. *Material:* We tested 20 sportsmen of combined team of Ukraine. *Results:* it was found that climbing hills of different length and steepness is accompanied by certain functional tension of organism and changes in cardio-respiratory system. It influences on effectiveness of further descent and moving on plain. It was also determined that correlation of aerobic and anaerobic efficiency changes according to trail relief. *Conclusions:* we worked out model characteristics of skiers' fitness most important parameters, usage of which can facilitate maintaining high special workability on all segments of competition distance. In particular it concerns climbing hills of different steepness.

Key words: skiers, racers, functional fitness, relief, ski trail, cardio-respiratory system.

Introduction

At modern stage of sportsmen's training simulation of sports functioning's different sides is widely used. The developed models are results of profound analysis and study of the researched processes. They become one of main means of control over complex systems of sportsman's training [8].

Further specification and approaching of model characteristics to competition requirements are presented in appropriate works. It is noted that building of sports training is impossible without simulation of some trainings, competitions and different training aspects [5].

It should be noted that simulation shall not be reduced to working out generalized models and prognostic model characteristics of sportsmen's potentials. The models shall reflect individual features of sport perfection in compliance with stage of sport training.

The presence of model characteristics permits to raise effectiveness of training process control and creates necessary pre-conditions for working out system of promising sportsmen's selection.

In skiing kinds of sports there are specific peculiarities of competition's simulation, which are connected with competition conditions, competition's rules and other factors. Leading specialists in skiing note that for systematic and purposeful functional preparation for the highest sports achievements of ski-racers it is necessary to consider metrical and time parameters of competition load on different parts of trail relief [1, 4, 15, and 17]. Orientation on competition functioning structure is one of the most important factors, when working out optimal model characteristics of ski-racers [2, 6, and 10].

In our previous works, on the base of systemizing of female-skiers' special fitness indicators, we determined model characteristics of functional fitness quantitative values for conditions of climbing hills of different complexity. We also conditioned values of aerobic and anaerobic energy supply mechanisms' contribution. Anaerobic mechanisms are one of key components of high results in ski racings, when climbing hills [8, 24].

Hypothesis: it is assumed that functional fitness of skiers is taken as the basis of sportsmen's workability in conditions of passing competition distance. That is why there is a need in increasing the significance of elite sportsmen's functional potentials' study. The purpose of such work is substantiation of clear requirements to training process's building, considering targeted models of competition functioning and sportsmen's functional fitness.

The purpose of the work: is to substantiate model characteristics of components of elite ski-racers' functional fitness, depending on conditions of competition functioning.

Material and methods

Participants: in the research 20 skiers of 21-34 years' age took part. Their qualification was: international masters of sports (n=6), masters of sports (n=14). They were 10 girls and 10 boys. All sportsmen were members of National ski-racing combined team of Ukraine.

Organization of the research: model studies were fulfilled on the base of university's laboratory. Testing of special endurance and realization of sportsmen's functional potentials in natural conditions of competition distance passing was carried out at sports training base "Tysovets" (Lvovskaya region). Functional potentials of sportsmen were assessed with complex testing. The testing included ergo metering, speed metering, analysis of respiratory system with the help of gas analyzer «MetaMax 3B» (Cortex, Germany) and pulse metering. Objective measurements of muscular work's characteristics in laboratory conditions were realized with the help of specialized ergo meter with increased area of track Wide Folding Track (POMA, Germany). Application of ergo meter permits to move on ski-rollers in free style.

In natural conditions we used system of GPS-navigation of HBR telemetric register «Polar RS800» («Polar», Finland), which permitted to register heart beats rate (HBR), speed of distance passing and height above sea level. On the base of these indicators we determined trails' relieves; received the data of sportsman's speed on different parts of distance, power of work and etc.

Statistical analysis: statistical processing of materials was fulfilled with the help of Statistica 10.0 and Excel 2003, 2007 programs. Confidence of differences between groups was found with Wilkinson's criterion.

Results of the research

The data, received in our research, permitted to find certain dependence of competition functioning's effectiveness indicators on current functional and working state of sportsmen, reflected in model characteristics.

Model characteristics of functional potentials' realization in conditions of simulation of competition distance's passing were worked out on the base of regression models' construction. As a reference value (see table 1) we offered mean values of functional indicators, required for maintaining speed 6.2 m.p.sec. (22.3 km.p.h.) at distance 6 km.

Table 1. Reference and mean-group values of respiratory and blood circulation functional indicators of sportsmen, -ski-racers

Indicator			Reference values	Mean values for group
f	Breathing frequency	l/min	56.94	57.2
VE	Lung ventilation	l/min	153.66	131.25
V _{O2}	Level of oxygen consumption	l/min	4.30	3.68
V _{CO2}	Level of carbon dioxide release	l/min	4.349	4.12
V _{O2} /m	Level of oxygen consumption per 1 kg of body mass	ml/min/kg	71.44	65.75
RQ	Respiratory coefficient	conv.un.	1.01	1.12
VE/V _{O2}	Ventilation equivalent by O ₂	conv.un.	38.91	34.37
VE/V _{CO2}	Ventilation equivalent by CO ₂	conv.un.	36.5	30.725
HR	Heart beats rate (HBR)	l/min	191	186
V _{O2} /HR	Oxygen pulse	ml	24.43	19.775

The values, given above, do not contain peak values, which are characteristic for climbing hills. They significantly depend on hill gradient (relation of hill length to differential of heights) and height above sea level, as well as on weather conditions. For working out the model of dynamic functional reactions we made a map of trail profile, on which competitions would take place.

The conducted by us researches showed that mean-distance speed at competition distance depended on characteristics of anaerobic metabolism threshold (TAM). Power of anaerobic metabolism threshold (TAM, W; W/kg⁻¹ of body mass, % form maximal oxygen consumption) is a characteristic of work, with which intensity of anaerobic energy supply reactions is insufficient for satisfying energy demand. As a result there happens active start of glycolytic processes, which are accompanied by lactate accumulation to more, than 4 mmole⁻¹. In sports practice TAM is used

for dozing of loads. That is why in practice relation of current oxygen consumption to its maximal value is often used (%). Besides, it is known that workability at TAM level is one of leading criteria of ski-racers' special endurance assessment [3, 7, 9].

Model characteristics were worked out on the base of concept about significance of workability at TAM level for prediction of high sport results in kinds of sports, which require high endurance. As reference we determined values of functional indicators at TAM level, required for maintaining speed 6.2 m.p.sec. (22.3 km.p.h.) at distance 6 km. Such characteristics were obtained on the base of regression equations (see fig. 1).

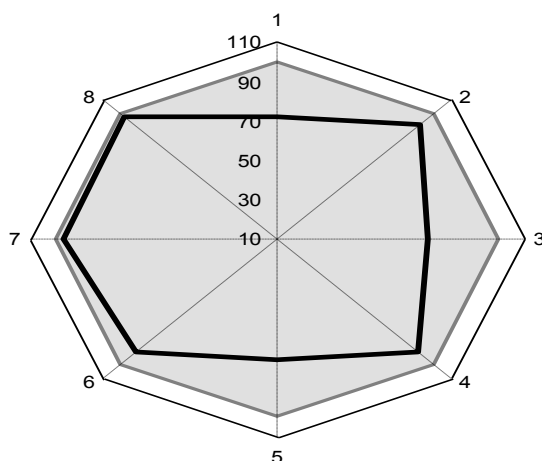


Fig.1. Functional characteristics of ski-racers at TAM level (% from reference value):

1 – TAM power; 2 – TAM power per 1 kg of body mass; 3 – lungs ventilation; 4 – lungs ventilation per 1 kg of body mass; 5 – oxygen consumption; 6 – intensity of oxygen consumption per 1 kg of body mass; 7 – heart beats rate (HBR); 8 – oxygen consumption in % from maximal oxygen consumption (MOC).

We also determined model characteristics of functional potentials' realization in conditions, simulating passing competition distance (see fig. 2).

We worked out and experimentally tested method of application of experimental data, received in laboratory conditions (ski treadmill) for prediction of speed, energy consumption and economy of skiing in real conditions of ski trail.

For assessment of functional potentials indicators we studied regression dependences between characteristics of skiers' special workability, their functional potentials and specificities of ski trails relief. We found that sportsmen's special workability is determined by indicators of maximal aerobic and anaerobic efficiency, economic character of external breathing in conditions of intensive muscular functioning ($R=0.71$; $p<0.05$).

The model, reflecting interconnection of functional fitness indicators and specificities of hills permitted to assess influence of hills steepness and speed of their climbing at distance as well as realization of sportsmen's organism's functional potentials. From many indicators of sports efficiency in ski racings and aerobic (anaerobic) energy supply contribution in work we chose the most significant: level of oxygen consumption, excess of carbon dioxide (ExCO₂) and heart beats rate (HBR).

We determined special workability of skiers, connected with aerobic efficiency. It reached the highest values at low values of speed of hills climbing and slope angle. It reached the least value at the highest slope angle and the least speed of its climbing (see figs. 3, 4).

The presented characteristics permit to conclude that for achievement high result in ski racings it would be insufficient to realize only aerobic potentials of sportsmen's organism. To achieve this target it is necessary to realize anaerobic potentials. Due to anaerobic energy supply mechanisms skiers climb hills of different complexity, which are more than 50% of all trail.

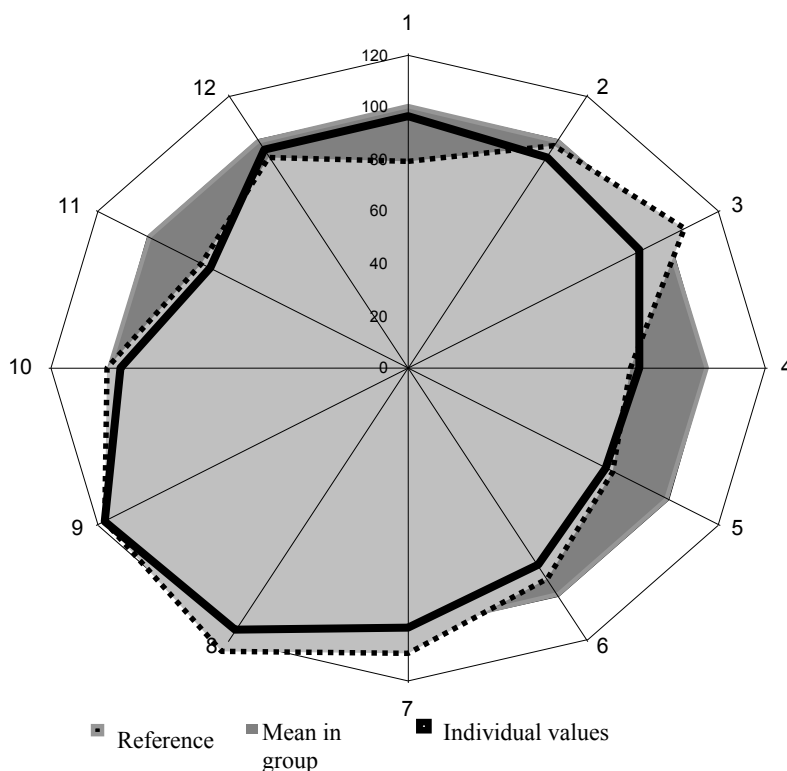


Fig. 2. Functional indicators of ski-racers in conditions, simulating passing competition distance (% from reference value):

1 – volume of inhale; 2 – breathing frequency; 3 – lungs ventilation; 4 – oxygen consumption; 5 – carbon dioxide release; 6 – carbon dioxide release per 1 kg of body mass; 7- intensity of oxygen consumption per 1 kg of body mass; 8 – respiratory coefficient; 9 – ventilation equivalent by oxygen; 10 – ventilation equivalent by carbon dioxide; 11 – heart beats rate; 12 – oxygen pulse.

$$V_{O_2} = 0,4658 + 0,3146 * x + 0,1731 * y - 0,0099 * x * x - 0,0081 * x * y - 0,0049 * y * y$$

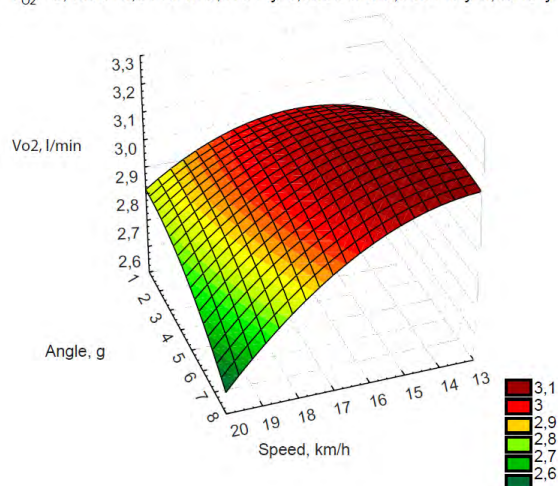


Fig.3. Model of interdependence of ski racers' aerobic efficiency and speed of hills' climbing, slope angle

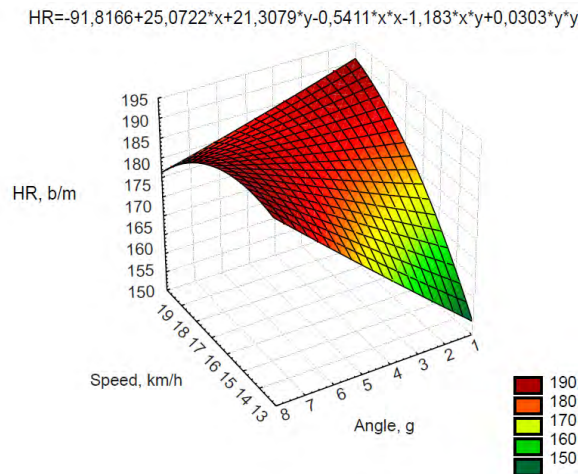


Fig.4. Model of ski racers' HBR interdependence and speed of hills' climbing, slope angle

To prove elite skiers' special workability's interconnection with economizing of respiratory functional system's reaction in conditions of special loads we worked out the model of interconnection of slope angle, speed of hill climbing with ExcCO₂ (excess of CO₂ release). This model reflects anaerobic metabolism processes in organism (see fig. 5). With characteristic of sportsmen's functional maintenance on hills of different steepness and length ExcCO₂ is an important indicator. This indicator is a result of metabolic acidosis (disorder of internal medium constancy at excessive acids' formation, when buffer reserves drop lower than norm). It reproduces rather exactly the changes of lactic acid and blood bi-carbonates content. It permitted to determine the sportsmen's optimal range of anaerobic lactate power realization.

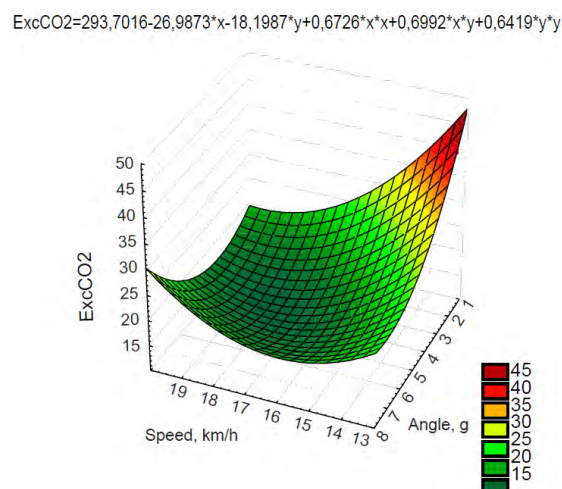


Fig. 5. Model of ExcCO₂ interconnection of ski-racers with hills' climbing speed and slope angle

Thus, we showed possibility of orientation with assessment of sportsman's organism's functional reserves on interconnection of several indicators. These indicators characterize organism's potentials. They permits to predict realization of skiers' special workability, assess effectiveness of their functional fitness some components. Comparison of individual data of single sportsman with model indicators permitted to determine correspondence of sportsmen's functional potentials to the pre-set level of fitness, depending on sportsman's specialization.

Discussion

Results of the researches proved confident interconnection of ski trails characteristics with level of sportsman's organism's functional potentials realization. The received data comply with the data of other authors [12, 13, 20, and 21] about need in determination of sportsmen's special workability optimal parameters. The conducted researches resulted in finding that work at competitions on rugged trails is of alternative character. The main source

of energy supply of sportsman's workability is organism's aerobic potentials. Their level reaches 92-95% from maximal values. Alongside with it passing of different by length and time hills and descents causes unequal intensification of anaerobic metabolism. We found that during climbing hills significant role in energy supply of skiers' organism belongs to anaerobic sources. Their volume reaches 80% from maximal values. Thus, correlation of metabolic reactions conditions higher orientation of adaptation changes of main functional systems, which ensure sportsmen's special workability. Functional potentials of sportsmen with high level of aerobic and anaerobic reserves realization are close to proper values of functional fitness.

Analysis of advanced specialists' publications witnesses [11, 14], that simulation of sportsmen's special fitness includes development of complex of the most important and ranked by significance level indicators – model characteristics. Such characteristics shall be received in the process of training by the beginning of competitions. Special attention is paid to simulation of sportsmen's functional potentials, required for hills climbing. This fact is a fundamental condition of skiers' special workability formation.

Analysis showed that one of the most problematic questions of increasing of sportsmen's functional potentials is development of respiratory function, compensating metabolic acidosis. Such approach is in agreement with the data of other authors [16, 18, and 19]. In the base of this function's assessment is the change of lungs ventilation's reaction, which characterizes organism's ability to release excessive CO₂. With it, among the found factors of aerobic power, the most significant are absolute and specific indicators of oxygen consumption ($r=0.96$; $p<0.05$) and maximal level of work intensity ($r=0.73$; $p<0.05$). Among the found factors of anaerobic power the highest specific weight belongs to total speed of CO₂ formation and release ($r=0.79$; $p<0.05$), respiratory coefficient ($r=0.98$; $p<0.05$) and excess of formed CO₂ ($r=0.96$; $p<0.05$). It is a factor, which proves impossibility to achieve high efficiency in ski racings without noticeable realization of anaerobic potential in process of competition distance passing.

Materials of our researches to certain extent supplement theoretical principles, devoted to the problem of ski-racers' functional fitness perfection at different segments of distance. For the first time we determined model characteristics of ski-racers' functional potentials at hills' climbing of different complexity, which can serve as the basis of assessment of sportsmen's special workability components at different segments of competition distance.

Conclusions

On the base of our researches we worked out model characteristics of most important parameters (functional and competition functioning) of elite sportsmen's fitness. Their application can facilitate maintenance of special workability at high level on all segments of competition distance. Especially it concerns the trails with hills of different steepness.

The found individual distinctions in special workability of ski racers permit to work out training programs with accent on "leading" indicators. Besides, they permit to build group and individual models of competition distances' passing, considering sportsmen's functional fitness. These results can be used for control over special fitness dynamic on stages of preparatory period and realization of individual approach to control over training process.

Acknowledgements

The work has been fulfilled in compliance with combined plan of SRW in sphere of physical culture and sports of Ukraine by topic 2.22. "Development of complex system for determination sportsmen's individual-typological properties on the base of genome's manifestation"; (state registration № 0106U010778; USC 796.072.

Conflict of interest

The author declares that there is no conflict of interests.

References

1. Batalov AG. Model'no-celevoj sposob postroeniia sportivnoj podgotovki vysokokvalificirovannykh sportsmenov v zimnikh ciklicheskikh vidakh sporta [Model-target method of construction of elite sportsmen's training in winter cyclic kinds of sports] *Teoriia i praktika fizicheskoi kul'tury*, 2001; 11:46–52. (in Russian)
2. Vlasenko SO, Kuz'menko LN. Osoblivosti prokhodzhennia riznikh za rel'iefom dilianok distancii v lizhnikh gonkakh [Peculiarities of passing of different by relief distances in ski racings] *Pedagogics, psychology, medical-biological problems of physical training and sports*, 2005; 1:18-22. (in Ukrainian)
3. Dunaev KS. *Tekhnologiia celevoj fizicheskoi podgotovki vysokokvalificirovannykh biatlonistov v godichnom cikle trenirovki. Dokt. Diss.* [Technology of targeted physical training of elite biathlon sportsmen in annual cycle of training. Doct. Diss.], Sankt Petersburg; 2007. (in Russian)

4. D'iachenko AIu. Praktichni aspekti optimizacii fiziologichnoi reaktivnosti v sportivnij pidgotovci kvalifikovanih sportsmeniv [Practical aspects of optimization of physiological reactivity in sports training of elite sportsmen]. *Teoriia i metodika fizichnogo vikhovannia i sportu*, 2010;3:22-27. (in Ukrainian)
5. Kotliar SN. Model'nye kharakteristiki funkcional'nykh vozmozhnostej lyzhnikov-gonshchikov vysokoj kvalifikacii uspesjno vystupaiushchikh v gonkakh klassicheskim i kon'kovym stiliami peredvizheniia [Model characteristics of functional potentials of elite ski racers, who successfully participate in racings with classic and skate styles] *Pedagogics, psychology, medical-biological problems of physical training and sports*, 2002;27:86-92. (in Russian)
6. Mikhajlovskij SP. Upravlenie trenirovochnym processom na osnove modelirovaniia vedushchikh pokazatelej podgotovki lyzhnikov-gonshchikov [Control of training process on the base of simulation of most important indicators of ski racers' training] *Uchenye zapiski universiteta imeni P.F. Lesgafita*, 2009;7(53):74-77. (in Russian)
7. Mulik VV. *Sistema mnogoletnego sportivnogo sovershenstvovaniia v uslozhnennykh usloviiakh sopriazheniia osnovnykh storon podgotovlennosti sportsmenov (na materiale lyzhnogo sporta). Kand. Diss.* [System of many years' sport perfection in complicated conditions of combination of main sides sportsmen's fitness (on materials of ski sports). Cand. Diss.], Kiev; 2002. (in Russian)
8. Nesterov VN, Khmelnytska JK. Obschaia kharakteristika funkcional'noj podgotovlennosti lyzhnikov-gonshchikov vysokoj kvalifikacii. [General characteristic of elite ski racers' functional fitness]. *XIII Mezhdunarodnyj nauchnyj kongress «Sovremennyj Olimpijskij sport i sport dlia vsekh»* [XIII International scientific congress "Modern Olympic sports and sports for all], Almaty: KazAST, 2009. p. 249-252. (in Russian)
9. Platonov VN. *Obschaia teoriia podgotovki sportsmenov v olimpijskom sporte* [General theory of sportsmen's training in Olympic sports]. Kiev: Olympic Literature; 2004. (in Russian)
10. Filippov MM, Davidenko DN. *Fiziologicheskie mekhanizmy razvitiia i kompensacii gipoksii v processe adaptacii k myshechnoj deiatel'nosti* [Physiological mechanisms of training and compensation of hypoxia in process of adaptation to muscular functioning], Sankt Petersburg-Kiev, BPA; 2010. (in Russian)
11. Khokhlov G.G. Testirovanie lyzhnikov-gonshchikov v estestvennykh usloviiakh [Testing of ski racers in natural conditions]. *Slobzhanskij naukovo-sportivnij visnik*. 2002;5:120-122. (in Russian)
12. Astorino TA. Effect of high-intensity interval training on cardiovascular function, VO₂max, and muscular force. *J Strength Cond Res*, 2012;26(1): 138-145.
13. Carlsson P, Ainegren M, Tinnsten M, Sundström D, Esping B, Koptioug A, & Bäckström M. *Cross-Country Ski. In The Engineering Approach to Winter Sportsm.* Springer: New York; 2016.
14. Dubrovinskiy SS, Batalov AG. modelling of technical and tactical actions in competitive sprint activity of elite cross-country skiers (the case of olympics 2010 and 2014). *Theory and practice of physical culture*, 2015;9:20-25.
15. Gabrys T, Szmatlan-Gabrys U, Plewa M. Dynamics of aerobic capacity in cross-country skiing in the view of training loads structure. In: Koskolou M. (ed.), *European College of Sport Science, Proceedings of the 7th annual congress of the European College of Sport Science, Athens, Greece, 24-28 July 2002.* (p.448). Athens: Pashalidis Medical Publisher; 2002.
16. Holmberg H. Integrative biomechanics and physiology in c-c skiing. *6 International Congress on Science and Skiing* (p. 7). Austria; 2013.
17. Klusiewicz A, Faff J, Starczewska-Czapowska J. Prediction of maximal oxygen uptake from submaximal and maximal exercise on a ski ergometer. *Biol. Sport.* 2011;28:31-35.
18. Losnegard, T. Seasonal variations in VO₂max, O₂-cost, O₂-deficit, and performance in elite cross-country skiers. *J Strength Cond Res*, 2013;27(7): 1780-1790.
19. Losnegard T, Hallén J. Physiological differences between sprint-and distance-specialized cross-country skiers. *Int. Journal Sports Physiol. Perform.* 2014; 9(1): 25-31.
20. Saltin B. Success in cc skiing: no longer just a question of a high aerobic capacity. *6 International Congress on Science and Skiing* (p. 14). Austria; 2013.
21. Vandbakk K. *Effects of upper body sprint interval training on endurance performance, aerobic capacity and work economy in female cross-country skiers during classical roller skiing.* Høgskolen i Nord-Trøndelag; 2015.

22. Žiška P, Olasz D, Krčmár M. The Impact of Endurance Training on Functional Parameters During the Preparation Phase among Cross-Country Skiers. *Acta Facultatis Educationis Physicae Universitatis Comenianae*, 2016;56(1):53-65.
23. Szmatlan-Gabrys Urszula, Cepulenas Algirdas, Gabrys Tomasz, Gromisz Wilhelm, Mroz Anna, Plewa Michal. Anaerobic Threshold Indices of Cross-Country Skiers During Preparatory Yearly Macrocycle Period. *Education. Physical Training. Sport*, 2004;3(53): 65-73.
24. Khmelnytska J.K., Filippov M.M. Characteristics of functional tension of qualified skiers when passing rises of different difficulty. *Pedagogics, psychology, medical-biological problems of physical training and sports*, 2015;10:70-76. doi:10.15561/18189172.2015.1011

<p style="text-align: center;">Information about the author:</p> <p>Khmelnytska J.K.; http://orcid.org/0000-0002-0231-1879; juliya_2008@bigmir.net; National University of Physical Education and Sport of Ukraine; Fizkultury str. 1, Kiev, 03680, Ukraine.</p>
<p>Cite this article as: Khmelnytska J.K. Simulation of realization of ski-racers' functional potentials in passing ski trails of different complexity. <i>Pedagogics, psychology, medical-biological problems of physical training and sports</i>, 2016;4:42–49. doi:10.15561/18189172.2016.0407</p>
<p>The electronic version of this article is the complete one and can be found online at: http://www.sportpedagogy.org.ua/html/arhive-e.html</p>
<p>This is an Open Access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited (http://creativecommons.org/licenses/by/4.0/deed.en).</p>
<p>Received: 22.07.2016 Accepted: 26.07.2016; Published: 30.08.2016</p>