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BIOMECHANICAL ANALYSIS OF MOTIONAL ACTIONS OF ATHLETES ENGAGED IN SHORT TRACK SPEED SKATING DURING THE TURNING PHASE

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Purpose: development of a model for theoretical analysis and assessment of optimal biomechanical characteristics in the turn phase of short track skating athletes using existing biomechanical ergogenic devices and information technologies in the training process.

Material and methods: theoretical analysis of scientific and methodological literature, analysis of web resources, pedagogical observation, video filming, biomechanical analysis of motor actions. The test group consisted of 10 young short trackers 9-12 years old and 5 short trackers aged 18-24 years, who practice short track speed at least three times a week (from 1 year old, for young athletes) and regular trainings five times a week (about 6-10 years, for adult athletes).

Results: the paper theoretically analyzes the characteristics of the technique of passing the turning phase of short track speed skating athletes by means of biomechanical analysis. By calculation, the theoretical dependences of the indicators of the passage of the turning phase were determined: speed, the angle of inclination of the athlete's body in the turn, the position of the general center of mass of the body and their relationship. The main mistakes of the technique of motor actions fulfillment of beginner athletes in the turning phase are highlighted.

Conclusions: these theoretical studies confirm the feasibility of using special devices to create conditions that simulate the real situation of an athlete passing a short track turn on one skate, and the coach can control the correct execution of movements by novice athletes from the point of view of biomechanics. The use of special elastic bands as ergogenic means for improving the motor actions of short track speed skating athletes is grounded. The ways of improving the biomechanical indicators, which the athlete is able to implement in practice, are indicated.

Keywords: biomechanics, short track, turn phase, technical training of athletes, analysis of motor actions.

Introduction

Short track is especially popular among the winter Olympic sports and is a promising discipline for Ukraine. Unfortunately, today foreign short track schools are in great competition for Ukrainian athletes. This prompts the search for means to increase the effectiveness of the formation of sports and technical skills of our athletes.

Evaluative studies of sports results in short track (Kashuba V. and Litvinenko Y. (2008) [5], Kugaevsky S. and Bleshunova K. (2010) [4]) indicate that an increase in the effectiveness of training athletes by increasing the volume and the intensity of the training load does not guarantee a dramatic improvement in competitive results. In addition, it is very difficult to work on their increase, especially in the technique of the short trackers' motor actions fulfillment, which are closely related to the quality and temperature conditions of the ice cover.

In addition, Ashanin V.S., Druz V.A. & et.al (2012) [1]; Fintelman, D.M. (2010) [14] indicate that it should be borne in mind the desire of athletes to improve their results by eliminating the discrepancy between technical readiness and lag in the development of physical condition, as well as due to impaired muscle coordination.

Thus, the question of searching for modern effective methodological measures to build a system of sports training of short trackers, increasing the technique of motor actions fulfillment, is a priority direction of the training process improvement. The research of the authors in this direction [8, 10] substantiates the possibility of using information technologies in organizing the training process among athletes.

Correctly organized training, both in short track speed skating and in other sports [9, 17-19], is the most effective pedagogical tool that helps to increase sports performance in general. Coaches, together with biomechanics specialists, develop and implement in the training process innovative approaches to improve the physical level of athletes' perfection. This, as the most accessible, includes the improvement of the physical condition of an athlete with the help of special simulators and general physical training.

Mastering and using the technical skills and techniques of short track speed skating is a very complex step-by-step algorithm. From a biomechanical point of view, this requires special approaches to control the process of formation of special motor skills; improvement of the coordinated geometry of the athlete's movements; creation for this, as it is given in the works of Gamaliy V.V. (2013) [3]; Ratova I.P., Popova G.I. & et.al (2007) [7], Laputina A.M. (2005) [2], models of biokinematic or biodynamic interaction of a human biolac, as an object of research and mathematical modeling, taking into account the mechanical factors of interactions between the human body and simulators.

The use of special biomechanical ergogenic means in sports is based not only on knowledge of the fundamental laws of physics, but also on the knowledge of modern technologies of sports training [6, 11]. Thus, improving the performance of athletes presupposes the simultaneous use of knowledge of the laws of physics, taking into account the biomechanical laws of the human motor system and the technical and tactical features of the competitive system and training activity.

Practice shows that simulators as mechanical devices with a controlled degree of freedom help in the process of training to simulate certain conditions for the future real activity of athletes. They allow directed transformation of the energy of the external environment in such a way that it acquires a useful form necessary for utilization by the body. From a biomechanical point of view, it is most expedient to single out such important fragments of the systems of mastering and improving sports movements as geometric, biokinematic, biodynamic, coordination, informational and some other structures [15].

Purpose of the study is to develop a model for theoretical analysis and assessment of the optimal biomechanical characteristics of the turn phase of short track athletes using existing biomechanical ergogenic means and information technologies in the training process.

Objectives of the study:

1. To analyze the special literature, existing biomechanical technologies and ergogenic means in the preparation of short track athletes.
2. Develop a model to determine the system of forces acting on the general center of mass of the athlete's body when entering a turn. To determine the influence of the main biomechanical factors of the successful fulfillment of motional actions on the basis of the position of the center of mass, the angle of inclination of the athlete's body, etc. during the turning phase.
3. Make recommendations on the reasonable use of biomechanical ergogenic means and information technologies to improve the quality of the training process of short trackers.

Material and Methods of research

Research methods: theoretical analysis of scientific and methodological literature, analysis of Internet resources, pedagogical observation, video filming, biomechanical analysis of motor characteristics. The test group consisted of 10 young short trackers 9-12 years old and 5 short trackers aged 18-24 years old, who go in for short track speed skating at the Youth Sports School of the Olympic Reserve in Kharkov and have at least three workouts per week (from 1 year old, for young athletes) and regular sessions five times a week (for 6-10 years for adult athletes).

Results of the research

Since the attention of short track coaches is focused on improving the running technique of athletes when cornering, the theoretical model of the technique of movements allows them to highlight the characteristics of the trajectory of the athlete's body depending on the speed of the general center of inertia of body mass, the angle of inclination of the *AB* line to the support line on the ice, the height of the center of mass and the radius of the entrance to the turn (Fig. 1)

Let us consider in more detail some of the features in the running technique of athletes in short track speed and strength, which an athlete needs to control when performing movements to maintain balance on the trajectory when turning.

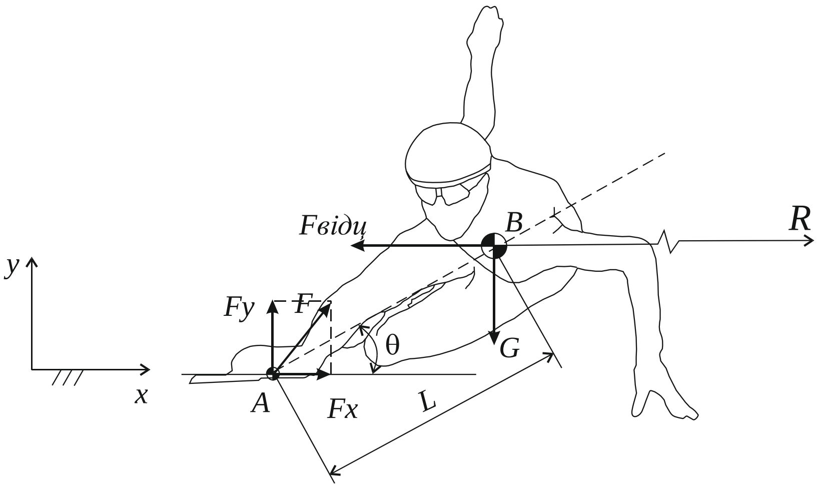

Fig. 1 The system of forces when cornering in a short track,

where – is the horizontal force $\vec{F}_x$ – the result of interaction between ice and skates; vertical force $\vec{F}_y$ – support reaction as a result of the ice providing resistance to the athlete; force of gravity $\vec{G} = m\vec{g}$; centrifugal force $\vec{F}_{відц}$ (the inertial force arising from a change in speed or direction of movement tries to displace the athlete in the direction opposite to the center of the turn when cornering); A - point of resistance; B - general center of mass of body mass (GCBM)

In short track skating, all attention is focused on the turns, during which the athlete needs to balance the centrifugal force with the gravity of his body. The combined action of centrifugal forces and body weight significantly increases the load on the muscles of the lower extremities. Entering a turn, the athlete tries to sit down. At the exit from the turn, centrifugal force acts, which the athlete must balance. Athletes on short track of low qualifications stand up, which reduces the speed of movement, and more qualified athletes change the angle of the torso to the ice to 25-30°. In doing so, the athlete extends his right arm and bends over a corner to counter centrifugal force. To maintain balance, the left hand touches the ice, and the athlete enters the turn on one leg. These motor actions allow to reduce the effect of the buoyancy force, and the time worked out between the fourth and sixth chips leads to the addition of forces (centrifugal and gravity) and contributes to further gaining speed.

Coaches always devote a lot of time to practicing the correct rotational motor actions of athletes, improving the technique of cornering. For a positive use of centrifugal force and entry into a turn at high speed, it is necessary to make the rolling time on one skate as long as possible in this section. This affects the overall speed of passing the distance due to the longer application of force in the support during repulsion.

Consider the physical aspect of this problem with the construction of special equations for this. Figure 1 shows the position of the athlete's body on the short track in a turn on one leg and shows the forces acting on the athlete's GCBM while moving in the turn.

Vector sum of two components $\vec{F}_x$ and $\vec{F}_y$– it is a total force $\vec{F}$, arising from the contact of the skate and ice. The vertical component of the contact force balances the force of gravity $\vec{G}$, and the horizontal component of the contact force pushes the person towards the center of the circle and opposes the centrifugal force depending on the mass m and speed $\vec{V}$ athlete's movement.

As a first approximation, let us consider the equilibrium equation for the center of mass of an athlete in a static state. Let's make some assumptions:

1) in the vertical direction, the general center of mass of the body has no acceleration;

2) equilibrium equation is written for the "instantaneous" position of the athlete's general center of mass.

The balance system for translational and rotational movements is presented as:

$$\begin{cases} \sum X = 0; \quad F_x - F_{\text{відц}} = 0 \\ \sum Y = 0; \ F_y - G = 0 \\ \sum M_B = 0; F_x \cdot L \sin\theta - F_y \cdot L \cos\theta = 0 \end{cases}, \tag{1}$$

where L - the distance between point A and point B, θ- the angle of "tilt" of the center of mass, measured between the line through points A and B and the horizontal line of the roller.

The centrifugal force is calculated using the formula:

$$F_{\text{відц}} = m\ddot{x}, \tag{2}$$

where $\ddot{x} = a_{\text{відц}}$ – the acceleration of the GCBM located in the horizontal plane along the height x, it can be calculated by the formula:

$$a_{\text{відц}} = \frac{V^2}{R}, \tag{3}$$

where V – the speed of the athlete's GCBM, it is directed along the tangent to the trajectory of movement; R – the radius of curvature of the trajectory. Substituting this equation into the previous one, we get an expression for the centrifugal force

$$F_{\text{відц}} = \frac{mV^2}{R}. \tag{4}$$

Centrifugal force $F_{\text{відц}}$, as can be seen from expression (4), it is inversely proportional to the turning radius and directly proportional to the square of the speed of movement.

In Figure 2 shows the calculated values of the centrifugal force of an athlete with a mass of kg depending on the radius of the turn for different values of the speed of movement (V=20 m·s^{-1}, 30 m·s^{-1}, m·s^{-1}).

An analysis of the comparative graphical characteristics of the magnitude of the centrifugal force (Fig. 2) demonstrates how, with an increase in the turning radius, the action of the force $F_{\text{відц}}$ per athlete decreases. But the speed of movement on a corner changes the magnitude of the centrifugal force in a quadratic relationship: if the speed is increased by 2 times, the action of the lateral force will increase by 4 times.

It is natural to slow down for safe cornering, but there is a risk of leaving your good position in the distance. Therefore, the main task when passing the turning phase with your motor actions is to resist the action of the lateral force $F_{\text{відц}}$, that is, repulsion to the board. Experienced athletes maintain their trajectory and do not change its radius during the turn phase, which does not allow competitors to take a position that follows the optimal trajectory and is the best for maintaining speed and further successful passing the distance.

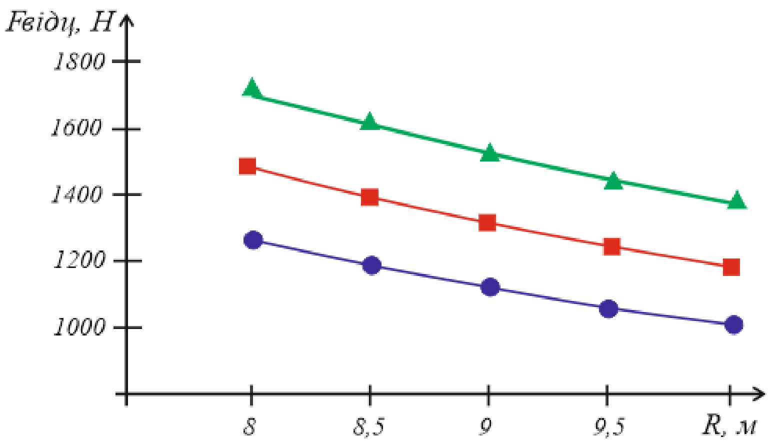

Fig. 2 Dependence of the centrifugal force of inertia on the radius of the trajectory of an athlete with a mass $m = 70$ kg for different speed values V: green – 20 m·s^{-1}, red – 30 m·s^{-1}, blue – 40 m·s^{-1}

In Figure 3 shows a series of calculated curves for various values of the center of mass of the body of athletes (m = 40 kg, 50 kg, 60 kg), characterizing the dependence of the magnitude of the centrifugal force on the radius of passage of the turn at a constant speed of movement 20 m·s^{-1}.

Analysis of comparative graphical characteristics of the quantity $F_{\text{відц}}$ shows that an increase in mass also leads to an increase in centrifugal forces in a corner and decreases with an increase in the radius of a corner R.

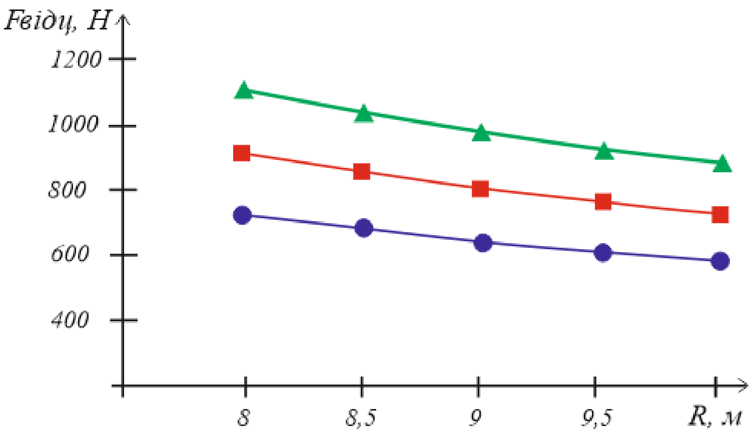

Fig. 3 Dependence of the centrifugal force of inertia on the mass of the athlete's CMR at the speed of movement $V = 20$ m / s for different values m: green - 60 kg, red - 50 kg, blue - 40 kg

With skillful use of the overall center of mass, the athlete can use this force in conjunction with gravity and lean angle θ to keep the leading position at a distance. To do this, you need to skillfully manage your center of mass during dynamic movement on the roller, especially in the turning phase. In addition, you should practice the ability to maintain the angle of inclination in the turn with a "low landing", that is, with a low location of the general center of mass of the body (Fig. 4).

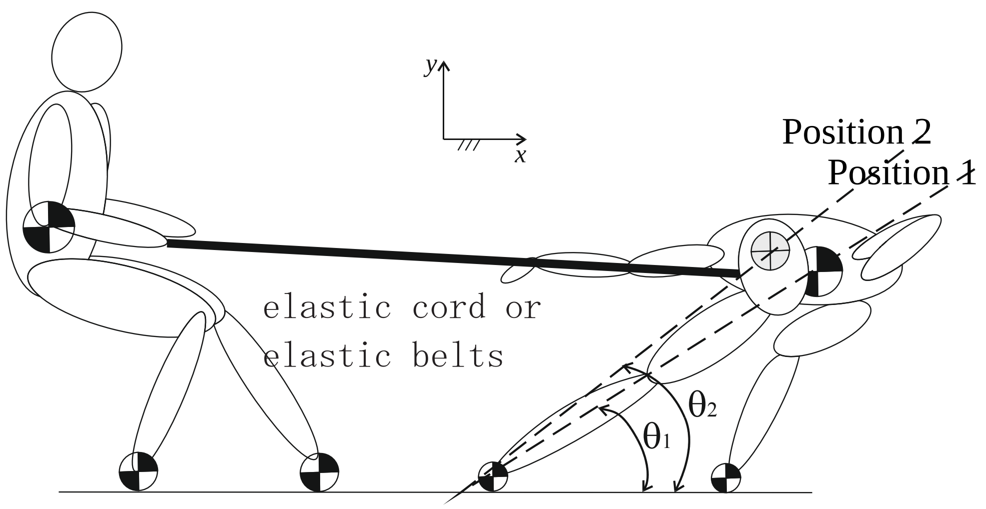

Fig. 4 Schematic representation of the training process with special tools for practicing correct biomechanical movements in a turn

Beginner athletes cannot achieve the required degree of "incline" (position 2, Fig. 4), because the effect of self-protection from falling is triggered, which prevents them from making the necessary incline to the center of the trajectory of movement. Therefore, in the short track, when practicing the technique of performing the turning phase, special training aids are used, which simultaneously play the role of an insurance "lounge" (Fig. 4). These include an elastic cord or elastic belts. The common center of mass of the partner's body is used as inertial parts.

A short track trainer, when working with athletes on the technique of cornering at low speeds (on ice or on land), uses such aids. Its task is to correct the position of the athlete's legs and body for the formation of correct motor actions and the ability to control the location of his center of mass and biomechanical circuits. It should be emphasized that the position of the center of mass of the body of each athlete is different according to his anatomical and morphological data, as well as the initial values of the entry speed into the turn.

Conclusions / Discussion

The study confirmed the data of the authors Eline van der Kruk, Marco M. Reijne, Bjorn de Laat & DirkJan (HJ) Veeger (2019) [12] regarding the biomechanical characteristics of the turning phase, which are typical for the world's leading athletes. Analyzing the technique of cornering in a short track, which depends on the radius of the athlete's trajectory. We have confirmed the results of [13, 16] and supplemented with our own calculations the dependence of the centrifugal force of inertia on the mass and radius of the trajectory.

The study examines the possible location of the general center of mass of the athlete's body using special tools that help to work out the optimal options for the trajectory of movement in a turn. The use of similar means and technology is substantiated in works [11, 14, 20] and is generally accepted in world practice. Taking into account the individual technical characteristics of cornering in the short track of novice athletes has become its own legacy to the generally accepted methodology.

In the literary sources of the Ukrainian professional editions in the field of sports, there is practically no information on the study of the biomechanical characteristics of the short track running technique, especially in the turning phase.

The analysis of videos and photographs taken at competitions and short track trainings showed that in order to ensure a high result, an athlete needs to be able to perform high-quality motor actions in the turning phase. To do this, it is necessary to take into account a number of multiply connected factors that ensure the maximum speed of passing the distance.

These factors, mainly, include biomechanical characteristics that an athlete can realize, namely: the speed of the run, the radius of the athlete's entry into the turn, the height of the athlete's general center of inertia at the time of the turn, etc.

Biomechanical equations for the dependence of centrifugal forces on the angle of inclination of the body and the radius of the trajectory of movement of athletes along the short track are given, as well as the visualization of the theoretical understanding of the relationship of individual elements of movement, which makes it possible to model various situations and determine the optimal values of the kinematic characteristics of the movement of an athlete.

Based on the data of theoretical studies, with the help of special simulators, it is possible to create conditions that simulate in space the real situation of an athlete passing a short track turn on one skate, and the coach will be allowed to control all biomechanical characteristics of the correct performance of competitive movements. In addition, it is possible to correct movements directly during training..

Thus, training exercises with biomechanical aids form in athletes muscle memory to perform the correct motor action when passing through the turning phase at high speeds during the competition, and the feeling of the correct location of the general center of body mass in the rolling position on one leg is recorded. This helps to develop the skill of increasing the rolling time on one skate as long as possible on this section in order to positively use the centrifugal force and the sharp entry into the turn. In turn, this affects the speed of passing the distance due to a longer application of force in the support during repulsion.

With the help of the above simulators, conditions are created that simulate in space the position of the rolling state in the turn phase, and it is convenient for the coach to control all biomechanical characteristics that characterize the correct position of the athlete's center of mass when entering the turn.

The introduction of an arsenal of biomechanical ergogenic means into the practice of the training process on a short track opens up opportunities for improving the technical training of athletes in an entry-level short track and improving the training of highly qualified athletes.

Prospects for further research will focus on the development of biomechanical models for the implementation of other technical elements in the short track, based on computer modeling and information technology.

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References

1. Ashanin, V. S., Druz', V. A., Zadorozhnaya, E. A., Pyatisotskaya, S. S., Litvinenko, A. N. (2012), « Theoretical foundations for constructing an assessment of the physical development and physical health of the surveyed contingent», Slobozhans′kyy naukovo-sportyvnyy visnyk, No. 2, pp. 131-137. (in Russ.).

2. Biomekhanika sportu [Biomechanics of sport] (2005), navchal′nyy posibnyk dlya studentiv vyshchykh navchall′nykh khakladiv z fizychnoyi kul′tury ta sportu / edited by Laputin.A.M, Kyiv: Olympic Literature, 319 p. (in Ukr.).

3. Gamaliy, V. V. (2013), Teoretiko-metodicheskiye osnovy modelirovaniya tekhniki dvigatel'nykh deystviy v sporte [Theoretical and methodological foundations of modeling the technique of motional actions in sports], Kiev: Poligrafservis, 300 p. (in Russ.).

4. Kugaevsky, S. O., Bleshchunova, K. M. (2010), «Priorytetni napryamy udoskonalennya trenuvalʹnoho protsesu ukrayinsʹkykh short-trekovykiv vysokoyi kvalifikatsiyi u makrotsyklakh pidhotovky», Teoriya i metodyka fizychnoho vykhovannya i sportu, №4, pp. 20-25. (in Russ.).
5. Litvinenko, Yu. V., Kashuba, V. A. (2008), «Biomekhanicheskiy analiz tekhniki dvigatel'nykh deystviy sportsmenov razlichnoy kvalifikatsii, spetsializiruyushchikhsya v short-treke», Nauka v olimpiyskom sporte, No. 1, pp. 94-101. (in Russ.).
6. Meleshko, V. I. (2010), Erhohenni ta erholitychni zasoby sportyvnoho trenuvannya: navchalʹnyy posibnyk [Ergogenic and ergolytic aids of sports training: a textbook]. Dnipropetrovsk: DDIFKiS, 124 p. (in Ukr.).
7. Ratov, I. P., Popov, G. I., Longinov, A. A., Shmonin, B. V. (2007), Biomekhanicheskiye tekhnologii podgotovki sportsmenov [Biomechanical technologies of athletes training]. M .: Physical culture and sport, 120 p. (in Russ.).
8. Filenko, L. V. (2017), «Alhorytmichni osnovy pobudovy navchalʹno-trenuvalʹnoho protsesu studentiv-sport•smeniv iz vykorystannyam informatsiynykh tekhnolohiy», Visnyk Prykarpatsʹkoho universytetu. Seriya: Fizychna kulʹtura, Issue 27-28, pp. 318-323. (in Ukr.).
9. Filenko, L. V., Nesen, O. O. (2018), Informatyzatsiya pidhotovky studentiv-handbolistiv zasobamy mulʹtymediynoyi kompʺyuternoyi prohramy «Handbol» [Informatization of training of handball students by means of the multimedia computer program "Handball"], Sportyvni ihry, №1 (7), pp. 54- 61. (in Ukr.).
10. Filenko, L. V. (2016), Kompʺyuterni navchalʹni ta kontrolyuyuchi prohramy u fizychnomu ykhovanni ta sporti [Computer training and control programs in physical education and sports], Naukovyy chasopys. Seriya 15: Naukovo-pedahohichni problemy fizychnoyi kulʹtury (fizychna kulʹtura i sport), Issue 10 (80) 16, pp. 139-145. (in Ukr.).
11. Platonov, V. N., Bulatova, M. M., Kashuba, V. A. (2006), «Biomechanical ergogenic means in modern sport», Stiinta sportului. Academia Romana, Bucuresti, No. 53, pp. 19-49. (in Eng.).

12. Eline van der Kruk, Marco M. Reijne, Bjorn de Laat & DirkJan (H. E. J.) Veeger (2019), «Push-off forces in elite short-track speed skating», Sports Biomechanics, Vol. 18 No. 5, pp. 527-538. (in Eng.).
13. Felser, S., Behrens, M., Fischer, S., Heise, S., Bäumler, M., Salomon, R., & Bruhn, S. (2016), «Relationship between strength qualities and short track speed skating performance in young athletes», Scandinavian Journal of Medicine and Science in Sports, Vol. 26, pp. 165–171. (in Eng.).
14. Fintelman, D. M. (2010), Literature study: Biomechanical models for speed skating, Technical University Delft. (in Eng.).
15. Lanka, Ya. Ye., Gamaliy, V. V, Habinets, T. O. (2017), «Biomechanical substantiation of mechanical impulse transfer mechanisms in the "athlete – sports equipment" system when performing moving actions in sports», Slobozhanskyi herald of science and sport, №3 (59), pp. 29-34. (in Eng.).
16. Lozowski, E., Szilder, K., Maw, S. (2013), «A model of ice friction for a speed skate blade», Sports Engineering, Vol. 16, Issue. 4, pp. 239–253. (in Eng.).
17. Pasko, V., Rovniy, A., Nesen, O., Ashanin, V., Filenko, L., Okun, D., Shevchenko, O., Dzhym, V., Pilipko, O. (2019), «Efficiency of performing rugby's technical elements depending on the speed and strength quality level of 16-18-year-old rugby players», Journal of Physical Education and Sport, No. 19(1), pp. 546-551. (in Eng.).
18. Rovniy, A., Pasko, V., Karpets, L., Nesen, O., Ashanin, V., Filenko, L., Pomeshchikova, I., Mukha, V., Korsun, S., Shaposhnikova, I. (2018), «Special aspects of preparation of student`s teams for competitions in Rugby», Research Journal of Pharmaceutical, Biological and Chemical Sciences, No. 9(4), pp. 1402-1413. (in Eng.).
19. Rovniy, A., Pasko, V., Nesen, O., Tsos, A., Ashanin, V., Filenko, L., Karpets, L., Goncharenko, V. (2018), «Development of coordination abilities as the foundations of technical preparedness of rugby players 16-17 years of age», Journal of Physical Education and Sport, No. 18(4), pp. 1831-1838. (in Eng.).

20. Yuki, M., Ae, M., Fujii, N. (1996), ド ケ ト の ド反 [Blade reaction forces in speed skating], Society of Biomechanisms Japan (SOBIM), No. 13, pp. 41–51. (in Japan.).

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