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PARAMETERS OF THE IN-RUN POSITION OF JUNIORS' BODY AT THE BEGINNING OF TAKE-OFF

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Abstract
The objective is to determine the differences in the technique of the in-run position execution at the beginning of take-off by junior ski-jumpers of different qualification (sports training).
Materials and methods. The participants in the study were 22 junior ski-jumpers aged 14-16 (a group of junior ski-jumpers) performing during the Ukrainian Ski-Jumping Championship (October 9, 2010, Vorokhta, Ukraine). The correlation analysis thereof established the relations between the jump length and the angular parameters: in the ankle joint, knee joint, hip joint, and pelvis joint, which condition the positional relationship of the body joints and the position of the ski-jumper at the beginningof take-off.
Results. The study established the correlation relations between the jump length and the angular parameters that condition the horizontal positioning of the body. The correlation coefficient for the jump length at the inclination angle of the segment of the straigt line passing through the axes of the ankle and shoulder joints to the direction of the skier's movement is r=–0.563 (p = 0.006), and that at the inclination angle of the segment of the straight line passing through the general center of body weight and the axis of the ankle joint to the direction of the skier's movement is r= –0.355 (p = 0.105).
Conclusions. A position of lowly groupping at the beginning of the take-off allows to improve the sporting result. The study established the correlation between the jump length and the angle, particularly in the ankle joint, to be r= –0.2244 (p = 0.274), in the knee joint — r= –0.165 (p = 0.464), in the hip joint —r= –0.127 (p = 0.574). It determined the statistically reliable differences in the parameters of the body position at the beginning of the take-off on the jump ramp (p <0.05).
Key words: ski jumping; take-off; technique; kinematics; parameters.

Introduction

Ski jumping is one of the complex coordinative and high-level technical kinds of sport. The effectiveness of flight phase significantly depends on the take-off. The jump length and sport result also depend on take-off. While straightening from the in-run position, a skier jumps and moves COM (centre of overall mass) up-forward. Speed of COM movement can be divided into horizontal and vertical speed. Maximal increasing of COM horizontal speed in take-off phase enhances the movement speed and its influence is similar to the in-run speeding. COM movement forward the area of stability on the take-off table creates the rotation, which increases the body inclination in flight phase. Vertical speed component of COM movement at the end of the take-off table increases the height of the flight trajectory. It depends on the length of COM movement from the lowest to the highest position. It sets the requirements to the body pose at the beginning of take-off while in-run position. Improvement of movements in take-off phase requires the usage of patterns, which help to control effectively and determine discrepancy between young skiers' technique and optimal technique. As a standard it is the most appropriate

to use model characteristics (A.Kazmiruk et al., 2016), which are based on mathematical modelling or analysis of better sportsmen's technique in a definite group or the best skiers' technique.

The scientific literature shows angle parameters of body poses during in-run and take-off for different researched groups of highly qualified skiers (Maryniak J. et.al., 2002; P. Grimshaw P. & Marqes-Bruna, 2009; R. Puumala, 1995), but the usage of these parameters is not advisable while improving young skiers' technique on not high trampolines. The article (I. Zanevskyy & V. Banakh, 2010) reveals kinematic parameters of young skiers' body pose at the beginning of take-off on trampoline HS-75 and two-parameter model which can be used while improving skiers' technique and increasing jump length.

Medium and low pose, which provides a powerful take-off, is the most efficient before movements on the table (R. Puumala, 2005; H. Hoshino et. al., 2001). Low pose is provided by decreasing the value of angles in knee, ankle and hip joints. Decreasing the value of angles increases the potential for demonstration of power-speed qualities in the process of take-off (Jost B. 1998; H. Hoshino et. al., 2001).

It is considered that decreasing of ankle joint angle during in-run phase helps to place the body in the position, which decreases the muscle tension of shin and hip front part. Decreasing of muscle tension reduces the muscle fatigue and promotes better muscle functioning in take-off phase. Aerodynamic characteristics of in-run pose are defined by decreasing of ankle joint angle. Low body pose decreases the cross-wind resistance while in-run and increases the speed of movement.

The authors determined significant correlations between the jump length and five parameters of skier's body pose, namely with angles in the ankle ($r = –0.614$; $p < 0.001$), knee ($r = –0.596$; $p < 0.001$), and hip joints ($r = –0.437$; $p < 0.012$), with the angle of incline to direction of skier's motion of line which passes through the COM of the body and axis of ankle joint ($r = – 0.556$; $p<0.001$), and also with the angle of incline to direction of skier's motion of line which passes through the axis of ankle and shoulder joints ($r = –0.402$; $p < 0.03$). These correlations prove that if the direction of correlation for all the five parameters of the body pose with jump length is negative, it is possible to accept a conclusion that as more compact body parts are grouped, the probability of achieving a better sporting result is higher. These data supplement the statement (I. Zanevskyy & V. Banakh, 2010).

The developed model defines the lowest values of particular parameters: ankle joint angle – 42,8°, knee joint angle – 56,9°, the angle of incline of line which joins COM and the axis of ankle joint to the direction of skier's motion – 57,2°.

Research objective. To identify the differences in the body pose parameters of young ski jumpers at the beginning of take-off during the in-run.

Materials and methods

The article presents the results of a comparison of kinematic parameters of body pose at the beginning of take-off during the in-run. Comparison of kinematic parameters of body pose at the beginning of take-off has been carried out. In the course of research we received preliminary information on kinematic characteristics and peculiarities of in-run at the beginning of take-off done by ski jumpers of different qualification and sports fitness levels. Correlations of the studied parameters with the length of jumps have been set as well. The used information (Zanevskiy, Banakh, 2010) considers kinematic parameters of 33 ski jumpers aged 16-17 years (senior group of ski jumpers) who participated in international competitions «Lotos Cup» January 30, 2010 in city Szczyrk (Poland). We also analyzed video recordings of take-off of 22 ski jumpers aged 14-16 years

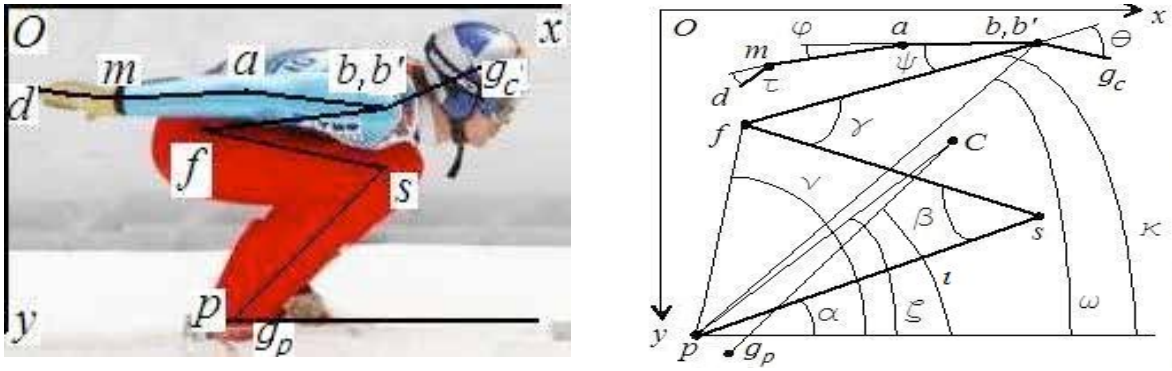

Fig. 1. An image of a ski jumper on the take-off table and a scheme model of his body with the rectangular coordinate system xOy (I. Zanevskiy & V. Banakh, 2010)

(group of junior ski jumpers) in the championship of Ukraine in ski jumping October 9, 2010 in village Vorokhta (Ukraine). Parameters of ski jumping technique performance and sport results were processed on the basis of video recordings of first series of competitions.

Videorecording was done with the help of digital camera Canon S3 IS with frequency of 60 Hz. The camera was located on the side of the take-off table at the distance of 20 meters perpendicular to the ski in 3 meters to the edge of the table. The horizontal axis of the camera is tilted at an angle of the table. During the recording camera was rotated around its vertical axis. We have taken into account weather conditions in which the shooting was carried out and the technical requirements for its implementation, which allows to minimize systematic and random error associated with the properties of optics and video technology. To zoom videorecordings, layout of the distance was set in front of ski rail on the take-off table (between the camera and the object of recording). Identification of necessary information, quantitative kinematic parameters was carried out using the proposed video analysis. It was believed that the beginning of the in-run of the skier was prior to take-off beginning.

We used the technology of measurement and analysis for take-off technique based on the processing of body images projected on the sagittal plane (Zanevskyy, Banakh, 2010) and determination of kinematic parameters using computer programs Excel and Paint (Fig. 1). Since skis during take-off are not detached from the take-off table, we can assume that the skis are in the horizontal position relative to the table. The structure scheme of the skier's body is taken as flat branched hinge-rod chain composed of eight parts: the foot with the ski, legs, hips, trunk, head, shoulder, forearm and hand. Parts of the body form together joints that simulate kinematic pairs of fifth grade: p - ankle; s - knee; f - hip; b - shoulder; b '- neck; a - elbow; m - wrist (Fig. 1). Coordinates of the mass centers of head and foot are defined by the relevant markers on the helmet of skier (point gc) and shoes (point gp). Joint angles, as well as four more angles, parameters of the skier's body pose are calculated by trigonometric formulas.

Thus, skier's body pose is defined by parameters corresponding to the respective joint angles that are shown in the kinematic scheme of skier's body (Fig. 1). Additionally, four parameters that are appropriate to characterize position of ski jumper are used. These are angles of inclination to the direction of skier's motion (on the take-off table - it's tilted at 10 ÷ 12 ° to the horizontal) of lines that pass through the axis of ankle and shoulder joints (angle ω), ankle and hip joints (angle ν), through the axis of ankle joint and COM of the body (angle ξ), through COM of the body and the center of the foot (angle ζ); and through the axis of hip and shoulder joints (angle κ).

Research results

In Table 2 data of statistical analysis concerning take-off technique in the initial phase (in-run) are presented, namely parameters that characterize compact grouping of body parts. The study involved 22 less skilled ski jumpers aged 14,9 ± 0,8 years belonging to Kremenets, Vorokhta, Verkhovyna, Nadvirna sports schools of Ukraine.

Starting position at the beginning of the motion is facilitating the further implementation of take-off. According to the authors, the lower parts of the body are grouped in a pose, the less air resistance during in-run is observed. The result is saving of energy, caused by the scattering of skier's potential energy, which increases the velocity of skier's body during motion on the take-off table. At the same time, a compact body pose potentially enables skier to jump higher from the take-off table. The higher position of skier is, the greater may be flight time, and hence the length of the jump.

The angle of incline of shin in the initial position of the body determines the location of COM of the body relatively to the stability area during in-run. In particular, the values of angles: ankle joint - (α), knee joint - (β),

Table 1. Parameters of skier's body pose at the beginning of take-off (N = 22)

Stat.	α°	β°	γ°	ψ°	φ°	θ°	κ°	ζ°	ω°	ν°
M	61,5	86,8	29,6	5,8	9,4	–21,5	4,7	84,0	66,4	111,3
SD	4,6	6,4	3,8	6,8	4,2	5,5	5,4	4,1	3,7	4,4
r	–0,244	–0,165	–0,127	–0,097	0,040	0,243	–0,026	–0,355	–0,563	–0,036
t	1,125	0,746	0,572	0,435	0,179	1,123	0,117	1,699	3,049	0,161
p	0,274	0,464	0,574	0,668	0,860	0,275	0,908	0,105	**0,006**	0,874
Max	68,7	99,9	37,7	16,6	15,8	–11,1	15,3	91,3	73,4	119,2
Min	50,5	78,4	22,8	-9,5	–1,8	–31,0	–8,3	73,8	58,9	101,8

Table 2. Parameters of skier's body pose at the beginning of take-off in ski jumping

№	Parameter	Unit	Stage		Difference	p
			Senior ski jumpers (N = 33)	Junior ski jumpers (N = 22)		
			M ± SD			
1	α	degree	52,8±4,3	61,5±4,6	–8,7	0,001
2	β	degree	74,1±7,6	86,8±6,4	–12,7	0,001
3	***γ***	degree	34,5±4,3	29,6±3,8	4,9	0,001
4	***ψ***	degree	9,6±4,5	5,8±6,8	3,7	0,030
5	***φ***	degree	8,3±4,7	9,4±4,2	–1,1	0,376
6	***θ***	degree	–3,7±8,3	–21,5±5,5	17,8	0,001
7	***κ***	degree	13,5±5,6	4,7±5,4	8,8	0,001
8	**ζ**	degree	74,4±3,5	84,0±4,1	–9,6	0,001
10	**ω**	degree	60,7±3,5	66,4±3,7	–5,8	0,001
11	**ν**	degree	100,6±3,2	111,3±4,4	–10,7	0,001
12	L, м	metre	63,4±8,2	55,8±8,01	7,6	0,001

hip joint (γ) determine the relative position of parts and pose of the skier's body at the beginning of take-off. Relevant parameters of young ski jumpers amounted to 61,5 ± 4,6˚; 86,8 ± 6,4; 29,6 ± 3,8˚, where there are minor, reverse correlation relationship with the length of jump (p>0,05) (Table. 1). Trunk inclination relative to the direction of motion determine the value of these angles. Reducing the angle of trunk inclination i. e. the line that passes through the axis of the hip and shoulder joints relative to the direction of skier's motion – (***κ)*** (that corresponds to 4,7 ± 5,4˚), to a great extent provides favorable aerodynamic conditions while fast moving of skier during in-run, reduces drag of the oncoming air. Statistically significant correlation relationships for this parameter was also not set r = -0.026 with p = 0,908.

Parameters of the body that determine the location of the body and its parts in a horizontal position are considered to be the location of the shoulder and hip joints relative to the stability area. In the angle of incline to the direction of skier's motion the line passing through the axis of the ankle and hip joints — (***ν*)** its value is 66,4 ± 3,7˚, correlation with the jump length is r = -0,036 at p = 0,874. In the angle of incline to the direction of skier's motion the line passing through the axis of the hip and shoulder joints — (***ω)*** its value is 111,3±4,4 we received r = -0,563 at p = 0,006. Reduction of the angle of incline to the direction of skier's motion of the line passing through COM of the body and axis of ankle joint improves stability of system "skier - skis" and creates favorable conditions for reveal of muscles potential and the best course of take-off — (***ζ)***. The value of this angle was 84,0 ± 4,1˚ we received r = -0,355 at p=0,105.

Reduction of the angle of incline of head relative to the body — (θ**)** to some extent reduces the drag force. In ski jumpers at the stage of specialized basic training it amounts to 21,5 ± 5,5˚.

In the preparation process of young athletes who are less skilled (e. g. Ukrainian ski jumpers) it is better to use model characteristics of exercise techniques of higher qualification athletes (e. g. Poland, Szczyrk) (Zanevskiy, Banakh, 2010). The differences in the values of parameters between older and younger ski jumpers determine the reserves for improvement of technique and improvement of sport result for less skilled ski jumpers of Ukraine.

Data of statistical analysis of kinematic parameters of body pose at the beginning of take-off are given in Table. 2. In groups of junior ski jumpers as compared with senior ones, there are significant differences in most of the studied parameters.

According to value of parameters that determine sport result, length of jump - a group of senior ski jumpers, the value of this parameter was 63,4 ± 8,2 m against 55,8 ± 8,0 m compared with less skilled ski jumpers who were at the stage of specialized basic training.

Thus, the angles of incline of shin relative to the direction of motion - (α) and in knee joint - (β) in group of junior ski jumpers were 61,5 ± 4,6˚ and 86,8 ± 6,4˚ vs 52.8 ± 4, 3º and 74,1 ± 7,6º in senior athletes. The value of the angle in hip joint (γ) – was 29,6 ± 3,8˚ against 34,5 ± 4,3˚ respectively. According to parameters *α, β, **γ*** there are significant differences in average values of these parameters in both groups (p <0.001). Reduction of average values of parameters *α, β, γ* to a great extent determines compact grouping of the body parts at the beginning of take-off. At the same time, active flexion of

hip joint reduces resistance to the oncoming air which on one hand is due to the need to reduce the drag of the already high rack, on the other hand – to a certain extent determines the location of COM of the body and allows to keep stability on the take-off table before take-off in less skilled skiers.

The value of the following parameters are highly important: the angle of trunk incline, that is the line that passes through the axis of hip and shoulder joints to the direction of motion of skier (κ); the angle of incline to the direction of motion of skier – the line passing through the axis of the hip and ankle joints ($\boldsymbol{\gamma}$); the angle of incline to the direction of motion of skier – the line passing through the axis of the ankle and shoulder joints ($\boldsymbol{\omega}$). These values describe position of skier's body parts and depend on parameters presented above. In the position of the body at the beginning of take-off there are significant differences ($p>0,001$) in average values of the relevant parameters (κ, $\boldsymbol{\omega}$, $\boldsymbol{\nu}$), in a group of young ski jumpers 4,7 ± 5,4˚; 66,4 ± 3,7˚ and 111,3 ± 4,4˚ against 13,5 ± 5,6˚; 60,7± 3,5˚ and 100,6 ± 3,2˚ in a group of older and more qualified ski jumpers.

In groups of ski jumpers placement and hand position are determined by minor differences in terms of values, namely the angle of shoulder joint (ψ), the angle of elbow joint (φ). In the group of junior ski jumpers, as compared with the senior ones, values of these angles constituted 5,8 ± 6,8˚ against 9,6 ± 4,5˚; and 9,4 ± 4,2˚ against 8,3 ± 4,7˚. Inter-group difference in average values of two parameters viewing the angle of elbow joint (φ) had no statistical significance ($p> 0,05$). In terms of averages in shoulder joint (ψ) inter-group differences in groups under study was 3,7˚ ($p <0,030$).

In the parameters concerning angle of incline of head relative to trunk there are significant differences. The difference in value of incline was 17,8˚ ($p <0.001$). In less skilled athletes, in the group of junior skiers, the value of this angle was -21,5 ± 5,5˚ against -3,7 ± 8,3˚ in the group of more qualified jumpers. On the one hand, the lower is location of the head relative to the body, the more reduced resistance to the oncoming air we observe, on the other hand, the less incline of the head forward allows to follow better visually the edge of the table, allowing accurate and timely execution of motor actions.

In the position of the skier's body at the beginning of take-off, there is an important indicator, i.e. the angle of a line, passing through COM of the body and axis of ankle joint to the direction of the skier's motion. Thus, in the position of the body at the beginning of take-off in less skilled young ski jumpers, it is 84,0 ± 4,1˚ against 74,4 ± 3,5˚ in the group of senior ski jumpers. Inter-group difference of average values was 9,6˚ ($p <0.001$).

Discussion of results

As a result of processing video recordings we have defined parameters of body poses of 22 ski jumpers during in-run at the beginning of take-off. According to the values of parameters we can see that there are differences in terms of joints angles during in-run in the poses of ski jumpers. This variability can be seen as the standard deviation. This can be explained by individual peculiarities of jumping techniques.

The authors argue that reducing the incline of COM of the body at the beginning of take-off in a static position decreases muscle tension of shin and hip front part and creates more potential for muscle tension, and increases power while performing take-off. Reduction of angle values in ankle, knee, hip joints help to reduce COM of the body, reduce the angle of incline of the body relative to the direction of movement and therefore, aerodynamic properties of skier's body pose. All of these will enhance speed of movement, thus increasing the length of jump.

These data have been confirmed by inverse correlation relationship of angle values of skier's body pose with the length of jump. In particular, we observe minor reverse correlation relationship with the length of jump, of the following angles values: in ankle joint - (α), in knee joint - (β), in hip joint (γ). At the beginning of take-off of young jumpers (N = 22) these values were r=-0,244, r = -0165, r = -0,127 ($p>0,05$) (Table. 1).

The data in Table 2 indicate a statistically significant difference $p<0,05$ in values of angles parameters that determine compact grouping of skier's body parts and location of COM of the body during the in-run at the beginning of take-off between the groups of junior and senior ski jumpers. Such values of senior ski jumpers are smaller than in junior ones. These differences indicate reserves for improvement of technique. An even greater difference is observed in values of ankle and knee joints angles and angle of incline of line that connects COM of the body and ankle joint axis relative to the direction of movement of young ski-jumpers 61,5 °, 86,8 ° and 84.0 ° respectively with lower marginsof values of respective parameters of the authors' mathematical model (I. Zanevskyy, V. Banakh, 2010); angle of ankle joint - 42,8 °, in knee joint - 56,9 °, angle of incline of line that connects COM of the body and ankle joint axis relative to the direction of movement - 57,2 °.

Conclusions

1) Inverse correlation relationships between the jump length and angles in ankle (α) — 61,5±4,6˚, r=–0,244 ($p>0,05$); knee (β) — 86,8±6,4˚; r= –0,165 ($p>0,05$); and hip joints (γ) — 29,6±3,8˚, r=–0,127 ($p>0,05$) define the relative position of links and skier's

low body pose at the beginning of take-off (молодші лижники, N=22).

2) The lower position of links and the smaller values of joint angles during in-run pose are, the higher probability of achieving better sporting result is. The jump length is defined by the horizontal position of body and the position of body links relatively to the stability in the angles: incline of line which passes through the axis of ankle and shoulder joints to the direction of skier's motion (ω) -111,3±4,4˚ r=–0,563 (p=0,006), and the line which passes through the body COM and ankle joint axis to the direction of skier's motion (ζ).—84,0±4,1˚ r= –0,355 (p=0,105).

3) Statistically significant difference p<0,05 in angle values of skier's body pose at the beginning of take-off between the group of young skiers (22) and the group of older skiers (33) is revealed. The jump length of younger skiers was 7,6 m (p=0,001) shorter and average angle values of skier's body pose were bigger than the parameters of older skiers. The difference was the following: ankle joint angle (α) — 8,7˚; knee joint angle (β) –12,7˚; the angle of incline of line which passes through the axis of hip and ankle joints (ν) –10,7˚; the angle of incline of line which passes through the axis of ankle and shoulder joints (ω) – 5,8˚, the angle of incline of line which passes through the COM of the body and the axis of ankle joint to the direction of skier's motion (ζ) – 9,6˚ (p<0,001). It defines the reserves for angle decreasing and requires the development of program for improving of young skiers' (14-16 year old) in-run pose.

Conflict of interests

The author declares that there is no conflict of interests.

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ПАРАМЕТРИ ПОЗИ ТІЛА ЮНІОРІВ В СТІЙЦІ РОЗГОНУ НА ПОЧАТКУ ВІДШТОВХУВАННЯ

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Реферат. Статья: 6 с., 2 табл., рис. 1, 7 джерел.

Мета роботи. Виявити відмінності у техніці виконання пози тіла на початку відштовхування у стійці розгону юних лижників-стрибунів різної кваліфікації (спортивної підготовленості).

Матеріали і методи. В дослідженні взяли участь 22 юних лижників-стрибунів віком 14–16 років (група молодших лижників-стрибунів) під час чемпіонату України зі стрибків на лижах з трампліна (9 жовтня 2010 р., смт. Ворохта, Україна). В результаті кореляційного аналізу були встановлені зв'язки між довжиною стрибка і кутовими параметрами: у гомілковостопному суглобі, у колінному суглобі, у кульшовому суглобі, що визначають взаємне розташування ланок тіла та позу лижника-стрибуна на початку відштовхування.

Результати. Встановлені кореляційні зв'язки між довжиною стрибка і кутовими параметрами, що визначають розташування тіла у горизонтальному положенні. Коефіцієнти кореляції для довжини стрибка із кутом нахилу відрізка прямої лінії, яка проходить через осі гомілковостопного й плечового суглобів до напрямку руху лижника стано-

вить r=–0,563 (p = 0,006), для кута нахилу відрізка прямої лінії, яка проходить через ЗЦМ тіла й вісь гомілковостопного суглоба до напрямку руху лижника – r= –0,355 (p = 0,105).

Висновки. Низько згрупована поза на початку відштовхування дозволяє покращити спортивний результат. Встановлено кореляцію між довжиною стрибка і кутом зокрема у гомілковостопному суглобі r= –0,244 (p = 0,274), у колінному суглобі r= –0,165 (p = 0,464), у кульшовому суглобі r= –0,127 (p = 0,574). Виявлено статистично достовірні відмінності в параметрах пози тіла на початку відштовхування на столі трампліна (p < 0,05).

Ключові слова: стрибки на лижах; відштовхування; техніка; кінематика; параметри.

ПАРАМЕТРЫ ПОЗЫ ТЕЛА ЮНИОРОВ В СТОЙКЕ РАЗГОНА В НАЧАЛЕ ОТТАЛКИВАНИЯ

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Цель работы. Определить различия в технике выполнения позы тела в начале отталкивания в стойке разгона юных лыжников-прыгунов различной квалификации (спортивной подготовленности).

Материалы и методы. В исследовании приняли участие 22 юных лыжника-прыгуна в возрасте 14-16 лет (группа младших лыжников прыгунов) во время чемпионата Украины по прыжкам на лыжах с трамплина (9 октября 2010 г., пгт. Ворохта, Украина). В результате корреляционного анализа были установлены связи между длиной прыжка и угловыми параметрами: в голеностопном суставе, в коленном суставе, в тазобедренном суставе, определяющие взаимное расположение звеньев тела и позы лыжника-прыгуна в начале отталкивания.

Результаты. Установлены корреляционные связи между длиной прыжка и угловыми параметрами, определяющими расположение тела в горизонтальном положении. Коэфициенты корреляции соответственно для длины прыжка с углом наклона отрезка прямой линии, проходящей через оси голеностопного и плечевого суставов к направлению движения лыжника составляет r = -0,563 (p = 0,006), для угла наклона отрезка прямой линии, проходящей через ОЦМ тела и ось голеностопного сустава к направлению движения лыжника - r = -0,355 (p = 0,105).

Выводы. Низко сгруппированная поза в начале отталкивания позволяет улучшить спортивный результат. Установлена корреляция между длиной прыжка и углом в голеностопном суставе r = -0,244 (p = 0,274), в коленном суставе r = -0,165 (p = 0,464), в тазобедренном суставе r = -0,127 (p = 0,574). Установлено статистически достоверные различия в параметрах позы тела в начале отталкивания на столе трамплина (p < 0,05).

Ключевые слова: прыжки с трамплина; отталкивание; техника; кинематика; параметры.

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