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PECULIARITIES OF INTERACTION BETWEEN TRAMPOLINE AND TRAMPOLINIST – AS A COMPLEX BIOMECHANICAL SYSTEM IN THE ASPECT OF PHYSICAL FORCES AND BIOMECHANICS OF THE ATHLETE

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Abstracts

Aims. The purpose of this work is a detailed and detailed consideration of forces acting in the system «trampoline-trampolinist» from the point of view of the laws of classical physics. Concretely – the movement of the body of the athlete in space, mechanics of «work» of trampoline and system «trampoline trampolinist», as well as some aspects of the biomechanics of movements of the trampolinist when leaving the bed of the trampoline, coming to it and being out of contact with it. ***Study Design.*** This work is an independent scientific research review with an analysis of questionnaire data on the problematic issue. ***Methodology:*** the study was based on the application of a number of theoretical and empirical methods. The study uses theoretical analysis, systematization, and generalization of scientific literature, documentary sources, and guidelines in the field of physical education, biomechanics of movements of the trampolinist, a compilation of literature sources to identify the essence of the problem forces and interaction of the athlete with the trampoline and identify ways to solve. ***Results.*** In the article theoretical aspects of processes occurring in the interaction of trampoline as a mechanical system and trampolinist as a biomechanical system are considered. In connection with the increased requirements for the performance of athletes on trampolines since 2017 and the new rules of evaluation of performance in trampolining, the basic forces acting in the system «trampoline – trampolinist» are considered in detail. By calculation according to anthropometric and physical data of trampolinists and data of the analysis of their movements in the process of jumping by means of the special computer program «Kinovea» quantitative characteristics of forces acting in the «trampoline-trampolinist» system at different stages of their interaction in the process of their training or competitive programs were determined. A clear correlation of essential increase of these forces in proportion to the age of the sportsman, growth of his sports skill, and mass of his body is shown. The program allowed tracking the dynamics of athletes' in-flight movements in slow motion and determining the angles of their body parts' positions. A theoretical analysis of the main reasons that lead to violations in the combined operation of the trampoline as a mechanical system and the trampolinist as a biomechanical object was carried out. The consequences of these violations are shown and the ways of correcting these phenomena to increase the level of sportsmanship of trampolinists and increase their performance grades are proposed. ***Conclusion.*** When teaching trampoline athletes in the early stages and especially at the stage of specialized basic training, the authors point out that it is important to explain them and achieve a proper understanding of the physical forces and their real values acting on athletes in different phases of flight.

Key words: training of trampoline athletes, trampoline jumps, biomechanics of trampolinist's movements.

Марія Пимоненко, Ольга Костюченко. Особливості взаємодії батута та батутиста як комплексної біомеханічної системи в аспекті фізичних сил і біомеханіки спортсмена. ***Мета.*** Метою цієї роботи є детальний і докладний розгляд сил, що діють у системі «батут–батутист» із погляду законів класичної фізики, а саме: рухи тіла спортсмена в просторі, механіки «роботи» батута та системи «батут–батутист», а також деяких аспектів біомеханіки рухів батутиста за відходу від сітки батута, заходу на неї й перебування поза дотиком до неї. ***Структура дослідження.*** Ця робота – це огляд незалежного наукового дослідження з аналізом анкетних даних із проблемного питання. ***Методологія.*** Дослідження ґрунтувалося на застосуванні низки теоретичних й емпіричних методів. У дослідженні використано теоретичний аналіз, систематизацію та узагальнення наукової літератури, документальних джерел і методичних рекомендацій у галузі фізичного виховання, біомеханіки рухів батутиста, узагальнення літературних джерел для виявлення сутності проблеми сил і взаємодії спортсмена з батутом та визначення шляхів вирішення. ***Результати.*** У статті розглянуто теоретичні аспекти процесів, що відбуваються під час взаємодії батута як механічної системи й спортсмена батутиста як біомеханічної системи. У зв'язку з підвищенням із 2017 р. вимог до виступу спортсменів на батуті й новими правилами оцінки виступу у стрибках на батуті, детально розглянуто основні сили, що діють у системі «батут–батутист». Розрахунковим шляхом за антропометричними і фізичними даними спортсменів-батутистів та даними аналізу їх руху в процесі стрибків за допомогою спеціальної комп'ютерної програми «Kinovea», були визначені кількісні характеристики сил, що діють у системі «батут–батутист» на різних етапах їх взаємодії в ході виконання спортсменами тренувальних чи змагальних програм. Показано чітку кореляцію суттєвого

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збільшення цих сил пропорційно до віку спортсмена, зростання його спортивної майстерності та маси його тіла. Програма давала змогу відслідковувати динаміку руху спортсменів у польоті в уповільненому часі й визначати кути положень частин його тіла. Проведено теоретичний аналіз основних причин, що призводять до порушень у поєднаній роботі батута як механічної системи та батутиста як біомеханічного об'єкта. Показано наслідки цих порушень і запропоновано шляхи корекції цих явищ із метою підвищення рівня спортивної майстерності спортсменів-батутистів та підвищення оцінок за їх виступи. ***Висновок.*** Під час навчання спортсменів-батутистів на ранніх етапах й особливо на етапі спеціалізованої базової підготовки автори відзначають, що важливо пояснювати їм і домагатися належного розуміння ними фізичних сил і їх реальних величин, що діють на спортсменів на різних етапах фаз польотів.

Ключові слова: навчання спортсменів-батутистів, стрибки на батуті, біомеханіка рухів батутиста.

Introduction. Individual trampoline, being an Olympic sport, each year attracts more and more attention all over the world with its high aesthetic beauty, spectacularity, and effect [1]. Besides, interest in trampolines has long been available in special fields of activity in which it is necessary to train people to act in a state of weightlessness or flight (pilots, astronauts, parachutists, contingent of special operations units). Except for sports and special interest and entertainment, this kind of sports also becomes more and more popular every year among youth at the amateur level – as entertainment or as a way of health improvement and correction of body weight and body figure.

Despite the above, there is still very little information in the literature concerning the theoretical foundations of trampolining [1]. There are no scientific data on the assessment of this sport in terms of trampoline mechanics, the biomechanics of the trampolinist, the forces acting in this system, and their interaction with each other. There are no data on the consequences to which various violations in the coordinated work of these two systems lead. The lack of scientific research in this area leads to tangible shortcomings in the theory and practice of teaching and training trampoline athletes [2]. Many coaches teach their students the technique of trampoline, accompanied by the execution of complex acrobatic exercises, often based not on solid knowledge of the scientific theory of the matter, but simply on their own personal experience and intuition. Without a deep understanding of the forces acting on the athletes and their magnitudes.

Along with these facts, in 2017 new international rules were introduced to evaluate the performances of trampolinists. In particular, the so-called «horizontal displacement» – the horizontal plane deviation of trampolinists' arrivals to the trampoline bed from the central zone – «cross-zone» – began to be quantitatively assessed. For this or that value of displacement from the center points for performance began to be removed. Also added a separate score for the height of the jump.

Insufficient attention is given today to the development of modern training programs for trampoline athletes in the early stages, at the stage of specialized basic training (SBT), and at the stages of sportsmanship. This leads to a potential lag of our Ukrainian athletes, their injuries, lack of understanding of the cause-and-effect relations in the errors during the jumps, and insufficient understanding of the forces acting in the system trampolinist-trampoline. As a result, all this leads to low scores at competitions and the lack of timely formation of athletes in the early stages of the proper conscious skills and muscle memory.

The purpose of this work is a detailed and detailed consideration of forces acting in the system «trampoline-trampolinist» in terms of the laws of classical physics. Concretely – the movement of the body of the athlete in space, mechanics of «work» of trampoline and system «trampoline-trampolinist», as well as some aspects of the biomechanics of movements of trampolinist when leaving the bed of the trampoline, coming on it and being out of contact with it. Quantification of forces acting on the athlete's body and on the trampoline at different stages of the athlete's program. The forces and interaction of the athlete with the trampoline, as well as the reasons that lead to violations of this system and the consequences of these violations, in particular their impact on the «horizontal movement» of athletes.

Materials and Methods. The study uses theoretical analysis, systematization, and generalization of scientific literature, documentary sources, and guidelines in the field of physical education of trampolinist' movement biomechanics, a compilation of literature sources to identify the essence of the problem forces and interaction of the athlete with the trampoline and identify ways to solve it; synthesis – to substantiate the structure and content of the physical training program and identify the main problems as well as the reasons that lead to violations in the physical education system to develop a program for the training of trampoline athletes in the early stages, at the specialized basic training (SBT) and at the stages of sportsmanship.

Results. Trampoline, in terms of physics, can also be viewed as a sports mechanical device or projectile that allows the trampoline athlete to cycle to a relatively significant height above the trampoline and provides him or her with a safe landing on the bed after a downward motion – a fall [3].

High-level trampoline athletes, almost all of them, perform their jumps at a height of usually about 8 meters. Individual very high-level athletes have reached a height of about 9 meters. Providing themselves with such a margin of take-off height, athletes perform spectacular and spectacular complex-coordination exercises in the air [4].

The motion of the trampoline player in terms of classical laws of physics should be considered as the motion of the body thrown up and after falling down.

During free ascent or fall near the surface of the Earth, the bodies of trampolinists, regardless of their weight (bodyweight) acquire the same value of free-fall acceleration – g, equal to 9,81 m/s.

The vector or direction of the free-fall acceleration of the trampolinist is directed - strictly downwards perpendicular to the bed of the trampoline. Since the trampoline jumps near the surface of the Earth, the value of the free-fall acceleration can be assumed to be constant. Therefore, the trampolinist's movements along the vertical axis of his flight over the trampoline, regardless of direction, is a body movement under the action of a constant force and the movement is equi-accelerated. And, both upward and downward movements of the athlete are equi-accelerated. But when moving upwards, the acceleration has a negative value – **«-g»**, and when moving downwards, it has a positive value – **«+g».**

Trampolinist starts his performance with a «bounce» – rhythmic, increasing in height hops, jumps up. During each upward jump, the trampoline jumper moves uniformly slowly with a certain speed of the initial jump – $\mathbf{V_0}$, the speed at a single moment of movement – ***V***, and acceleration A **=** ***-g***. The athlete's displacement in time – ***T*** represents the height of ascent by the value – ***H***.

As a result of a series of initial jumps up – «bounces», under the action of cyclic muscular efforts of the trampolinist, spent on pushing from the bed to bounce up and then coming to the bed down. The deflection of the bed increases with each arrival at the bed. The stretch of the springs cyclically increases. The trampoline begins to push the athlete to greater and greater heights.

The speed of the athlete's upward movement decreases as the height increases. At the highest point of flight, the upward motion of the athlete's body ceases. There is no upward movement as well as no downward movement. The speed of movement in space at this point is zero. This is the moment of «hovering» in the upper point of the trajectory. It lasts a fraction of a second. After this moment, the athlete, solely due to the gravitational force of the Earth and the mass of his body, begins to move downward.

For the phase of the athlete's upward movement from the trampoline bed, the formula applies:

$$H = V_0\, T – (gT^2)/2, \quad (1)$$

where V_0 – initial velocity at which the athlete's body is thrown upwards, *m/s;*

T – flight duration, *s;*

g – free-fall acceleration – 9,81 m/s^2 [5].

For the phase of the athlete's downward movement to the bed, the formulas apply:

$$V_п=gT, \quad (2)$$

where: V_n **–** velocity of the athlete's body falling on the bed, *m/s;*

T – the time of its flight down from the point of maximum takeoff, *s;*

g **–** free-fall acceleration – 9,81 m/s^2.

The downward displacement distance of the athlete's body is determined by the formula:

$$H= (gT^2)/2, \quad (3)$$

where: H – a distance of the trampolinist's body movement from the upper point downwards, *m;*

T – time of flight down from the point of maximum takeoff, *s;*

g – free-fall acceleration – 9,81 m/s^2 [6].

Theoretically, in real conditions, due to the friction force of the athlete's body against the air, the mechanical energy of the athlete's body partially transforms into thermal energy, both during his takeoff and during his fall. As a result, theoretically, the maximum height of an athlete's body ascent when pushing up from the trampoline will actually be less than it could be when moving without such resistance, and at any point of his trajectory when going down the speed is less than when going down without such resistance.

Theoretically, in the presence of friction against the air, the body of an athlete in free-falling down to the trampoline bed has acceleration equal to g only in the initial moment of motion, i.e., when moving away from the «hovering» point. As the velocity increases, the acceleration slightly decreases, and the body motion tends to be uniform [7].

But in the case of trampoline jumping, these phenomena are so insignificant and the associated errors in trampoline jumping conditions are so small that they can be neglected and, knowing about them theoretically, their real impact on the jumping parameters of athletes cannot be considered. And quantitatively not to assess because of the complexity of these calculations.

The body of the athlete flying at the highest altitude for the given jump above the trampoline has at this point at the moment of «hovering» – the maximum potential energy for him. The potential energy of the athlete Epot flying above the trampoline bed at the height H can be calculated by the formula:

$$Epot = mgH, \tag{4}$$

where: *Epot* **–** Potential energy of the athlete's body, J;

m – body weight, and *g* – acceleration of free-fall at the Earth's surface. ... In this case we assume that the **potential energy of the body** on the surface of the Earth is zero [8].

After the «bounce», and as a result of it, the athlete achieves stabilization of the cyclic set of potential and kinetic energy. Also stabilizes the trajectory of takeoff and fall. Also achieves maximum stability in minimizing «horizontal displacement» relative to the center of the trampoline when coming to the bed. After that, the trampolinist immediately begins performing complex coordination exercises. At the same time, the main task in addition to the successful performance of these exercises in the air is to prevent displacement of the center of gravity of his body from the conditional line (ideally – perpendicular) connecting the center of the trampoline from which was obtained the athlete jerk, breakaway, take-off and movement to the point of «hovering». After completing another complex coordination exercise, the athlete performs an element of «opening», usually near the point of «hanging» and moves down to the bed of the trampoline, preparing to come into contact with it.

When in contact with the bed and its smooth, and soft braking action, the athlete puts pressure on the bed with his feet (or another part of his body) and, squeezing the non-stretchable bed of the trampoline, causes stretching of its anchoring springs.

The springs, by stretching the coils of their spirals, begin to accumulate energy for the subsequent contraction. Later there comes a moment in which the force of the impact of the kinetic energy of the athlete is equalized with the energy of the trampoline springs and there comes a moment of equilibrium of these forces in which the squeezing of the mesh and stretching of the springs stops.

At this point, the trampolinist's body is in contact with the trampoline bed and occupies the lowest position in relation to the floor of the gym. This «hovering» at the lowest point of the trajectory.

When the kinetic energy of the athlete stops acting on the trampoline bed, the springs stop stretching and begin to contract with acceleration. The bed moves upward with acceleration and again produces an upward push of the athlete.

It is important to note the fact that the direction vector of this push depends on the position of the trampolinist's point of arrival on the bed. A perfectly directed vertically upward vector of trampoline bed pushing takes place only in its central point in the «cross-zone» and a small area adjacent to it. If the trampolinist's point of arrival on the bed is moved from the «cross point» to any other point on the plane of the trampoline bed in the direction of its perimeter, the vector of back pushing of the athlete by the bed will be different from the strictly vertical.

Coaches have a term for this – a «thwarted jump». This is a phenomenon where the athlete interferes with the trampoline's ability to push his/her body upward. This mistake lies in the misunderstanding and misconception that the jerk from the bed should be done by the athlete himself or help the bed to push him. This usually occurs either at the lower point of «hanging» or in an attempt to leave to perform a difficult coordination exercise without waiting for the bed to work out the full phase of the pushing.

When coming to the bed with legs slightly bent the knee joints is allowed (but legs can be straight – not bent) to ensure the maximum possible potential in body balance when coming to the bed as oscillating support.

The kinetic energy **Ekin** of an athlete moving with acceleration to the trampoline bed can be determined by the formula

$$Ekin = (mV^2)/2, \quad (5)$$

where: *Ekin* – kinetic energy of the athlete's body, J;

m – athlete body weight, *V* – the velocity of its fall at any point of the flight along the trajectory of its fall, m/s [8].

According to Newton's law of conservation of energy

$$Epot + Ekin = CONST, \quad (6)$$

i.e., the sum of potential and kinetic energy is constant [9]. These two types of energy in the athlete in the course of his performance do not disappear but cyclically transform – pass one to the other depending on the point in the course of his trajectory and the phase of flight. It is important to note that until the moment the athlete touches the trampoline bed in the phase of his downward flight, his body is in a state close to weightlessness.

During the downward movement phase, the athlete comes into contact with the trampoline bed and exerts a force on it as a result of his accumulated kinetic energy. The maximum of this energy is at the moment the athlete touches the trampoline bed. The impulses of force or force impact on a trampolinist to the bed according to the laws of classical physics is determined by the mass of the athlete's body, by the speed of his body the moment he touches the trampoline bed, and, very important(!), by the time (duration) of his body contact with the trampoline bed before it stops bending down and the maximum extension of trampoline springs occurred. This time is the time of transition of the kinetic energy of the trampolinist during the fall, in the potential energy of the metal of the stretched springs. In general, this momentum of force or force impact on the trampoline bed – ***F*** can be determined from Newton's second law by the formula [10].

$$F=(V_{max} \text{ x } m) / T_{к}, \quad (7)$$

where: *F* – the momentum of the arrival force on the bed, N (in newtons) (1 N ≈ 0,10197162 kgf);

V_{max} – the greatest or maximum velocity of the trampolinist's fall on the bed (this is the velocity of his body at the moment of contact with the bed (at the moment of touching it), *m/s;*

m – athlete's body weight, *kg;*

$T_к$ – duration of trampolinist' contact with the bed from the moment of its touching to the moment of its maximum stretching, *s* [5].

It is important to note that from the moment the trampolinist performer comes into contact with the trampoline bed, his downward movement is slowed down by the resistance forces of the bed and the springs of the trampoline, and the air resistance is displaced by the woven material of the trampoline bed between it and the floor of the sports hall. The dominant influence on the braking of the athlete's body has, of course, the bed through the stretching of the trampoline springs.

When in contact with the bed of the trampolinist, the trampoline jumper exerts on it, in addition to the momentum of force, also the pressure ***P*** of one of his body parts (legs or part of the body frame.) The magnitude of the pressure that the athlete exerts on the bed depends on the momentum and the area of contact (contact) of his body with the surface of the bed. The value of this pressure is determined by the formula

$$P = F/ S, \quad (8)$$

where: *F* – the momentum of the arrival force on the bed, in kgf or N (newtons),

and *S* – the perimeter area of the athlete's body part in contact with the trampoline bed (feet, back, abdomen, depending on the type of coming to the bed), m^2.

After the moment of contact with the trampoline bed and as it squeezes downward, the athlete's body speed rapidly slows down. The athlete experiences a greatly increasing compressive load (G-overload). It is directed downward along the athlete's body axis (when coming to the bed with his/her feet) or compresses his/her body torso transversely when coming, for example, on the back or abdomen.

After that, at the moment of «hovering» of the athlete in the lower point of his movement trajectory. This moment, as a rule, has a duration of 0,02 to 0,1 s. After that, the kinetic energy of the fall is exhausted and maximally transferred to the potential energy of stretching of the trampoline springs. The springs begin to contract with acceleration, the trampoline bed with acceleration straightens out of deflection, moving upwards, and the trampoline begins to push the athlete's body upwards with acceleration, transferring to him the energy of the springs' tension. The body of the athlete again begins to experience increasing G-overload from the upward movement and the subsequent takeoff with height gain.

It is very important to understand that the maximum speed of upward movement of the trampoline bed is reached by the moment when the trampoline bed is aligned in a horizontal line. But due to the inertia of the bed (because it has its own mass) and its flexibility, the moment the bed arrives in a strictly horizontal position its upward movement does not stop but continues for a few fractions of a second more and is accompanied by a slight upward bend. Then the bed freezes in the upward bent position and returns to the horizontal position through the fading oscillations of its central part – up and down. Very close by analogy to the bowstring movements in archery [11].

The moment the bed slightly rises above the conditional line of its horizontal position and the moment the athlete finally pulls away from it is the «Moment of Truth». The moment of the true push – the final transfer of the kinetic energy of the bed from the potential energy of the contracting, previously stretched springs to the athlete's body.

As the bed is approaching its horizontal position, there is no need for the athlete to make an independent additional full-fledged push with his legs, much less with his body from the trampoline bed. The real task of a trampolinist at this moment is only to «catch» the jerk of his body by the bed, not to «break» it, and to apply the jerk of the trampoline bed correctly. This term – «to apply» the push by trampoline to your body means to provide the conditions most favorable for the perception of the center of mass of your body vector and force of the push by trampoline, in the direction strictly vertically upwards perpendicular to the support surface of the trampoline structure or perpendicular to the bed. At the same time directing it along the optimal line of movement from the center of the cross area strictly vertically along the line connecting the center of the cross-area with the point at the maximum height of «hovering» above the trampoline.

All of these considerations are realized as accurately as possible only when the athlete is pushed by the bed from the central area of the trampoline.

Tables 1 and 2 show the data of quantitative calculated values of movement parameters of trampoline athletes and forces acting on them, as well as the energies acquired by them, based on the time of their movement from the point of «hanging» to the trampoline bed, the time of penetration of the bed and their age and anthropometric parameters. The data were obtained by calculating using the above formulas 1–8. Time of movement from the hover point was estimated by a special video recording of trampoline jumps with subsequent analysis and quantification of time intervals in slow motion using a special computer program «Kinovea» designed for such actions [12].

Table 1

Estimated Values of Movement Parameters and Forces Acting on Trampolinists Determined Based on Their Movement Time from the Point of «Hovering» to the Trampoline Bed, Time of Squeezing the Bed, and Their Age and Anthropometric Parameters and Training Level

Trampolinist Parameters		Physical parameters of the trampolinist's movement, its impact on the bed, and the impact of the bed on the trampolinist						
Number, Designation of trampo-linist and age, *years*	Body weight, *m, kg*	Time of movement down from the max altitude point to the touching of the bed *T, s*	Time of contact with the mesh before it deflects downwards, Tcont., *s*	Potential energy at maximum point height E_{pot}J	Kinetic energy at the moment of touching the bed E_{kin}J	Momentum of the force incoming onto the bed F, Kgf/N	Residual force momentum after the mesh deflection F_{res}, Kgf/N	Impulse of the trampoline bed push, F- F_{res}= $F_{bat.}$ Kgf/N
1	2	3	4	5	6	7	8	9
1 K 12	39,2	0,66	0.20	822.94	820.45	253.62/ 2511.13	202.9 2008.9	50.72 502.21

End of the Table 1

1	2	3	4	5	6	7	8	9
2 M 15	56,3	0,86	0,42	2004,86	2005,23	475,17 4704,65	275,6 2728,71	199,57 1975,94
3 W	55,0	1.25	0.49	4111,37	4133.46	674,30 6676,24	330,41 3271.35	343,89 3404,85
4 G 20	58,1	1,32	0,53	4873,17	4871.76	752,40 7449,46	398.77 3948,24	353,63 3501,29

Trampolinist designation:
K – male athlete with 1st grade, training stage – SBT;
M – male athlete candidate master of sports, stage of preparation – SBT;
W – female athlete honored master of sports, the stage of preparation – the maximum realization of individual opportunities;
G – male athlete, honored master of sports, the stage of preparation – the maximum realization of individual opportunities.

From the data presented in the tables, we can see how great the forces acting on the athletes in different phases of their programs are. There is a clear correlation of a significant increase in these forces in proportion to the age of the athlete, the growth of his sportsmanship, and his body weight. These forces, naturally increase in proportion to the height of their jumps athletes. It should be noted that the values given in the tables do not take into account the additional loads experienced by the athlete's body due to the performance of complex coordination movements in the air. To assess their influence, as well as to create a full-scale biomechanical model of a trampoline athlete's movement in the air during complex coordination exercises, it is necessary to have wireless remote motion sensors capable of transmitting the necessary information remotely [13]. Unfortunately, Ukrainian sports science does not have such capabilities yet.

Table 2

Physical Values of Trampolinist Height, Trampolinist Speed to the Trampoline Bed at the Moment of Touching, and Pressure Value on the Bed Depending on Some Anthropometric Parameters of Athletes and Their Level of Training

Trampolinist Parameters			**Physical parameters of the trampolinist's movement, its impact on the bed**			
Number, designation of trampo-linist and age, *years*	**Body weight, *kg***	**Foot size / Foot area, S, X $^{10-3}$m2**	**Time of downward movement, T, *s***	**Jump height H, *m***	**Speed at the moment of touching the bed, V, m s^{-1}**	**Pressure on the bed in the contact area, P, kg/cm^2**
1 K 12	39,2	24,5/ 34	0,66	2.14	6.47	7,45
2 M 15	56,3	25,5/ 36	0,86	3,63	8,44	13,2
3 W 28	55,0	26,0 /37	1,25	7,62	12,26	18,22
4 G 20	58	26,5 / 38	1,32	8,55	12,95	19.80

Trampolinist designation:
K – male athlete with 1st grade, training stage – SBT;
M – male athlete candidate master of sports, stage of preparation – SBT;
W – female athlete honored master of sports, the stage of preparation - the maximum realization of individual opportunities;
G – male athlete, honored master of sports, the stage of preparation - the maximum realization of individual opportunities.

Discussion. The real system – «trampoline – trampolinist» is much more complex than the system described above. It is a system in which interconnections are formed between the central nervous system, visual, auditory, muscular, and respiratory subsystems of the athlete, and the mechanism of trampoline operation as a catapult for throwing the athlete's body upwards. The ideal final result of the interaction of these subsystems is the formation of a properly functioning biomechanical model in which the push of the athlete's center of mass by the trampoline and the subsequent retention of the athlete's center of mass as precisely as possible to the vertical line of the «bounce» axis is performed due to the perfection of the automatic unconscious preparation of the athlete at neuromuscular, statokinetic and statodynamic levels. Physiological changes occurring in the above subsystems during trampoline jumps occur: in the central nervous system; in muscles; in visual and motor sensory systems; in heart and respiratory function.

The central nervous system transmits decision command impulses to various muscles. The muscles convert the nerve impulse into mechanical energy, causing various mechanical effects, which begin to be used during the termination of the trampoline bed pushing action.

Conclusions. From all of the above and based on the video recordings and calculations we can draw a number of important conclusions:

1. The design of a trampoline as a mechanical system performs several important functions not only jerk-catching mechanical ones listed above. It allows, with proper training of athletes to perfect the technique of capturing the momentum of the athlete's pushing by the trampoline bed, to achieve qualitatively better performance in such parameters as - the set of higher jumping height and minimization of «horizontal displacement».
2. When teaching trampoline athletes at the early stages and especially at the SBT stage, it is very important to explain and achieve a proper understanding of physical forces and their real values acting on athletes at different phases of flight.
3. In the methodology of training of trampoline athletes, it is necessary to pay more attention to the creation of special new author's training programs aimed at the formation of qualitatively new skills in athletes by improving their statodynamic and statokinetic resistance to statodynamic and statokinetic loads. The relevance and importance of these parameters were previously noted in the literature [14]. But for trampoline athletes, it was formulated for the first time.
4. It is necessary to pay attention to the completely underestimated value of G-overloads that a trampoline athlete experiences at certain moments when performing his programs and that almost none of the modern coaches take into account.
5. It is necessary to develop special complexes of preparatory exercises minimizing the negative influences that lead to some deviations in the trampolinist movements from the ideal model and providing stable correct conscious skills, and stable correct muscle memory.
6. The importance of methods of formation of necessary muscular groups of internal and external muscles, capable to provide the performance of all necessary for the trampolinist's optimum movements is designated. And what is especially important – is the formation of these skills at the initial stages of training, especially at the stages of SBT, as well as at the following stages.

Conflict of interest. The authors declare no conflict of interest.

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