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**Articles**

## Training Devices: New Solutions

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**Abstract**

At present, it is impossible to imagine the physical development of a person without the introduction of modern technologies aimed at the maximum realization of his biological abilities, which are inherent in him from birth. The use of new training devices in the educational or training process allows you to effectively form new motor skills, to develop and improve human movement abilities. The development of training devices is a creative and rather complicated process, since many different fitness equipment which allow to selectively influence various muscle groups of a person have already been created Taking this into account, the development of training devices by us was carried out in two directions: the first is the creation of fundamentally new devices; the second is the improvement of the already created devices. Some of them can be used not only for the development of motor abilities, but also for rehabilitation in medicine. In recent years, teachers of the Faculty of Physical Culture and Sports of Vitebsk State University named after P.M. Masherov (Belarus) have received 11 patents for inventions and utility models in the field of physical culture and sports and sports medicine, which have certain fundamental differences compared to traditional sports equipment and devices. In the article we discuss the features of new technical solutions used in training devices.

**Keywords:** physical development, training devices, movement abilities.

### 1. Introduction

The aim of the work was the development and improvement of training devices for the development of human movement abilities. The article offers you a description of the training devices developed by us: a device for training the muscles of the upper body, a hand expander, a gymnastic bench, a sports weight, a tennis simulator, a device for training basketball players, a gymnastic ladder, a device for developing human power abilities, a device for training muscles of the lower extremities of a person, a device for measuring strength indicators of various muscle groups of a person, a device for restoring mobility and training ankle muscles.

### 2. Material and methods

Research material – training devices for the development of human movement abilities; research methods – patent search, analysis of scientific and methodological literature on the research problem.

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## 3. Discussion

Preservation of essential life values, the main one of which is human health, is assuming ever greater importance in today's world. The deterioration of the ecological situation, irrational and unhealthy diet, sedentary lifestyle, bad habits, stress – all these lead to decreased quality of human life and, in turn, affect life duration. Scientists from various subject areas have to solve more and more issues related to preservation and strengthening of human health. The developers (Vodlozerov, 2003; Evseev, 2003; Shukshunov, 2001) of various gym machines and systems designed for development and improvement of human motor skills do not stand aside from solving these issues. Some works consider the use of exercise equipment in the development of students' motor abilities (Skripko et al., 2013; Sharafeeva, Popova, 2014); others consider the use of training devices during the training process of sportsmen (Zelenin, 2014; Zelenin, Kanaev, 2015). Since 1997, a group of authors from the Faculty of Physical Culture and Sports at Vitebsk State University named after P.M. Masherov (the Republic of Belarus) has been addressing these issues. Our main objective is to help a person unlock their motor potential using various gym machines and devices. In the section of the article "Study results", a description of the gym machines designed by us in the recent years is brought to your notice.

## 4. Results

4.1. A device for training the muscles of the upper body of a person (Patent BY 3975 C1, 2001).

The invention is intended to improve the effectiveness of training by dosing physical activity, depending on the level of physical fitness of the trainee. This object is achieved by the fact that in the device for training the muscles of the upper body of the person containing the traverse and mounted on the traverse means for grabbing hands made in the form of a drum, the outer surface of which is formed on the traverse with the possibility of rotation, and the handrails are installed at an angle of 45-90 ° to each other and performed trapezoidal. In addition, to expand the functional capabilities of the device, drums with different angles between the handrails are mounted on the traverse sequentially (or mutually perpendicular to each other), and the device can be made portable.

The device comprises a traverse with a means for gripping with hands mounted on it, made in the form of a drum. The outer surface of the drum is formed by symmetrically arranged trapezoidal handrails. The drum is mounted on a traverse with the possibility of rotation through bearings.

To dose physical activity, depending on the level of physical fitness of the trainee, you can increase or decrease the number N of the drum handrails, setting them at different angles α with respect to each other. The larger the angle α and the smaller the number of handrails N, the greater the effort a student must expend to rotate the drum. The optimal number of handrails N is from 8 to 4, with α = 45 ° - 90 °. The maximum load is achieved with the number of handrails N = 4 and α = 90 °. With the number of handrails equal to three (N = 3) and α = 120 °, the trainee will not be able to reach the next handrail, and the exercise will become impossible.

To expand the functionality of the device, as well as to provide simultaneous training of several people and increase the motor density of the occupation, traverses are installed drums with different angles between the handrails, for example, with $\alpha_1 = 45°$ and $N_1 = 8$; $\alpha_2 = 60°$ and $N_2 = 6$; $\alpha_3 = 90°$ and $N_3 = 4$.

Moving from one drum to another, the trainee can increase or decrease the load. The drums are installed on the traverse sequentially one after another (or mutually perpendicular to another friend). Any combinations of installing drums are possible, the device can be made portable and mounted on a gymnastic wall or the like.

The device operates as follows. The trainee is in the initial position in the hang, holding the handrail with his hands. Then, taking first with one hand, and then with the other hand the next handrail of the drum, the practitioner causes the drum to turn and again finds itself in its original position. Since the drum rotates with each subsequent interception by hands, the trainee will return to the original position.

Increasing the speed of the exercise, dosing the number of interceptions and the number of revolutions of the drum per unit of time, physical activity is dosed. The invention improves the efficiency of strength training of the muscles of the upper body of a person by dosing physical activity depending on the level of physical fitness of the trainee, and also extends the functionality, increases the motor density of the occupation due to the simultaneous training of several people.

4.2. Carpal expander (Patent BY 8486 C1, 2006).

A disadvantage of the known hand expanders is that their action is aimed only at training a group of muscles that perform the function of extending the fingers to the sides and bringing them to their original position. The load on the extensor muscle group is absent.

The hand expander developed by us contains a ring, to which 4 springs (elastic elements) are sequentially attached at one end, and which is worn on the phalanx of the thumb. The second end of the springs is attached to the rings worn on the distal phalanges of the remaining fingers. The diameter of the rings is adjusted depending on the size of the distal phalanges of the fingers. In the working position, when the fingers are extended and extended, the springs are stretched and the extensors of the fingers of the hand create a load on the muscles. When the fingers are bent, the springs of the carpal expander come to their original position. Hand expander is made of metal or plastic. The carpal expander allows you to effectively train the muscles and joints of the hands, has a simple structure, is easy to use and can be manufactured industrially.

The carpal expander can be used for the rehabilitation of constituent elements (muscles, ligaments, tendons) of the hand and extensor (abducting) fingers of the hand (forearm) damaged as a result of injuries or operations, as well as patients who have suffered an acute cerebrovascular accident with peripheral damage nerves of the upper extremities, for training paretic and weakened muscles, for the education of differentiated movements in the joints of the affected limb.

4.3. Gymnastic bench (Patent BY 9569 C1, 2007).

The invention relates to sports equipment, in particular, to devices for training coordination of movements. Known sports equipment used to train coordination of movements – gymnastic bench. A gymnastic bench is used as a simulator for coordinating human movements in two positions: seat up and seat down. Sports equipment ensures safe exercise. A disadvantage of the well-known gymnastic bench is that, due to the static nature of the device, high training efficiency is not achieved.

The problem to be solved is improving the design of the gymnastic bench in order to increase the efficiency of the exercises for training coordination of movements. The problem is solved in that in a gymnastic bench including a seat, legs, a bar, the latter is installed with the help of metal rods fixed at its ends and can be swung relative to its horizontal axis and slide using bearings fixed in the bar along the surface of U-shaped nests made in legs while in the holes of the U-shaped sockets there are limiters for adjusting the angle of rotation of the beam.

To achieve higher training efficiency, the gymnastic bench is set to the seat down position. The beam is mounted movably relative to the horizontal axis to the legs using metal rods located at the ends of the beam and rotating in the bushings of the legs. When a person moves along the gymnastic bench, the beam makes swinging movements in U-shaped nests using bearings. The angle of rotation of the beam is regulated by limiters.

Training coordination of movements is as follows. Depending on the complexity of the exercises performed, the gymnastic bench is used in 2 positions: seat up and seat down. The greatest effect of training is achieved when performing exercises in the 2nd position of the gymnastic bench. When a person moves along the working surface of the beam, an uneven load on the projectile occurs, causing oscillating movements of the beam relative to its horizontal axis. In this case, a man, trying to maintain balance, trains coordination of movements. Depending on the person's fitness, the angle of rotation of the beam can be adjusted with the help of limiters, thereby complicating the exercises. Gymnastics bench is industrially applicable, as it is manufactured on standard equipment using available materials.

4.4. Sports kettlebell (Patent BY 5035 U, 2009).

Sports kettlebell refers to sports equipment, in particular, to devices for training the muscles of the body. Sports kettlebell can be used for the development of power, speed-strength, coordination abilities of a person.

The problem to be solved is the improvement of the design of sports weights in order to reduce injuries and increase the effectiveness of the exercises when training a person's strength abilities. The problem is solved in that in a sports gear containing a body and a handle, the central part of the handle is movably with the possibility of horizontal axial rotation.

A kettlebell is composed of a body and a handle. The handle has a fixed base and a movable central part, which is fastened with a screw and washers to the base of the handle. Training of a person's power abilities occurs when performing exercises with an upper or lower grip for a rotating handle from various starting positions. When performing motor actions, the wrist and wrist remain in a static position, which leads to a decrease in injuries and an increase in the effectiveness of the exercises by increasing their number and training in general.

4.5. Tennis simulator (Patent BY 5660 U, 2009).

Tennis simulator refers to sports equipment, and can be used in training sessions when playing table tennis, for practicing attacks in a specific predetermined area of the tennis table.

The task to be solved is to improve the design of the tennis table in order to increase the effectiveness of the training when practicing attacks in a specific predetermined area of the tennis table. The problem is solved in that in a tennis simulator containing a game table consisting of two parts separated by a grid, one of the table parts is separated from the second one, makes up one fourth of its area and can move relative to the second part within the boundaries of the area of the tennis table.

The mobile part of the tennis simulator is installed anywhere within the boundaries of the technical table area where one of the players will purposefully send a tennis ball with a racket to practice attacks.

The device helps to improve the accuracy and speed of reaction when performing attacks in different areas of the tennis table, which allows to improve the technique and tactics of the game, enhances the training effect of the training session.

4.6. A device for training basketball players (Patent BY 6426 U, 2010).

A device for training basketball players relates to sports simulators, namely, devices for training basketball players and can be used to correct movements in violation of a person's motor function.

The task at hand is to simplify the design of a device for training basketball players, expand its functionality and reduce manufacturing costs. The problem is solved in that in the device for training basketball players containing a support and guides, the elements are pivotally interconnected with the possibility of changing the position of the guides.

A device for training basketball players contains a support with which the guides are mounted on the crossbar of the gymnastic stairs. The support and the guides are interconnected to change the position of the guides depending on the movement practiced: throwing into the basket, passing the ball.

The device is used as follows. After installation on the gymnastic staircase, using the support, the position of the guides is adjusted depending on the method of throwing. The student becomes his back to the gymnastic ladder, while one of his hands with the ball is between the guides. The movement of the hand is limited by guides that specify the path of the hand. The exercise ends by throwing the ball into the ring or to the partner taking the pass. Repetition of certain movements allows you to form and stabilize the technique of performing special movements and throw accuracy in basketball players and in people with impaired movement functions.

4.7. Gymnastic stairs (Patent BY 6425 U, 2009).

Gymnastic ladder refers to sports and medical equipment, in particular, to devices for training the muscles of the body and correction of deformation of the spinal column of a person. The gymnastic staircase can be used to equip gyms, medical physical culture rooms, rooms adapted for physical education and sports.

The problem to be solved is improving the design of the gymnastic ladder in order to increase the efficiency of the exercises for training various muscle groups and correcting the deformation of the human spinal column. The problem is solved in that in the gymnastic staircase, including vertical racks and crossbars, the latter can move in the horizontal plane along the grooves and be fixed in them by motionless locking elements within the boundaries (front and rear sides) of the vertical racks. To achieve higher training efficiency, the crossbars can be horizontally moved in grooves and fixed in them by stopping elements along the entire length of the gymnastic ladder relative to the vertical plane.

Training of body muscles and correction of human spinal column deformities can take place depending on their individual anatomical abilities. The practitioner is in the initial position – bangle with his back to the gymnastic ladder, a grip on the upper crossbar. The crossbars in the upper half of the gymnastic ladder are installed in accordance with the anatomical profile of the human spine, or taking into account the adjustment of a certain part of the spinal column. In this position in the hanging (static mode) or when performing movement actions (dynamic mode), the necessary effect on the spinal column of a person occurs to correct posture. The starting material for the manufacture of gymnastic stairs is wood and metal.

4.8. Device for the development of human power abilities (Patent BY 6881 U, 2010).

The simulator relates to sports equipment, in particular to devices for the development of human power abilities.

The training device for the development of human power abilities, contains a frame, an axle with a load, a retractable handle, supports made in an arc, while increasing or decreasing the load on the trained muscle groups occurs by lengthening the handle and moving the load along the axis. The technical result is achieved by the fact that, by changing the load, by lengthening the handle and moving the load, in various initial positions, training of all muscle groups of a person occurs.

A device for the development of human power abilities consists of a frame with supports having an arc shape, on which the limiters of movement of the supports are movably mounted. In the middle part of the frame is the axis along which the load is moved. A handle is attached at the ends of the supports, the position of which can be changed by moving along the grooves of the handle mounts.

You can use the device for the development of human power abilities in the following options – *A, B, C, D, E, F, G, H*.

In option *A*, the trainee assumes the initial position lying on his back on the bench, legs straight, heels touching the top of the handle of the device. By bending and straightening the legs at the knees, making movements down and up, the biceps femoris and calf muscles are trained. When performing the exercise, the load decreases when moving the weight along the axis and lengthening the handle; load increase – when moving from the training load along the axis and shortening the handle.

In option *B*, the trainee assumes the initial position standing facing the device, legs apart, grasping the handle with straight arms from above. When lowering and raising straight arms up and down, training of the pectoral, deltoid, triceps muscles and muscle groups of the forearm occurs. When performing the exercise, the load decreases when moving the weight along the axis and lengthening the handle; load increase – when moving from the training load along the axis and shortening the handle.

In option *C*, the trainee assumes the initial position lying on his back on the bench, the legs below are bent at the knees, the feet are brought under the handle. When straightening the legs and returning to the starting position, the training of the straight, tailor, wide muscles of the thigh occurs. When performing the exercise, the load decreases when moving from the training load along the axis and lengthening the handle; load increase - when moving to the training load along the axis and shortening the handle.

In option *D*, the trainee assumes the initial position, facing the device, legs apart, grasping the handle with straight arms from the bottom (reverse grip). When raising arms forward and up and returning to the starting position, the biceps and deltoid muscles of the shoulder are trained. When performing the exercise, the load decreases when moving from the training load along the axis and lengthening the handle; load increase – when moving to the training load along the axis and shortening the handle.

In option *E*, the trainee assumes the initial position, sitting on a chair, his hands in focus at the back, the legs are bent at the knees and pulled to the chest, the feet are located on the handle from above. When legs are straightened and returned to their original position, the muscles of the anterior surface of the thigh, the muscles of the lower leg and the foot are trained. When performing the exercise, a decrease in load occurs when moving to the training load on the axis, and lengthening the handle; load increase – when moving from the training load along the axis and shortening the handle.

In option *F*, the trainee takes the initial position, facing the device, legs apart, grasping the handle with his hands on top. When bending forward (arms straight or bent), and returning to the starting position, the trapezoid, latissimus dorsi muscles are trained. When performing the exercise, the load decreases when moving the weight along the axis and lengthening the handle; load increase – when moving from the training load along the axis and shortening the handle.

In option *G* the trainee assumes the initial position standing facing the device, half-inclined forward, legs apart. The handle is on the shoulders of the trainee, the hands are located on the handle on top.

In option *H*, the trainee assumes the initial position, sitting on a chair, arms at the back, legs straight, feet brought under the handle. When lifting straight legs up and returning to the starting position, abdominal muscles are trained. When performing the exercise, the load decreases when moving from the training load along the axis and lengthening the handle; load increase – when moving to the training load along the axis and shortening the handle.

In all cases, the stops limit the trajectory of the device in accordance with the trajectory of the trainee during the exercise. The training device allows you to increase the effectiveness of training various muscle groups of a person.

4.9. A device for training the muscles of the lower extremities of a person (Patent BY 7594 U, 2011).

The utility model relates to sports equipment, devices for training the muscles of the human body, in particular, for training the muscles of the lower extremities. The device can be used to equip gyms.

The problem to be solved is the development of a training device in order to increase the efficiency of training speed-power abilities of a person, namely, muscles of the lower extremities. The problem is solved in that the device for training the muscles of the lower extremities of a person contains a control panel, a platform, an electric motor, a gearbox, adjustable racks, platforms with crossbars. The technical result is achieved in that the crossbars can move in a circle at different speeds in the horizontal plane.

Speed-strength training of the muscles of the lower extremities of a person occurs as follows. The device is installed on the floor. The practitioner assumes the starting position – a stand in front of the crossbar. When you turn on the crossbar from the control panel of the electric motor, the rails installed on the gearbox platform begin to move in a circle, and the student jumps over them. When performing jumps through rotating rungs, an increase or decrease in physical activity can occur due to a change in the speed of rotation of the rungs, a change in their number from 1 to 4, adjustment of the height of the platform with adjustable racks and adoption of different starting positions by the practitioner. Up to 4 people can train using the device at the same time. When performing jumping exercises, the speed-power abilities of a person are improved, due to the training of the muscles of the lower extremities involved in motor actions in various sports: athletics, gymnastics, acrobatics, etc.

4.10. A device for measuring the strength index of various muscle groups of a person (Patent BY 8765 U, 2012).

The device relates to means for sports measurements and can be used to measure the strength of various muscle groups of a person. The device can be used as a technical tool for measuring the strength indicator of various muscle groups of a person in the educational and training process for "physical education".

The problem to be solved is the development of a device for measuring the strength index of various muscle groups of a person. The problem is solved in that the device for measuring the strength index of various muscle groups of a person contains a platform with guides fixed on it, on which vertical racks with crossbars are mounted with the possibility of movement, on one of which is a sliding clip with a hook for attaching a dynamometer with a belt; at the same time, the measurement of the indicator of muscle strength occurs when the subject performs the traction movement applied to the belt of the dynamometer in various initial positions.

The technical result is achieved by the fact that by moving the racks and the crossbeams of the device, changing the position of the dynamometer when performing vertical or horizontal traction, the measurement of the strength of the muscles of the body in various initial positions of the test subject.

A device for measuring the strength index of various muscle groups of a person consists of a platform with guides on which vertical racks with crossbars are movably mounted. A sliding clamp with a hook for attaching a dynamometer with a belt is installed on one of the crossbars depending on the measured indicator of muscle strength and the initial position of the subject's body.

You can use the device to measure the strength indicator of various muscle groups in a person in the following variants – *A, B, C, D, E, F, G, H, J, K, L, M. N*. In all cases, the test subject is inside the device, changing the position of the body depending on the measured indicator of muscle strength. In option *A*, the subject assumes the initial position while standing on the supporting leg, the other leg is raised forward and bent at the knee joint. The dynamometer is attached at one end to the hook of the sliding clamp on the horizontal bar below the hip of the bent leg, the second end of the belt from the dynamometer is fixed on the thigh of the raised leg near the knee joint. The subject performs a pulling movement of the bent leg up. In this case, the strength of the muscles of the hip flexors is measured.

In option *B*, the subject assumes the same initial position as in option *A*. The dynamometer is attached at one end to the clamp hook on the bar above the hip of the bent leg, with the other end the belt from the dynamometer is fixed under the hip of the raised leg near the knee joint. The subject performs a pulling movement of the bent leg down. The strength of the muscles of the extensors of the thigh is measured.

In option *C*, the subject assumes the initial position while standing on a supporting leg, the other leg is bent back at the knee. The dynamometer is attached at one end to the clamp hook on the horizontal bar below the ankle joint of the bent leg, the second end of the belt from the dynamometer is fixed on top of the ankle joint of the raised leg. The subject performs a pulling movement of the bent leg up. The strength of the muscles of the flexors of the lower leg is measured.

In variant *G*, the subject assumes the same initial position as in variant E. The dynamometer is attached at one end to the clamp hook on the bar above the leg of the bent leg, and the second end of the dynamometer is fixed below the leg of the bent leg. The subject performs a pulling movement of the bent leg down. The strength of the muscles of the extensors of the lower leg is measured.

In option *H*, the subject assumes the initial position, standing on two legs, one arm pressed to the body along the body, the other bent forward in the elbow joint. The dynamometer at one end is attached to the clamp hook on the crossbar installed at the knees from below under the bent arm, the second end of the belt from the dynamometer is fixed on top of the wrist joint of the bent arm. The subject performs the pulling motion of the bent arm up. The strength of the muscles of the flexors of the forearm is measured.

In option *J,* the subject assumes the same initial position as in option I. The dynamometer is attached at one end to the clamp hook on the bar located above the bent arm above the hand, with the second end the belt from the dynamometer is fixed from below under the wrist joint of the bent arm. The subject performs a pulling movement of the bent arm down. The strength of the muscles of the extensors of the forearm is measured.

In option *K*, the subject assumes the initial position, standing on two legs, one arm pressed to the body along the body, the other raised forward and bent upward in the elbow joint. The dynamometer is attached at one end to the clamp hook on the crossbar mounted at the level of the knees from below under a bent arm, with the second end the belt from the dynamometer is fixed on top of the shoulder near the elbow joint of the bent arm. The subject performs the pulling motion of the bent arm up. The strength of the muscles of the flexors of the shoulder is measured.

In option *L*, the subject assumes the same initial position as in option *K*. The dynamometer is attached at one end to the clamp hook on the crossbar located in front of the subject at chest level, with the other end the belt from the dynamometer is fixed at the level of the chest of the subject. The subject performs a pulling movement, tilting the body back. The strength of the muscles of the extensors of the body is measured.

In option *M*, the subject assumes the initial position while sitting on the gymnastic bench, one leg is straightened and located on the bench, the other is bent at the knee and lowered down, hands are arbitrary. The dynamometer is attached at one end to the clamp hook on the crossbar located in front of the test subject at the foot level, the second end of the belt from the dynamometer is fixed on top of the foot in its upper part. The subject performs traction with the foot, bending it toward himself. The strength of the muscles of the flexors of the foot is measured.

In option *N*, the subject assumes the same initial position as in option *M*. The dynamometer is attached at one end to the clamp hook on the crossbar behind the subject's back at the level of the belt, with the other end the belt from the dynamometer is fixed to the back surface of the foot in its upper part. The subject performs the traction movement, the foot unbending it from himself. The strength of the muscles of the extensor of the foot is measured.

A device for measuring the strength index of various muscle groups of a person allows you to measure the strength of various muscle groups of a person to obtain informative indicators of the effectiveness of the training process.

4.11. A device for restoring mobility and training the muscles of the ankle joint (Patent BY 12176 U, 2020).

The simulator relates to sports equipment, in particular to devices for training the muscles of the ankle joint and restoring its function (mobility) after injuries and operations.

A training device for restoring mobility and training ankle muscles contains a frame, a control panel, an electric motor, a gearbox, a disk, spherical joints, a platform for the foot, a locking element, while the disk has a groove in which the spherical joint is movably mounted, movably associated with the platform for the foot, and the locking element is made in the form of a screw with a lamb.

The technical result is achieved by the fact that when the disk is rotated, the platform is movably connected to it, on which the practitioner's foot is located, while adjusting the locking element of the spherical hinge can be moved along the groove, the platform connected to it, from the center to the disk to its edge and back, increasing (or decreasing) the amplitude of movement of the foot in the ankle joint, depending on the individual characteristics of the practitioner. A spherical hinge located on the side of the foot platform opposite from the gearbox is fixedly fixed in the center of the gearbox shaft on the device frame.

A device for restoring mobility and training the muscles of the ankle joint consists of a frame, located on it: a control panel, an electric motor, a gearbox with a disk, a platform for the foot. In the groove on the disk there is a spherical hinge, which is movably connected to the platform for the foot, and when moving it can be fixed in the groove of the disk with a lamb. A foot platform is connected by a hinge to the frame. From the control panel, the speed of rotation of the disk and the associated foot platform are varied.

A device for restoring mobility and training the muscles of the ankle joint allows you to adjust the speed and amplitude of the foot (when moving the platform for the foot from the center of the disc to its edge and back) in the ankle joint, depending on the individual characteristics of the student.

## 5. Conclusion

Our gym machines are designed for development and improvement of human motor skills (power, speed-power, coordination). Some of them can be used in medicine. Thus, for example, a wrist exerciser is used for rehabilitation of injured muscles, ligaments, tendons of the hand; gymnastic bench – for recovery of the function of movement coordination while walking; gymnastic ladder – for posture correction (spinal column). In addition, a device is used for medical purposes to restore mobility and train the muscles of the ankle joint. All gym machines devices can be manufactured using standard equipment and available materials.

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**Impact of Explosive Strength of Lower Limbs on Skating and Running Speed on a 10 M Distance in 14-15 Years Old Ice Hockey Players**

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**Abstract**

The aim of our study was to determine the effect of a specific program of plyometric exercises on the speed of skating and running speed in 14-15 year old youth in ice hockey at a distance of 10 m. The experiment consisted of 39 ice hockey players aged 14-15 years, we included 33 players in the final results (M; 14.7y ± 0.7; 166.5cm ± 7.3; 53.4kg ± 6.9), we eliminated 6 players due to various injuries and absences on all tests performed. The experimental group consisted of (n = 18) players of the cadet team HC 05 Banská Bystrica playing the highest cadet competition in Slovakia. The control group consisted of (n = 15) players of the cadet team MHC Martin, who also played the highest Slovak competition. The experimental set included the experimental factor of a plyometric exercise, performed twice a week on Tuesdays and Thursdays, always before the training unit on ice for 8 weeks. We used the statistical program R for the processing of statistical data, where we determined the statistical significance using the two-factor method of analysis of variance two-way ANOVA $p < 0,05$. The results of tests of the skating speed sprint at a distance of 10 m (on ice) show that neither in the third test was a statistically significant difference $p \leq 0.05$ in either the experimental or the control group. However, after applying the training protocol of plyometric exercises in the experimental set during the first 8-week mesocycle where the experimental set of plyometric exercises was included in the experimental set, there was an improvement of 0.05 s between input and output testing. from the original 2.12 s. to 2.07 s. In the control file, there was a deterioration of 0.02 s between the input and output measurements. from the original 2.11 s. to 2.13 s.

**Keywords:** ice hockey, plyometric exercises, speed abilities.

## 1. Introduction

Ice hockey is one of the fastest team sports in the world. Speed and strength skills play a very important role, but we must not forget dexterity and flexibility, which help players prevent various injuries (Terry, Goodman, 2020). A characteristic feature of the current development of world hockey is the process of its further intensification, increased pace of play, which leads to more performed individual game activities and game combinations (Tóth, 2010). In this context, speed training is becoming even more important, which is one of the important factors in increasing the technical skills of a hockey player. The volume of intense activity performed by the player increases. The player's actions take place under increasing temporal and spatial pressure, which is one of the characteristic features of modern hockey.

In today's hockey, it is necessary to be able to quickly start and overcome various long distances, quickly change direction and speed of movement, perform technical and tactical tasks of

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the game, respond quickly to opponents and teammates, evaluate the situation in the game, adopt rational solutions and perform appropriate actions. Blanár (2019), Paľov (2016), Sobota (2015) worked on similar experiments with ice hockey players, where, among other things, they also tested the speed of skating and running speed in teenagers at a distance of 10 m. There are no more extensive researches in the given issue in science, taking into account the age of hockey players and various variants of test batteries.

## 2. Methods

**Research model:** In our research, we chose a field two-group time-parallel experiment in which we worked with a control (n = 15) and experimental group (n = 18). Input, output, and post-experimental tests were performed in 8-week intervals.

**Study group:**

**Table 1.** Basic indicators of experimental (n = 18) and control group (n = 15)

| | Experimental group | | | | Control group | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Min. | Max. | Mean | SD | Min. | Max. |
| Calendar year (years) | 14.8 | 0.6 | 14.2 | 15.4 | 14.6 | 0.8 | 14.1 | 15.4 |
| Body height (cm) | 165 | 8 | 156 | 173 | 168 | 6.5 | 158 | 175 |
| Body weight (kg) | 52.6 | 7.2 | 45 | 65 | 54 | 6.6 | 48 | 69 |
| BMI | 19.5 | 2.1 | 17.4 | 21.6 | 19.1 | 3.5 | 15.6 | 22.6 |

**Instruments:** The tests consisted of two tests off ice and one test on ice. Before each test, the players warmed up.

**Test 1** – countermovement jump (off ice)

Test characteristics: explosive force of the lower limbs

Test implementation: After adjusting the body height and weight and then placing the Myotest to the belt on the left side, the proband started in a standing position, arms sideways, head straight and motionless position for a short beep (sound signal) proband bends his knees loosely and sets off to jump with his arms at his hips as high as possible, taking the previous position after. Each proband had two trials, the better of the two trials was recorded in the evaluation.

**Test 2** – 10m sprint (off ice)

Test characteristics: acceleration speed at 10 m

Test implementation: It starts from a standing start. At the sign of the trainer, the proband runs out and overcomes the photocells, which are located at a distance of 10 m. Each proband had two trials, the better of the two trials will be recorded in the evaluation.

**Test 3** – forward skating for 10 m (on ice)

Test characteristics: explosive force of the lower limbs

Test implementation: It starts from a standing start. At the sign of the trainer, the proband skates and overcomes the photocells, which are located at a distance of 10 m. Each proband had two trials, the better of the two trials will be recorded in the evaluation.

**Data analysis:** In processing and evaluating the obtained research facts, we applied qualitative methods of comparison, analysis, synthesis, induction and deduction. From quantitative methods, we used basic statistical characteristics such as arithmetic mean, standard deviation, median, maximum and minimum in descriptive statistics. For the processing of statistical data, we used the statistical program R, where we determined the statistical significance using the two-factor method analysis of variance two-way ANOVA $p < 0.05$ (Chráska, 2007).

## 3. Results
### Test 1: countermovement jump (off ice)

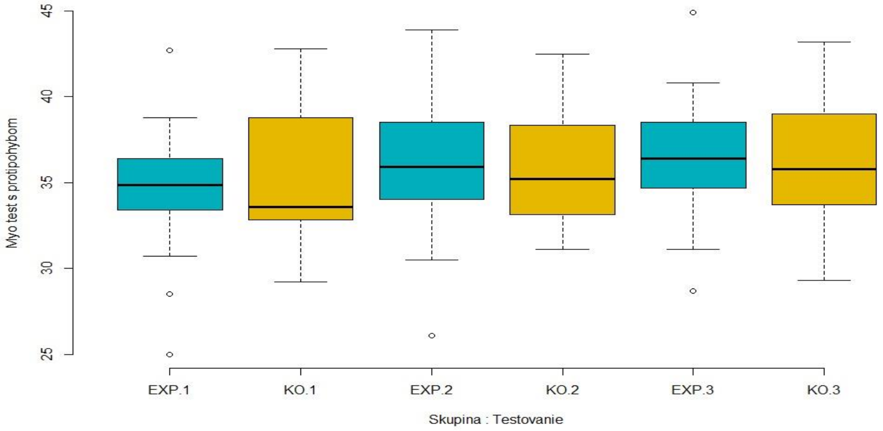


**Fig. 1.** Results of the countermovement jump test (off ice)
Note: EXP 1 – experimental set of input testing, EXP 2 – experimental set of output testing, EXP 3 – experimental set of post-experimental testing, KO 1 – control set of input testing, KO 2 – control set of output testing, KO 3 – control set of post-experimental testing

**Table 2.** Countermovement jump test results (off ice)

| Group | Testing | n | Mean (s) | SD (s) |
|---|---|---|---|---|
| EXP | Input | 18 | 34.50 | 4.00 |
| EXP | Output | 18 | 35.82 | 4.14 |
| EXP | Post-experimental | 18 | 36.26 | 3.76 |
| KO | Input | 15 | 35.34 | 3.84 |
| KO | Output | 15 | 35.84 | 3.50 |
| KO | Post-experimental | 15 | 36.49 | 3.77 |

Note: EXP – experimental group, KO – control group, n – number of probands

Our CMJ test results show that neither the experimental nor the control group showed a statistically significant difference $p \leq 0.05$ in 14-15 year old youth in ice hockey or in the first 8-week mesocycle with the experimental agent in the experimental group or in the second group. 8 week mesocycle without experimental factor. Between input and output testing in the experimental set, probands achieved an improvement of 1.32 cm. In the post-experimental period, the probands again achieved an improvement of 0.44 cm between the final and post-experimental testing. Probands in the control group achieved an improvement of 0.5 cm between input and output testing. In the post-experimental period between the final and post-experimental testing, they achieved an improvement of 0.65 cm. The results show that the probands in the experimental group during the first 8-week mesocycle with the experimental factor in the experimental group achieved more significant increases in the explosive power of the lower limbs than the probands in the control group.

**Test 2: 10m sprint (off ice)**

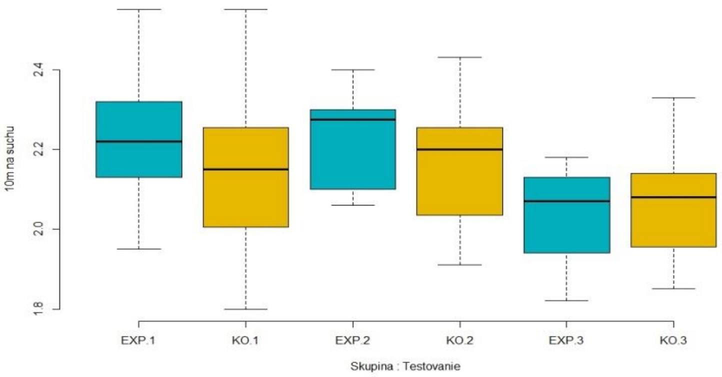


**Fig. 2.** Results of 10m sprint test (off ice)
Note: EXP 1 – experimental set of input testing, EXP 2 – experimental set of output testing, EXP 3 – experimental set of post-experimental testing, KO 1 – control set of input testing, KO 2 – control set of output testing, KO 3 – control set of post-experimental testing

**Table 3.** Results of 10m sprint test (off ice)

| Group | Testing | n | Mean (s) | SD (s) |
|---|---|---|---|---|
| EXP | Input | 18 | 2.22 | 0.14 |
| EXP | Output | 18 | 2.22 | 0.11 |
| EXP | Post-experimental | 18 | 2.03 | 0.11 |
| KO | Input | 15 | 2.14 | 0.19 |
| KO | Output | 15 | 2.15 | 0.15 |
| KO | Post-experimental | 15 | 2.06 | 0.14 |

Note: EXP – experimental group, KO – control group, n – number of probands

**Test 3.** 10m sprint (on ice)

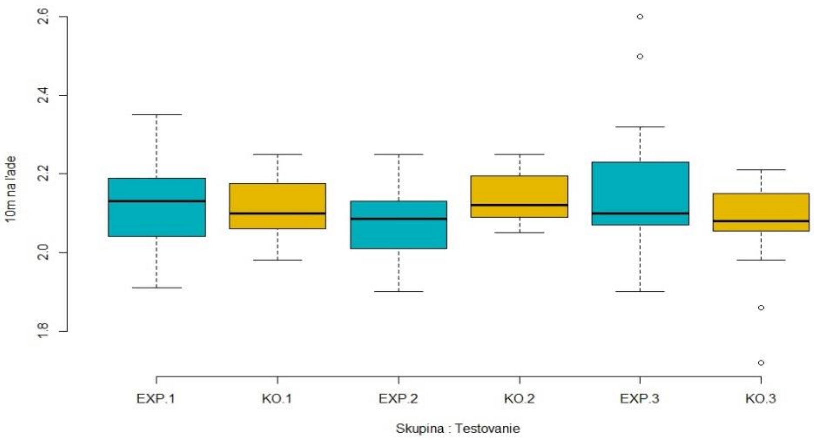


**Fig. 3.** Results of 10 m sprint test (on ice)
Note: EXP 1 – experimental set of input testing, EXP 2 – experimental set of output testing, EXP 3 – experimental set of post-experimental testing, KO 1 – control set of input testing, KO 2 – control set of output testing, KO 3 – control set of post-experimental testing

The results of the sprint test at 10 m (off ice) show that a statistically significant difference $p \leq 0.05$ was not demonstrated between the experimental and control groups in any of the three tests. In the experimental set there was no difference between input and output testing, probands achieved identical times of 2.22 s., Subsequently achieved a slight improvement only in post-experimental testing where they improved by 0.19 s. In the control file, there was even a slight deterioration between input and output testing from the original 2.14 s. to 2.15 s. Similar to the experimental group, as well as in the control group, there was an improvement only in the last post-experimental measurement, where the probands from the control group improved by 0.09 s. compared to the output measurement. Again, both in the first CMJ test and in the 10 m sprint test (off ice), thanks to the experimental factor of plyometric exercises, more significant increases in speed abilities were observed in probands in the experimental group.

**Table 4.** Results of 10m sprint test (on ice)

| Group | Testing | n | Mean (s) | SD (s) |
|---|---|---|---|---|
| EXP | Input | 18 | 2.12 | 0.11 |
| EXP | Output | 18 | 2.07 | 0.09 |
| EXP | Post-experimental | 18 | 2.15 | 0.17 |
| KO | Input | 15 | 2.11 | 0.08 |
| KO | Output | 15 | 2.13 | 0.06 |
| KO | Post-experimental | 15 | 2.06 | 0.12 |

Note: EXP – experimental group, KO – control group, n – number of probands

The results of tests of the skating speed sprint at a distance of 10 m (on ice) show that neither in the third test was a statistically significant difference $p \leq 0.05$ in either the experimental or the control group. However, after applying the training protocol of plyometric exercises in the experimental set during the first 8-week mesocycle where the experimental set of plyometric exercises was included in the experimental set, there was an improvement of 0.05 s between input and output testing. from the original 2.12 s. to 2.07 s. In the control file, there was a deterioration of 0.02 s between the input and output measurements. from the original 2.11 s. to 2.13 s. Post-experimental tests, on the other hand, show us an improvement in the control group and a deterioration in the experimental group.

## 4. Discussion

Brooks (1996), Caceka (2007), Horčička (2009), Pupišová (2013), Šimonek (2007), Vanderka (2006) and others have shown a positive effect of plyometric exercises on sports performance. Our CMJ test results (Table 2) agree with the results of Faigenbaum et. al. (2007) where he worked on research with 12-15 year olds, the experimental factor was also plyometric exercises for 8 weeks and a statistically significant difference $p \leq 0.05$ was not demonstrated, but his probands also improved.

Our results of the 10 m (off ice) sprint test (Table 3) coincide with the results of Kotzmanidis (2006), who worked on research with adolescent players. After applying a 10-week program of plyometric exercises, no statistically significant difference $p \leq 0.05$ was demonstrated in the 10 m sprint test. Our results show that even in the test of the running speed sprint at 10 m, a statistically significant difference $p \leq 0.05$ after the application of the 8-week training protocol of pylometric exercises in the experimental group was not demonstrated. Our results are partially consistent with those of Singh, et. al. (2018), who tested hockey players in two groups, did high to low plyometric exercises in one group and low to high in the other, while in the high to low group there was a statistically significant improvement in the 10m sprint test and in the low to high group the probands even worsened.

Our 10 m sprint test results (on ice) (Table 4) do not agree with Deahlin, et. al. (2017), who worked on a similar research with players of adolescent age (+2 years) who, after 8 weeks of training in plyometric exercises, showed a statistically significant difference $p \leq 0.05$ in the 10 m skating test.

## 5. Conclusion

The influence of plyometric exercises on the speed of skating has not been addressed by many authors so far. A few studies already exist, but more attention should be paid to this issue. Our results show that the 8-week training protocol of plyometric exercises in 14-15-year-old ice hockey players did not show a statistically significant difference p ≤ 0.05 in any of the tests. However, in each test between the input and output tests, the probands in the experimental group achieved a more significant improvement thanks to the training protocol with plyometric exercises.

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# The Tennis SensoriMotor Synchronisation Paradigm

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**Abstract**

The author proposes a new Paradigm for both research and practice regarding tennis. Sensorimotor Synchronisation (SMS) is the scientific field studying how people may synchronise their actions to an external stimulus (a pacer). SMS provides the most relevant set of concepts to tennis because synchronisation with both the ball and the opponent is the most decisive factor for performance: ball directionality, early preparation and economy of movement are all affected by good synchronisation skills but not so much by reaction time. In martial arts schools, synchronisation is the golden chalice of superior performance, which leaves many questions about the choices that have been made in tennis. Here, after a mini-review of SMS-related concepts and terms, an SMS application to tennis will be proposed and some drills will be described for the first time. Not all questions will or can be answered here, however a new Research Programme should be emerging: as is the case in all Programmes and Paradigms, they cannot be directly tested but they offer the background for specific experiments to follow. Tennis SMS is also compatible with bioinformatics since expert systems may be developed to both monitor and improve synchronicity.

**Keywords:** bioinformatics, distal method, motor skills.

## 1. Introduction

The Distal Method is a broader Paradigm (in the classic sense of Kuhn's Scientific Paradigms) about expertise attainment. It combines western scientific knowledge, epistemology and traditional School[*] insights. This means, its methodology is superior – (see for example Papageorgiou and Lekkas, 2020) while its applicability is maximised; in other words, while its theory is general, its applications (e.g. as guidelines and methods) are specific, practical and oftentimes deceptively simple.

The main application of the Distal Method has been in tennis and indeed, the main volume of publications concerning the Method, is about tennis (Papageorgiou, 2016; Papageorgiou, 2019; Papageorgiou, 2020; Papageorgiou, Papadopoulos, 2018). With this paper, a new Paradigm will be introduced; one that should have already been the main focus for researchers in tennis: The Sensory-Motor Synchronisation (SMS) Paradigm for Tennis (tSMS). Why SMS? Because it is what we mostly do in tennis: synchronise (not react) with an external pacer (both the opponent and the ball) – not to mention internal coordination themes (such as the kinetic chain). The SMS

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[*] A School is any system that aims at, and provides tools for, spiritual growth. Such schools are Aikido, Yoga, Vajrayana, Tantra, Mathematics (in the classical Greek sense), Art (various forms) etc. School methods and structures have not been adequately studied by western science; indeed, such a subject is often considered a *taboo*.

Paradigm resonates well with the Distal Method but is also an independent Paradigm for researchers to follow from now on in tennis (and even other sports).

This paper has three parts. In the first part I will select and present the most relevant SMS findings for tennis, along with some implications for practice. The second part consists of practical applications. There is an increasing cost along this path, since it cannot be crossed *salva veritate*: the most relevant theoretical and experimental findings are selected based on, and limited by, my own knowledge, perception and criteria. However, they accurately reflect the literature findings. One step further are the implications for practice. These implications are even more affected by my own judgment, previous experience and understanding; other researchers could propose different implications for practice – and this is fine. Taking the farthest step, we find the applications for practice. This step requires an even more catastrophic (for truth) process than the previous one (implications for practice). Catastrophic, save necessary. It is like proposing a Research Programme*; everything I propose may be a subject for various experiments, no matter how reasonable and plausible it may sound. This is my goal after all: to initiate a Paradigm, not to exhaust its implications and applications by myself in a single paper. The third part will propose ways for bioinformatics to be applied to tSMS.

## 2. Results and discussion

### From SMS to tSMS

Under the broader SMS Paradigm all relevant research takes place which has to do with the coordination of rhythmic movement with an external pacer. The basic mathematical discipline which deals with periodicity is the theory of music (but not the western one). The basic axiomatic foundation of this theory is the Fourier Analysis. The focus of the researchers in SMS spans all the way from the classic finger-tapping and metronome coordination, to interpersonal coordination of "hyper-followers", and to music ensemble performance. Two excellent reviews covered the most important aspects of research in the SMS until 2013 (Repp, 2005; Repp, Su, 2013). By no means is this an attempt to *repeat* the findings presented in greater detail in these two reviews. I refer the reader to these reviews as I consider them to be essential reading on this subject.

One relevant finding which should be stressed early on, to demonstrate the importance of SMS for tennis, comes from both visual occlusion and moving-target interception studies. Many such studies support that the opponent (in tennis and other sports) is a valuable source of information in the "prediction" of where the ball will go (Müller et al., 2006; Rowe et al., 2009; Müller et al., 2010; Goulet et al., 2016). It is not just the ball's trajectory; crucial fragments of information are revealed from the movement of the opponent's body (this is why bluffs and disguise happen in tennis). That is to say, we do not just coordinate – or even react – to the incoming ball which "appears" out of thin air; the coordination sequence starts before we get to see the ball, from kinematically relevant sources of information taken from the way the opponent moves; this skill to take advantage of contextual information is an hallmark of expertise (Murphy et al., 2018). It is a sort of "dance" between us and the opponent, not just a coordinated intercepting action against a moving target (the tennis ball).

### Basic terms

When referring to coordination, we usually mean *intentional coordination* which happens in cases where actions are intentionally coordinated with referents. Research (and common experience) has shown that SMS behaviour can also spontaneously emerge (relative coordination), especially in cases where we interact with a periodic phenomenon (Repp, 2005). In reality, there is a *continuum* between the two extreme consciousness states, not just a flip-flop between being fully aware or unaware of our coordination activity; coordinating with stimuli happens with various degrees of intentionality. There is a constant transition from intentional to unintentional coordination (and *vice versa*), exactly the way our control of breathing is constantly drifting from intentional to unintentional. This happens even in tennis: contrary to what we may believe, automaticity soon takes over and our intention to coordinate gradually vanishes until we discover we have "lost our focus", we have been hypnotised i.e. we have lost our intention, but alas, we only realise it too late. On the other hand, being too intentional (if we may say so), makes us rigid and

* I am referring to Imre Lakatos' Research Programmes.

anxious. The only real solution is to train our automaticity consciously, create reliable patterns, anchors and subdivision strategies (as we shall see in the process).

The external pacer has a rhythm; the minimum period between two reference points (such as the clicks of a metronome) is called *Inter-Onset Interval* (IOI). In theory (maths), we can have just one periodic phenomenon (one IOI so to speak) with an infinitely long period. The biggest known period in the universe is from the Big Bang to the next Big Bang. Below many orders of magnitude are the periodic phenomena occurring in, say, tennis. In tennis too, we can have a unique IOI and consider it periodical (it is a matter of using a suitable approximation theory which will help us decide how to treat each IOI in relation to others). The *Inter-Tap Interval* (ITI) is the period between two successive actions of an individual who is coordinating *somehow* with the IOI: indeed, an individual's ITI may coordinate in many ways with the external IOI. The IOI and the ITI may be *in phase* (even number of periods spanned by IOI and ITI) or antiphase (π rad difference between IOI and ITI) – see Figure 1. Other phase relationships are possible, but pose greater difficulties for the individuals (Mechsner et al., 2001). Moreover, there can be many IOIs for each ITI (1:*n*, meaning that 1 ITI is divided by *n* IOIs), or many ITIs for each IOI (*n*:1, meaning that 1 IOI is divided by many ITIs). When synchronising with the IOI, what we choose as the rhythmic pattern is called *tactus*, or the "preferred rhythm" (e.g. the "beat" of the music).

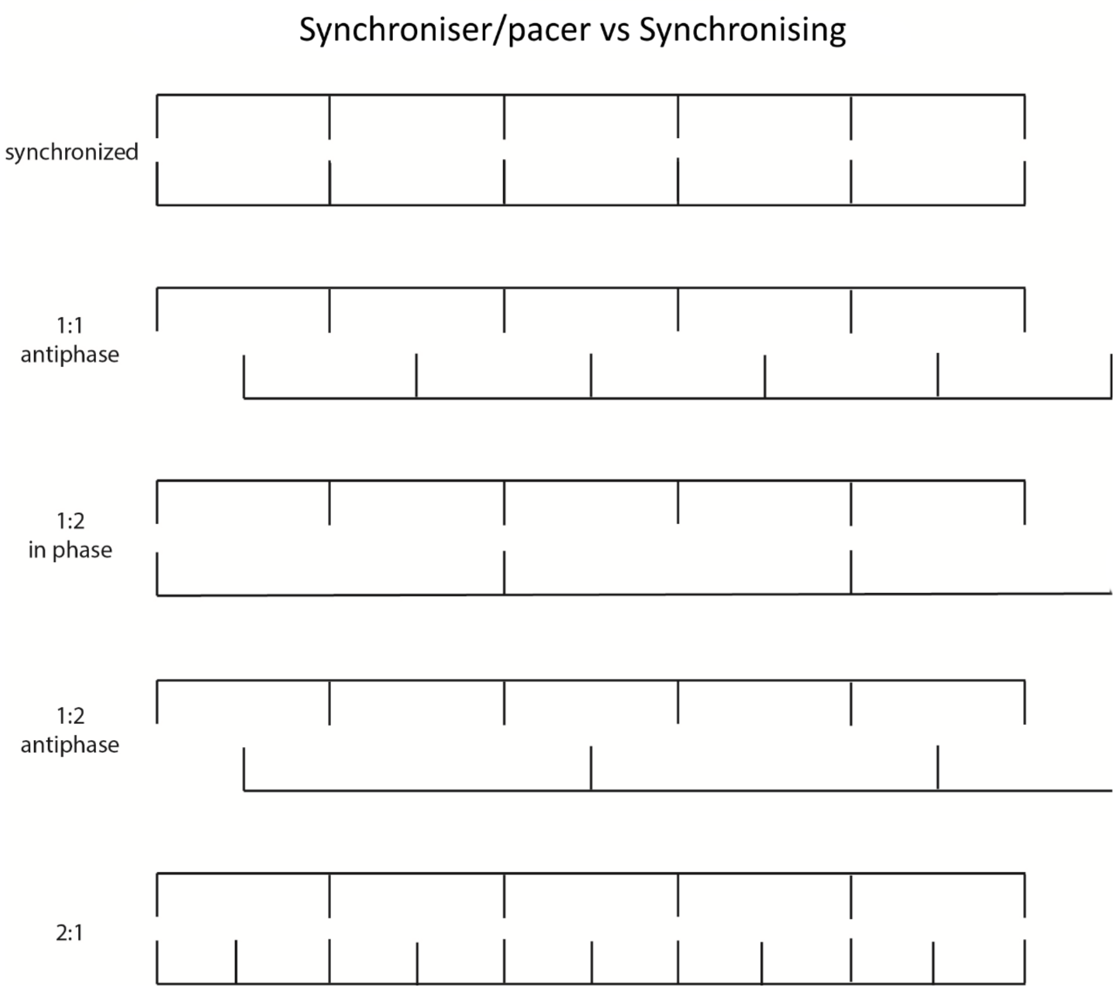


**Fig. 1.** Various synchronization cases between the pacer (IOI, always on top in the graph) and the synchronising (ITI, always on bottom in the graph)

For tennis, a good fit would be to consider as IOI the period between contact point (opponent's racket) and ball bounce on our court. Two IOIs would be: from the opponent's contact point until our own contact point (if the second IOI is of the same time-length as the first one).

Hitting on the rise, or hitting a second volley, would be hitting in antiphase. If we considered only phase and antiphase, all other strikes should be reducible to these two cases.* How would we decide which stroke is reducible to hitting in phase or in antiphase since many strokes clearly do not coincide with either (e.g. half-volleys)? A theory of approximations is needed, not only for tSMS or SMS but for the whole of western science. An epistemologically intense theory that helps us categorise the measured (ITI) in terms of the measure (IOI); the approximating (ITI) in terms of the approximated (IOI). Until then, we shall just use our common sense and best-guess what is *what* (e.g. smashes would be in-phase, while second volleys would be antiphase).

*Negative Mean Asynchrony* (NMA). A universally occurring phenomenon in SMS is that actions tend to precede signals: we tend to act too soon instead of in time or too late (Repp, Su, 2013). NMA also shows we *anticipate*, rather than *react*, to pacing stimuli – a difference detectable on the neurophysiological level as well (Pollok et al., 2008). NMA is of course an error, and the reduction in synchronicity errors is the focus of the emerging tSMS Paradigm.

**Synchronicity themes**

*IOI limits.*

Are there limits to IOIs – and what is meant by that? Limits to the IOI perception have long been identified (Fraisse, 1982). The IOI can be too long or too short and this could disrupt our coordination, but for different reasons. When the IOI is too short, there are two consecutive limits. The first one is the biomechanical limit. For example, in the tapping research protocols, it occurs when the participants cannot physically move their fingers any faster. In such instances the biomechanical limit is about 200 ms (Truman, Hammond, 1990). For tennis it should be much higher, since moving the lower arm-racket system is more difficult (in terms of inertia) than moving a single finger. But, even 200 ms is not our perceptual limit. Using two fingers instead of one, we are able to bypass the biomechanical limit and reach the perceptual limit where loss of SMS perception takes place. For expert participants (e.g. musicians), this limit is a bit more than 100ms (Repp, 2003). The upper limit is slightly less than 2s (1800 ms). What happens after that? SMS, which is based on anticipation and prediction, becomes reaction-time-dependent and participants' ITI tends to lag behind the IOI.

Several possible solutions exist in tennis for the problems posed by the IOI limits. As we move towards the lower limit, the stroke's kinetic chain could also start shifting from serial to one-unit (biomechanical adaptations). A form of subdivision benefit may be used in both types of limits, both as an anchoring method (long IOIs) and as a coordination enhancer (short IOIs). Metrical accents could also provide better coordination in both cases.

*Types of stimuli.*

What do we tune to? There are many possible types of rhythmic stimuli (at least as many as our senses). Three specific cases are of special interest for us: auditory, static visual and moving visual. Static visual pacers (flashes) are far worse pacers than auditory ones, that is, they are more difficult to follow (Repp, 2003; Lorås et al., 2012). Moving visual pacers fall in between being worse pacers than auditory, still far better than static ones (Repp, 2003; Hove et al., 2010). These differences may be of neurophysiological origin (Ruspantini et al., 2011). Auditory pacers are the easiest to follow, maybe due to the strong auditory-motor coupling on the neurophysiological level (Grahn et al., 2011).

Now, when it comes to coordinating with others, we do not need to put a lot of thought into it: coupled participants mutually and unconsciously adjust their ITI's, becoming a sort of "hyper-followers" (Konvalinka et al., 2010; Nowicki et al., 2013). They even synchronise their brainwaves (Lindenberger et al., 2009)! The human mirror neuron system seems to be responsible for this ability to coordinate with our opponents (Denis et al., 2017). Coordinating our actions with others increases positive feelings towards the other person and bonding, especially when the pairing synchronisations becomes more accurate (Hove, Risen, 2009; Kleinspehn-Ammerlahn et al., 2011). Coaches should stress and train the shared intentionality, which leads to better mutual coordination. They should also try to explain to their athletes, what "chemistry" between two players is all about and how to intentionally achieve joint attention as a common goal.

* There are many other ways to divide IOIs and that could be the subject of another article.

*Source of errors.*

Two main sources of errors may be recognised: central timekeeper, related to perceptual/behavioural aspects, and peripheral, related to motor centres (Repp, 2005). The first type is more error-prone than the second one – and this is a good thing since peripheral sources of errors is more difficult to address as they are related to *abilities* and not *skills*, hence they are stable and change-resistant. On the other hand, there are plenty of strategies to improve our perceptual skills, such as the *conscious automatization process* (Papageorgiou, 2014; Papageorgiou, 2016)*: train automaticity consciously, do not just "let it happen". To that extent, the Performance Spiral is a suitable method (Papageorgiou, 2019).

Before we get too excited, however, we should first confirm that SMS is trainable – and to what extent? In SMS studies, when untrained individuals are compared to expert musicians for example, the asynchronies are twice as large for the novices (Repp, Penel, 2002). This sounds as an impressive feat but how early can we reap the benefits of such an improvement? Even though SMS takes years to develop, reliable SMS is already achieved from three or four years of age; almost adult-level SMS is achieved by seven or eight years of age (McAuley et al., 2006; Kirschner, Tomasello, 2009). Having in mind that mature motor skills of all types (manipulation, ballistics, locomotion and stance) can reach maturity at about six years of age (Gallahue, Ozmun and Goodway, 2012), but also, that SMS and motor skills are the most important factors in tennis performance (in tSMS Paradigm), we reach a very interesting conclusion: by the age of 7 or 8, players with perfect form† could have developed (Papageorgiou, 2020b).

*Event Onset Shifts* (EOS) and *Adaptive Correction Responses* (ACR).

So, we follow an external pacer, but unexpectedly (or expectedly in. e.g. music *ritenutos*) the IOI is disrupted, either momentarily or continuously (Schulze et al., 2005; Repp et al., 2012; López, Laje, 2019). Such disruptions in SMS are called EOS and they are dealt with by ACR. ACR to EOS can cause errors (asynchronies to the next action) and this is the main reason we study them. ACR can be both intentional (e.g. music) and unintentional (automatic). In the special case we know EOS will happen our response is called Anticipatory Phase Correction (APC). APCs are important because they show us that intentional control may be exerted.

As is customary in the Distal Method, we always practice on and around the transition point – whatever that may be. Practicing around transition points is based on both the *deliberate and well-structured practice* approach of K.A. Ericsson and the classic *zones of proximal development* of Vygotsky (Papageorgiou, 2014). EOS provide us with such opportunities, especially in the case of APCs where we may attempt to stretch the limit of the APC we are able to make. Probably, from a point on, APCs revert to unexpected EOS corrections (or may be treated as such in an approximation theory). Anchors and subdivision strategies may be developed to help us deal with such (very usual) types of asynchronies.

Everything described until now is nice, but it presupposes that we have tuned to a pacer. So, *when* do we really start getting in tune? It seems we need at least three signals to "catch" the IOI and synchronise with it ("period setting" in Repp, 2005; see also Semjen et al., 1998). That makes the return of the serve a borderline case since we have to synchronise to two signals, i.e. one IOI (from the opponent's racket to the bounce in our service box). This seems to be as a problem seeking a solution.

Our previous experience may be helpful in quickly adjusting or anticipating the interceptable object (the ball). However, this is only a passive process which takes some time to build up and doesn't feel like a good competitive strategy. A much more useful solution could be *mental imagery*. Indeed, SMS is responsive to such approaches and this is also backed up by neuroscientific studies showing how similar the brain responses to covert and to overt SMS are (Osman et al., 2006). In a way, for the brain, it is the same thing whether we imagine something or actually experience it (Gentili et al., 2010). Since the main causes of errors are central, mental

* Based on the "attacking attractor" model, we attempt to consciously deepen suitable attractor basins and prevent recidivism to older coordination patterns.

† In the Distal Method we have at least three such components: *technique* (the biomechanical model drawn on a piece of paper), *form* (application of the model to a human body) and *style* (personalized form after years of practice). The other components are: *sense* (universal), *feeling* (personal), *emotion* (sum of feelings), *tactics* (set of sequences of skills, if "skill" is e.g. a specific technical form/tennis stroke), *strategy* (set of tactics), *life purpose* (set of strategies).

imagery seems as a fine strategy to apply to serve-returns. This way, the problem of tuning may be transformed to a problem of ACR or even APC, in case the actual pace of the serve is different from what we have imagined.

*SMS control.*

The final theme that I will discuss is one with many philosophical connotations, even though I will stick to the behavioural (and neural) ones: do we control SMS or does it control us? Experiments have taken place based on the pseudo-SMS methodology: participants were called to discern whether they were, or were not, in control of an isochronous metronome that unbeknownst to them, switched to feedback mode and vice versa (Repp, Knoblich, 2007). In both cases it took the participants several IOIs before they detected a shift in control. Not only that: participants were biased towards judging in favour of being in control. Just the causal belief about the locus of control by itself is enough to change the relative contribution among the sensorimotor networks (Buchholz et al., 2019). An important finding for us is also that when the feeling of control was ambiguous, performance was disrupted (Couchman et al., 2012).

This magical feeling of control should be enhanced and we must create exercises that both establish it (based on e.g. the tactus of the learner) and extend (or transfer) it to more difficult coordination patterns (always by working on the transitional points). Stressing control may also have implications for Csikszentmihalyi's flow state where the feeling of control is maximised (Csikszentmihalyi, 1990; Weinberg, Daniel, 2015). Playing, while being "in the zone" is one of the most universal characteristics of world-class performers, and it can be taught. Breathing exercises may also support this process.

As the final and most general message to take away, I will sum up the previous discussion in the phrase: *synchronization enhances basic perceptual and motor skills*.

**Practical applications in tennis**

*Directionality vs orientation.*

In our approach, having court orientation is the static skill of being able to accurately point to specific parts of the court without directly looking at them. Directionality is the skill of directing the ball to the desired target. Orientation is the prerequisite: we may be able to accurately direct the ball to where we *thought* the target was, even if we were mistaken about the location of the target. However, orientation does not guarantee directionality: we may accurately know where the target is but fail to direct the ball there. Directionality is heavily dependent on SMS; orientation is not.[*] All dynamic movements in tennis are affected by directionality, hence by SMS. This is the basic understanding we need to establish before saying anything more about tSMS.

*IOI in tSMS.*

The first theme in tSMS has to do with our decision to define the IOI. As is the case with everything I say from now on, this is also open to discussion and reform. But I will go on and attempt to establish the basics based on my own understanding.

What IOIs can we establish in tennis? An IOI from the opponent's contact point until the ball bounce to our court, seems to be the most appropriate candidate since it is easily identifiable, within the IOI limits and relevant to our decisions. Similar IOI would be from contact point to contact point (a necessity when it comes to volleys) or even from opening our rackets until the contact point (if we assume perfect control and the feeling that we set the IOI ourselves). This way one could view the period from the opponent's contact point until the bounce in our court as either the IOI or the ITI. Let us conventionally define IOI as the period between these two "clicks" (contact point – bounce). In this approach, the period from contact point to contact point is considered two IOIs.

*Subdivisions.*

In any way a task (skill) is organised (part or whole practice), two basic rhythms are proposed, 1:3 (123) for novices and 1:5 (12345) for all other levels. 1 in both cases may be the ball's contact with the opponent's racket and the ball bounce coincides with 2 for novices and 4 for all others. 3 and 5 correspond to (our) contact point. 1 may also be named as "check" salva veritate (instruct the player to check). Especially in the case of 1:5, the subdivision of the IOI is not symmetrical but seems to work very well with the flow of the game. In that case, 4 may coincide with the bounce of the ball or not (later if we face lobs and earlier if we play more aggressive shots).

[*] On the other hand, orientation may be affected by internal *Zeitgebers*; periodicity is always present in life!

*Metrical accents.*

Exercises should also target the unification of the contact point with that of the end position, in order for us to be able to incorporate metrical accents into our shots. One such exercise is proposed in the tennis Distal Method Coach Development program which uses the concepts of the universal reference point (the furthest point *after* contact point that the kinematics of the stroke remain the same) and of the hitting position (the furthest point *prior to* contact point that the kinematics of the movement remain the same). An advantage of this exercise is the unification of *part practice* with *whole practice* (or the shift from part to whole practice – a never ending process according to the Performance Spiral). The unification happens as follows: either using only 1:2 or 1:5 subdivisions, the whole movement is performed in three stages:

I. from contact point to contact point (almost no motion at all);
II. from hitting position to universal reference point;
III. from opening position to end-position.

The periods (time) from contact point to contact point; from contact point to universal reference point (II), from contact point to end position (III) should be equal in length.

*Antiphase and in-phase.*

Generally speaking, hitting the ball on the rise should be considered antiphase while hitting later should be viewed as in-phase (and hitting a semi-volley or volley or smash could all be categorised as in-phase). A good idea would be to start from in-phase strokes and then proceed to antiphase (before trying to mix them in any sort of serial or random practice programs).

*Training more complex rhythms.*

Apart from in-phase and antiphase there are more complex rhythms (such as ¾). More complex rhythms tend to revert to more stable[*] rhythms as we speed up to reach the Phase Reversion Point. Again, practicing at, and around that, (transitional) point is deemed necessary (in this Paradigm). Let us first see some ideas about IOI subdivisions that may be helpful in various conditions, from standard baseline rallies to volleys, returns, high-speed strokes etc. The general idea is:

A. 12345
B. 2345
C. 345
D. 45
E. 5

As simple as this classification may be, it includes all possible and trainable cases. A possible interpretation of this 12345-based subdivision method is that 4 in the cases of A, B and C corresponds to the ball bounce whereas cases D and E have no ball bounce (D could be first volleys and E could be second volleys which are closer to the net). Case C could be serve returns and case B could be used in fast baseline rallies. Case A in slower rallies. In all cases the first number designates the ball's contact point in the opponent's racket. Again, practicing these rhythms would require the proper use of practice programs (where "proper" in the Distal Method Paradigm is exemplified by the two kinds of periodisation protocols known as Performance Spirals, one for motor skills and one for physical conditioning).

*Antifragility…*

… which is expressed in sports as the *contextual interference effect* should also be a part of the practice – for antifragility (see Taleb, 2012). The introduction of perturbations and of distractor stimuli is an effective way to achieve that. In the case of SMS (and tSMS), the closer the distractor sequence is to the IOI, the more difficult the drill becomes.

*Practicing on the two IOI limits.*

In respect of the biomechanical limit, there would be a critical ITI which would designate the transition of a *serial kinetic chain* to a *unit kinetic chain*. That critical ITI should be treated as a transitional point. When the biomechanical limit poses less threat (in longer IOIs), using varying metronome sequences might be beneficial (hence the development of the tSMS app).

[*] westerners are addicted to a certain type of music that is based to simpler rhythms, such as 2/4 or 4/4). I say addicted because all modern western music is based on the tempered system; Helmholtz doubted that people will ever tolerate such dissonant musical intervals, alas, here we are listening to only such music…

For the upper limit, where SMS becomes reaction time, subdivisions strategies and cognitive anchors might do the trick. Both may be achieved by the 12345-subdivision strategy presented earlier. When the two limits have been practiced, they should be mixed as the random-practice rationale would dictate.

*Anticipatory phase corrections.*

The use of metronomes (or applications such as the tSMS app) could be used to achieve smooth speed changes (both accelerations and decelerations of the tempo). Tempo changes could be small or big up to the point of losing synchronicity. Again, transitional points should be identified and practice should revolve around them. Finally, practicing in many rhythmic variations should also be attempted (in-phase, antiphase etc.).

*Serve returns.*

Serve returns are identified as one of the most important strokes (since, like serves themselves, you cannot avoid them). 345-subdivision strategy is proposed. 3 would coincide with the check. In the first learning stages, the finish of the check (landing on both feet) should coincide with ball's contact point at the opponent's racket (in-phase). Later on, an antiphase strategy is preferable (contact point to coincide with our feet's greatest distance from the ground. 2 (ball bounce) coincides with our racket's maximum opening (which should be as big as time permits it to be). 3 is the returner's contact point.

*Eye training.*

The movement of the eyes has become a popular subject in various websites and discussions. Indeed, the eyes are our most valuable source of information, even if the sound is so important for effective SMS (hearing impaired people do play tennis, heavily visually impaired people usually do not). The "quiet eye" phenomenon is observed in expert performers (Gonzalez et al., 2017). The eye's saccadic movements may be trained with various methods so they become smoother and therefore, eyes spend more time "locked" on the ball or relevant stimuli; at any rate, more conscious training of gaze strategies is in line with the Distal Method principle that "everything is trainable". Again, transitional points may be identified and worked out.

*Paired synchronicity training.*

As is the case with martial arts, pairs should specifically work on their own synchronicity using e.g. mirroring games. Exactly the way two practitioners in Aikido mirror each other's movements in weapons' training in order to improve coordination, tennis players should do the same. Such exercises need no balls, just two players facing each other and mimicking each other in great detail, as if they were connected in some more concrete way (which indeed is the case as their brainwaves might reveal). Two transitional points may be identified here: one has to do with speed (at what speed does the synchronicity break) and the other one has to do with distance (ideally pairs could remain in perfect synchronisation even when being as far as behind the two baselines of the full court; however the connection is lost as they distance themselves from each other).

*Other synchronicity games.*

Following the general ideas presented above, one could devise a great number of drills and games to enhance synchronicity, such as playing through a flexible net (so when the ball is not hit in time, it is not hit at all), or vertical feeding drills with varying ball-height, while the eyes close before the ball bounces. The latter drill is similar to self-feed, but nevertheless it should be done by another person because self-feed is not SMS but rather a closed motor task.

**Bioinformatics and tSMS**

Bioinformatics deals with the analysis of biological data with the help of informatics technologies. Its applications extend from mapping the human genome to biomechanical analysis (Zhao, Chen, 2018).

It should be noted that bioinformatical applications in sports are rare and in tennis there is no prior experience. Hence, this is mainly an approach to possible applications of bioinformatics to tennis.

Advancements in smartphones (and smartwatches/wristbands) make it possible to develop applications with novel characteristics. Such characteristics may include the identification of various activity parameters in sports (Shoaib et al., 2014; Charlton et al., 2015).

The development of AI agents (in the form of expert systems) may provide new possibilities for training. Using the various sensors of the mobile phones (or even the camera), such systems could both monitor and guide the development of synchronicity. Transitional points (described in the previous sections) could be identified so that training may be adapted to each individual's needs.

Such systems may identify parameters regarding synchronicity (e.g. with a metronome) and measure mean error, providing both feedback in the end of the session and the possibility to adapt the stimulus (e.g. the IOI) to keep it within the optimum learning zone.

Another potential use may be in eye-tracking. For example, in exercises that require from the athletes to keep their eyes fixed on a rhythmically moving target, an application could monitor the eye's trajectory, its saccadic movements and its error in synchronicity.

In much more complicated, 3D representations, applications would provide all sorts of feedback about the coordination of the various body segments (in relation to each other or to the ball). The general idea is that bioinformatics could and should supplement the learning experience in tennis.

## 3. Conclusion

Based on the ideas presented here, both scholars and practitioners should reconsider their priorities when both researching and teaching tennis (or any other similar sport). For the tSMS, all other factors (physical conditioning, technical form etc.) are important, but they should complement sound SMS development protocols and computerised tools, not the other way around.

The obvious limitations of this study, as they have already been identified, are two: interpretation of data may vary among researchers and a lot of experiments and studies (indeed, a Research Programme) are needed to transform all these ideas into specific procedures and guidelines.

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# Development Opportunities of Pupils Physical Abilities by the Interventional Program

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**Abstract**

The paper presents partial results of grant assignment which was focused on verifying an impact of the applied intervention program BUBO on second primary education stage pupils‘ of Slovak republic selected physical abilities during Physical Education. The intervention program was applied on the experimental group of pupils (n = 174) during the compulsory subject Physical and sport education. The BUBO intervention programme was created to develop condition and coordination abilities of elementary school pupils and it uses exercises from athletics, gymnastics, moving and sport games. The movement programme was implemented in the mainstream education twice a week. The effectiveness of the program was verified by standardized motion efficiency and flexibility tests. Within the descriptive characteristics of descriptive statistics we used for measures of position the arithmetic average (x) and for measures of variability the (standard) deviation (SD). A normal data distribution was in all statistical analysis verified by the Shapiro-Wilk test. The F-Test was used when comparing the two dependent samples, while the degree of variance was checked with the use of a T-Test for the parity or disparity of the variance. In terms of data processing methods, we used the analysis and synthesis, inductive and deductive approaches and comparisons and generalizations. The most significant effectivness of the experiment was recorded on the fifth gradepupils‘ aerobic and speed abilities. Positive changes of motoric tests were noticed in sixth graders‘ experimental group. Output results recorded statistically significant progress in all tested abilities.

**Keywords:** intervention program, pupils, motion abilities.

## 1. Introduction

In the educational process of physical and sport education in elementary schools, we see the implementation of various movement programmes aimed at motivating students to physical activity, also increasing general physical performance or developing physical abilities. One way to increase pupil's physical activity is to pay attention to the motivational climate and PE class pleasure, because the set of actors are related to the intention to be physically active students (Navaro et al., 2019). The enjoyment of physical activity is related to motivation, both of which have an impact on the level of participation in exercise and physical activity in physical education classes (Navarro et al., 2016; Hashim, Grove, Whipp, 2008; Wallhead, Buckworth, 2004). Some investigations present how physical exercise produces physical, physiological, and above all, psychological beneficial effects (Pivovarniček et al., 2019) and there are positive results in mental health (Fox, 2001; Alfermann, Stoll, 2000; Sonstroem, Morgan, 1989).We perceive the interest in

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following the effectiveness of various intervention movement programmes both – at home, and abroad. Tannehill et al. (2015) are concerned with case studies illustrating the global practices of programs for teaching physical and sports education for young children, influenced by various didactic styles. Simultaneously, they provide the teachers with the basic components necessary for their creation and realization. Sallis et al. (2009) from South California created the SPARK (Sports, Play and Active Recreation for Kids) intervention programme for students of the 4th and 5th grades of elementary school. The aim of SPARK, a research-based curriculum, is to improve the health, fitness, and physical activity levels of youth by creating, implementing, and evaluating programs that promote lifelong wellness. Each SPARK program "fosters environmental and behavioral change by providing a coordinated package of highly active curriculum, on-site teacher training, extensive follow-up support, and content-matched equipment focused on the development of healthy lifestyles, motor skills and movement knowledge, and social and personal skills" (SPARK, 2013). Authors Farris et al. (2011) present the study "A 12-week Interdisciplinary Intervention Program for Children who are Obese". The National Institute of Health set up a movement programme to improve children's health. The programme's content includes aerobic exercises in a form of entertaining activities and sport lessons led by certified professionals. Movement activity aims to develop balanced and strength abilities through seasonal movement activities, also with an effort to build a permanent positive relationship with movement. Debra et al. (2011), in cooperation with health professionals and teachers of the concerned schools, publish the results of the impact of the intervention movement programme called „PA TAKE 10!", with an emphasis on the relationship between physical activity and the ability of elementary school children to achieve desired learning outcomes. Participating students achieved a higher level of physical activity, the time needed for study was reduced, and learning outcomes in maths and spelling were positively influenced ($p < 0.01$). Demetriou, Höner (2012) implemented a similar research, which was devoted to interventional physical activity in schools. Their results describe positive changes in the level of physical performance, physical activity and also in the general knowledge of physical activities. The programme "Daily Physical Activity in School" provides students with the opportunity to participate in all classes, including students with special educational needs, for at least 20 minutes of medium to intensive physical activity every day during the whole learning time (available on: www.edu.gov.on.ca). The authors Eather et al. (2013) confirmed the significant impact of the intervention programme Fit-4-Fun on health-oriented movement performance and the level of physical activity which was monitored by pedometers. Daubnerová (2017) developed the physical abilities by motion program. Sheehan, Katz (2012) found that among school-age children the use of active gaming added to development of postural stability, an important component of motor skills development.The main goal of the "BUBO" movement program is to support children's health, to use the sensitive period in an individual's life for the maximal development of his/her physical abilities and to develop the lifetime hobby of physical activity (available on: www.zsss.stranka.info). The authors Krull, Novotná (2015) also monitored the impact of the BUBO interventional movement programme on the movement performance of primary education students. They mainly focused on students' selected physical abilities. They also documented significant changes in the development level of running speed, with changes in direction and endurance ability in the whole research sample. Statistically significant positive changes were found in the level of flexibility of the girls, in the power ability of the lower extremities of boys, and the power ability of the abdominal and iliac-femoral muscles in first-year and third-year primary school students. The latest findings from the use of the BUBO movement program were also presented in other publications (Mandzak et al., 2018; Mandzák, 2018; Slováková, 2018).

## 2. Materials and methods

**Participants**

Our experimental group consists of 174 pupils at the second stage of elementary school; it is the 5th, 6th, 7th years of the elementary school in Ružomberok, Slovakia (Table 1).

**Table 1.** The overview of anthropocentric parameters of the 5th, 6th and 7th grade research groups of boys

| Boys | height | | weight | | BMI | |
|---|---|---|---|---|---|---|
| | initial test | final test | initial test | final test | initial test | final test |
| 5th grade | 145.88 ±6.16 | 149.60 ±6,50* | 40.32 ±6.93 | 44.22 ±7,01* | 18.67 ±2.80 | 19.75 ±2,74* |
| 6th grade | 153.17 ±7.05 | 157.39 7.26* | 44.72 ±10.99 | 49.47 12,06* | 18.82 ±2.83 | 19.72 ±3,10* |
| 7th grade | 159.61 ±8.56 | 165 ±9.65 | 50.50 ±11.12 | 54.42 ±12.15 | 19.68 ±3.20 | 19.87 ±3.36 |

**Organizing**

In the research we used a pedagogical experimental method. The experimental group received, within the standard education content including experimental stimuli, which took 32 weeks. The BUBO intervention programme was created to develop condition and coordination abilities of elementary school pupils and it uses exercises from athletics, gymnastics, moving and sport games. Its uniqueness is in organization of the types of movement, so it can be applied during the whole school year, without interrupting the main content of Physical Education and Sport. The movement programme was implemented in the mainstream education twice a week. The experimental exercises with content adjusted were undertaken within the first part for 10 minutes in every class. The main focus was intentionally given to developing condition (strength and endurance) and condition-coordination's abilities (movability and speed) by combining all games, exercises and activities while aiming to preserve the diversity of Physical Education and Sports lessons. The exercises that included the experimental factor were taught by the Physical Education and Sport teacher at the given school.

**Procedures**

- The back-saver sit & reach – flexibility test modified for right and left bend knee (Fitnessgram).
- Back-saver sit & reach (Moravec, 2002).
- The trunk & lift test in lying position on abdomen to test the flexor strength and flexibility of the lower back and hamstring musceles (Fitnessgram).

**Data Analyses**

Within the descriptive characteristics of descriptive statistics we used for measures of position the arithmetic average (x) and for measures of variability the (standard) deviation (SD). A normal data distribution was in all statistical analysis verified by the Shapiro-Wilk test. The Paired-T-Test was used to identify the significance of the inconsistencies by examined indicators between initial and output measurements. In the case of rejection of a normal data distribution the Wilcoxon nonparametric test for 2 dependent samples was used. The probability of Type I. errors was in all analyses set at a value a = 0.05. The F-Test was used when comparing the two dependent samples, while the degree of variance was checked with the use of a T-Test for the parity or disparity of the variance.

## 3. Results

The goal of our research is to verify the influence of the delivered content of the BUBO intervention programme within Physical Education and Sport lessons on chosen movement abilities of pupils at the secondary stage of elementary school.

Hypothesis: we assume that in the experimental group of all tested pupils the influence of the experimental factor will show statistically significant changes in back flexibility while the findings of the group will fulfil standards according to the assessment range FITNESGRAM**.**

Evaluation of flexibility of the lower back and hamstring musceles in the 5th – 7th grade pupils.

In this subchapter we deal with the shifts in backbone mobility, which were observed in tests: In the back-saver-sit & reach test with right and left bend knee, back-saver-sit & reach test and trunk & lift (cm). The results obtained from our measurements were statistically processed as well as compared with the results of the general population of primary schools carried out by Moravec and col. (2002) and according to the Fitnessgram standards (Cooper Institute, 1999).

**The level of the 5th grade pupils' mobility**

In the Back-saver sit & reach test we were testing flexibility of the lower back and hamstring musceles, whereby the test was performed with both right and left legs. When performing the back-saver sit & reach test with the right bend knee, a statistically significant 3 cm ($t = 2.05$, $p < 0.05$) progress in 5th grade pupils was found (Table 2). In the test with the left bend knee, a positive shift was found. However, its value is not that significant because there was only a 0.79 cm difference. The experimental group of boys did not meet the Fitnessgram standard. Their average final values were 3.83 cm lower on the left side and 3.27 cm on the right side. While in the initial testing only 3 pupils met the 20 cm standard, in the final testing we observed 6. In the second alternative test, when the forward bend with the left bend knee was performed, the Fitnessgram standards in the initial testing were again achieved only by 5 probands. In the final testing the standard was achieved by 9 pupils. This finding documents the insufficient mobility of lumbar spine in the experimental group of the 5th grade boys.

In the trunk & lift test, trunk extensor strength and flexibility was tested. The results have shown that a group of the 5th grade probands achieved progressive development in the final testing. There was a 2.35 cm difference in values in the trunk & lift. The aforementioned inconsistency was confirmed as statistically significant at the significance level of 5 % ($t = -4.93$, $p < 0.05$). According to Fitnessgram standards, the lower 23 cm and the upper 30 cm limit is defined. Within the frame of initial testing, 6 boys met the standard and 9 of them did so in the final testing. Despite the significant shift in the flexibility and strength level of the flexor muscles, according to Fitnessgram the 5th grade pupils did not meet the standards even in the trunk & lift test.

**Table 2.** Comparison of the initial and final results in a back-saver-sit &reach test with right and left bend knee, a back-saver-sit & reach test and trunk & lift test in a group of 5th grade boys

| 5th grade boys | Back-saver sit & reach(cm) | | | | Back-saver sit & reach (cm) | | Trunk & lift (cm) | |
|---|---|---|---|---|---|---|---|---|
| | In R | out R | In L | out L | In | out | In | out |
| M | 13.73 | 16.73 | 15.38 | 16.17 | 14.83 | 16.90 | 19.38 | 21.73 |
| Me | 16.00 | 19.00 | 14.00 | 15.75 | 17.25 | 19.00 | 18.50 | 21.00 |
| SD | 5.54 | 5.87 | 5.96 | 5.83 | 6.27 | 6.20 | 3.63 | 3.24 |
| Min | 4.00 | 9.00 | 5.00 | 6.00 | 3.00 | 3.00 | 13.00 | 17.00 |
| Max | 24.00 | 28.00 | 29.00 | 28 | 26.00 | 25.00 | 26.00 | 27.00 |
| t-test | * | | | | | | * | |

Legend: M – mean, Me – median, SD - standard deviation, Min – minimal, Max – maximal

When performing the back-saver sit & reach test with the right bend knee, an average 2.86 cm ($t = 2.05$, $p < 0.05$) progress in the 5th grade girls was found (Table 3). When checking the statistical significance of the averages, a significance level of 5 % was found at $t = -4.17$, $p < 0.05$. In the test with the left bend knee, it was found that the initial flexibility level was better (20.43±6.46) than with the right bend knee t (19.27±6.94). The final values in aback-saver sit & reach test with the left bend knee showed as statistically significant $t = -2.3$, $p < 0.05$. In comparison with the average values of lower back and hamstring musceles mobility in a single leg seated forward bend with a bend knee, the experimental group of girls did not meet the 25 cm standard. In the trunk & lift test the experimental group of the 5th grade girls met the Fitnessgram standard and the shifts were shown to be statistically significant at the $t = 7.84$, $p < 0.05$ level after the experimental program was applied. From the gender point of view it can be stated that a better level of lower back and hamstring musceles flexibility was found in the 5th grade girls than boys, which is in accordance with the research of Čillík et al., 2015; Mandzáková, 2003; Moravec, 2002.

**Table 3.** Comparison of the initial and final results in a back-saver-sit &reach test with right and left leg bend knee, a back-saver-sit &reach test and trunk & lift test in a group of 5th grade girls

| 5th grade girls | Back-saver sit & reach (cm) | | | | Back-saver sit & reach(cm) | | Trunk & lift (cm) | |
|---|---|---|---|---|---|---|---|---|
| | In R | out R | In L | out L | In | out | In | out |
| M | 19.27 | 22.13 | 20.43 | 22.82 | 21.18 | 21.36 | 23.75 | 25.00 |
| Me | 20 | 21 | 20.50 | 22.00 | 21.50 | 19.50 | 23.00 | 24.00 |
| SD | 6.94 | 8.04 | 6.46 | 7.71 | 8.03 | 8.60 | 5.11 | 5.09 |
| Min | 5.50 | 11.00 | 7.50 | 12.50 | 2.50 | 8.00 | 13.30 | 15.00 |
| Max | 30.00 | 37.50 | 32.00 | 38.50 | 36.00 | 38.50 | 34.00 | 35.00 |
| t-test | * | | * | | | | * | |

Legend: M – mean, Me – median, SD – standard deviation, Min – minimal, Max – maximal

**The level of the 6th grade pupils' mobility**

In the trunk flexibility tests in the 6th grade boys, a significant progress was made in a back-saver sit & reach – right bend knee test ($t = 3.44$, $p < 0.05$) as well as a left bend knee ($t = 3.24$, $p < 0.05$). According to Fitnessgram, pupils did not meet the 20 cm standard in the final testing. In the back-saver sit & reach test, a statistically significant progress was not noted, but when compared to the Moravec research (2002), the pupils achieved a 4.45 cm better level of trunk flexibility. In the trunk & lift test the shifts were statistically significant ($z = -4.33$ $p < 0.05$) after the experimental program was applied. The 6th grade pupils met the Fitnessgram 23-30 cm standard in initial as well as final testing (Table 4).

**Table 4.** Comparison of the initial and final results in a back-saver-sit & reach test with right and left bend knee, a back-saver-sit & reach test and trunk & lift test in a group of 6th grade boys

| 6th grade boys | Back-saver sit & reach (cm) | | | | Back-saver sit & reach (cm) | | Trunk & lift (cm) | |
|---|---|---|---|---|---|---|---|---|
| | In R | out R | In l | out L | In | out | In | out |
| M | 18.43 | 21.72 | 18.41 | 21.5 | 19.45 | 20.72 | 26.10 | 28.24 |
| Me | 19 | 22 | 20 | 20.5 | 19.00 | 22.00 | 25.00 | 28.00 |
| SD | 5.58 | 5.68 | 6.00 | 6.15 | 6.66 | 5.34 | 4.30 | 3.77 |
| Min | 7 | 6 | 6 | 8 | 5.00 | 7.00 | 20.00 | 22.00 |
| Max | 29 | 31 | 28.5 | 30 | 28 | 28 | 38.00 | 36.00 |
| t-test | * | | * | | | | * | |

Legend: M – mean, Me – median, SD – standard deviation, Min – minimal, Max – maximal

Girls again showed better backbone mobility than boys. Shifts in joint mobility were shown in all texts except the back-saver sit & reach test as statistically significant at the 0.05 level. According to Fitnessgram the defined standard was met by the 6th grade girls in both backward tilt test and single leg seated forward bend (Table 5). In the back-saver sit & reach test the pupils achieved 6.5 cm better level of mobility when compared to Moravec research (2002).

**The level of the 7th grade pupils' mobility**

In the results of aback-saver sit & reach test with a right bend knee, positive shifts were observed in at the final testing in the group of 7th grade boys (Table 6). The difference between the initial and final values were shown as significant at a significance level of 5 % ($t = -3.06$, $p < 0.05$). In the second test (back-saver sit & reach with the left bend knee) some progress can be seen as well. However, the 1.33 cm improvement is not that significant. When compared to the Fitnessgram standard for 13 years old boys (20 cm standard), it can be stated that in the first test the required level of flexibility was achieved by 5 pupils and in the final testing by 9 boys. In an alternative version of the test with the left bend knee, it was found the standard was met by 6 boys and in the final testing by 7 boys. The low overall level of flexibility can be stated here as well, because less than half of the research group achieve the standard. In the back-saver sit & reach test, the shifts were not confirmed as statistically significant, but when compared to Moravec research (2002), the 7th grade pupils achieved a 2.01 cm better level of lower back flexibility.

In the group of the 7th grade pupils, statistically significant progress ($t = -4.77$, $p < 0.05$) in the abdominal trunk & lift test was observed. Considering the Fitnessgram standard, 70 % of the group were included in a variance of minimum and maximum standard. We can therefore emphasize a higher level strength and flexibility of trunk extensor than in younger boys.

**Table 5.** Comparison of the initial and final results in a back-saver-sit & reach test with right and left bend knee, a back-saver-sit & reach test and trunk & lift test in a group of 6th grade girls

| 6th grade girls | Back-saver sit & reach (cm) | | | | Back-saver sit & reach (cm) | | Trunk & lift (cm) | |
|---|---|---|---|---|---|---|---|---|
| | In R | out R | In L | out L | In | out | In | out |
| M | 26.18 | 28.96 | 26.50 | 29.07 | 27.63 | 28.14 | 25.86 | 27.04 |
| Me | 26.00 | 31.00 | 27.50 | 30.00 | 27.00 | 27.25 | 24.50 | 26.00 |
| SD | 4.45 | 5.29 | 5.22 | 5.31 | 5.39 | 5.43 | 6.19 | 5.22 |
| Min | 14.00 | 14.00 | 15.00 | 11.00 | 15.00 | 14.00 | 18.00 | 20.00 |
| Max | 33.00 | 35.00 | 35.00 | 37.00 | 36.00 | 37.00 | 37.00 | 36.00 |
| t-test | * | | * | | | | Z 2.04, 0,04* | |

Legend: M – mean, Me – median, SD – standard deviation, Min – minimal, Max – maximal

**Table 6.** Comparison of the initial and final results in a back-saver-sit & reach test with right and left bend knee, a back-saver-sit & reach test and trunk & lift test in a group of 7th grade boys

| 7th grade boys | Back-saver sit & reach (cm) | | | | Back-saver sit & reach (cm) | | Trunk & lift (cm) | |
|---|---|---|---|---|---|---|---|---|
| | In R | out R | In L | out L | In | out | In | out |
| M | 17.08 | 18.42 | 18.11 | 19.92 | 18.42 | 18.98 | 25.85 | 28.00 |
| Me | 15.50 | 18.00 | 17.00 | 19.50 | 17.00 | 19.00 | 25.00 | 26.00 |
| SD | 6.89 | 6.99 | 6.48 | 6.04 | 7.08 | 7.13 | 7.03 | 7.35 |
| Min | 3.00 | 1.00 | 2.50 | 3.00 | 2.50 | 4.50 | 13.00 | 17.00 |
| Max | 35.50 | 36.00 | 35.00 | 33.00 | 37.00 | 39.00 | 43.00 | 45.00 |
| t-test | * | | | | | | * | |

Legend: M – mean, Me – median, SD – standard deviation, Min – minimal, Max – maximal

It can be stated that in the comparison based on the gender, the 7th grade pupils show higher level of strength and flexibility trunk extensor in trunk & lift test when it comes to boys (Table 7). In aback-saver sit & reach bend as well as two bend knees tests it was shown that girls had better mobility. Besides the back-saver sit & reach – legs bend test statistically significant progress was made in all other tests after the experimental program was applied. In comparison with Moravec research (2002) girls achieved a 0.7 cm lower level of joint mobility. The average final values of the girl group do not meet the standard for lower backand hamstring musceles flexibility represented by a back-saver sit & reach with bend knee. In a trunk & lift test the 7th grade girls achieved the defined 23-30 cm standard.

**Table 7.** Comparison of the initial and final results in a back-saver-sit & reach test with right and left bend knee, a back-saver-sit & reach test and trunk & lift test in a group of 7th grade girls

| 7th grade girls | Back-saver sit & reach (cm) | | | | Back-saver sit & reach (cm) | | Trunk & lift (cm) | |
|---|---|---|---|---|---|---|---|---|
| | In R | out R | In L | out L | In | out | In | out |
| M | 19.78 | 22.57 | 19.55 | 23.03 | 21.78 | 22.02 | 23.83 | 25.38 |
| Me | 18.00 | 23.00 | 18.00 | 21.50 | 21.00 | 23.50 | 24.00 | 24.00 |
| SD | 7.78 | 7.21 | 8.23 | 7.83 | 6.57 | 6.97 | 4.65 | 4.91 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Min | 7.00 | 10.00 | 6.00 | 7.00 | 9.50 | 11.00 | 17.00 | 20.00 |
| Max | 35.00 | 38.00 | 34.00 | 37.00 | 31.50 | 33.00 | 35.00 | 37.00 |
| t – test | * | | * | | | | * | |

*Legend: M – mean, Me – median, SD – standard deviation, Min – minimal, Max – maximal.*

## 4. Discussion

Flexibility tests and spine flexor strength tests bring us significant observations based on the comparison of stability and correct postures. There are many opportunities for active as well as passive activities for children and youth, which can cause some developmental errors, especially at an early age. We will therefore try to confront the research as well as the standards which deal with the given problem. In our research we reported an insufficient level of lower back and hamstring muscles flexibility and trunk extensor strength and flexibility in a group of 5th grade boys. According to the Fitnessgram standard (Cooper Institute, 1999) 60.83 % of the probands did not meet the required level at the end of the experimental period. In the experimental group of girls, 55.5 % of the probands did not meet the standard in the backbone flexibility test. Based on the results, it must be stated that, despite our effort to increase the flexibility level in these groups, we were not successful in achieving this goal. The results also confirmed an insufficient level of spine flexors, especially in the group of boys. Despite the fact that the results in the final testing showed positive shifts in the group, 60.83 % of the probands did not achieve the standard, which should be between 22.86 and 30.48 cm in the back-saver-sit & reach test forward bend. On the other hand, there was a positive shift in the group of girls, which according to the standard was confirmed in 92.6 % of the entire experimental group of girls. In the back-saver-sit & reach test, which is recommended by Eurofit (2002), it was found that the level of our experimental group of girls is lower compared to the Bence research (2005). This knowledge was also confirmed by 2002 Slovak population standards not only in girls but also in boys. There is even a 5 cm lower level of trunk flexibility in boys.

On the contrary, positive shifts were found when we compared the results of the group of the 6th grade boys. The results confirmed good backbone flexibility and flexor strength in girls and it can also be reported that girls achieved better results than boys. It can be therefore stated that the Fitnessgram standard (Cooper Institute, 1999) was met. More than half of the group of boys as well as girls achieved success. In the back-saver-sit & reach test, a higher level of flexibility was shown in our experimental group of boys as well as girls as reported by the 2002 general public average. When compared to the Bence research (2005), girls achieved on average 7 cm higher level and 6.4 cm in comparison to the 2002 Slovak average. A significant progress was also noted in boys, who in comparison to the Slovak average achieved an average performance of 3.17 cm.

The group of 7th grade boys achieved low performance level, especially in the backbone flexibility test. According to Fitnessgram (Cooper Institute, 1999), in the group of boys the standard was not met by 70 % and in the group of girls by 85 %. However, the backbone flexor strength tests confirmed a high performance level, because majority of the pupils met the standards in both groups. The results of the back-saver-sit & reach test showed a higher performance level in the group of boys as noted by the Eurofit standard (Moravec et al., 2002). The average performance of the group was 0.52 cm lower in girls as stated by standard of the 2002 Slovak average. Significantly different results are shown by Bence (2005), where the average performance of the tested girls in the seated forward bend test was 4.05 cm higher. Based on these results, it can be stated that the probands in the 5th and 7th grade did not meet the national level standard. The only exception are the 6th grade pupils. On the contrary, based on these results it is clear that the backbone flexor strength level is optimal with the exception of the 5th grade pupils in the kinetic ability test.

## 5. Conclusion

Our general research goal was to try to identify the problematic areas of the state ISCED 2 education programme implemented in schools of secondary education, which is reflected in the current physical and motoric level as well as in the functional ability of today's pupils. By meeting the objectives we experimentally verified the intervention kinetic programme with the implementation of the Physical Education and Sport lessons, which should, to a certain extent, stimulate kinetic development and adequately support development of the kinetic abilities.

The main goal of the research was achieved by acquiring results, which underlined the achievement of possible positive shifts in problematic areas of the pupils' current kinetic level.

The results gave us the following observation. Flexibility and backbone flexor strength demonstrated the significant impact of the kinetic programme on the $5^{th}$, $6^{th}$ and $7^{th}$ grade pupils. Despite that the only group which did not meet the minimal recommended Fitnessgram standard was the group of $5^{th}$ grade pupils, where we found a low general level of performance. In the group of $5^{th}$ grade girls we reported a positive impact of the exercises on the backbone extensor muscle strength level but the standard was not met in the back-saver-sit & reach test. In the group of $6^{th}$ grade girls, progress was seen and the standards were met in both tests. In the group of the $7^{th}$ grade girls, the average final values did not meet the standard in a back-saver-sit & reach test with right and left bend knee and so did not show the required lower back flexibility. In the trunk & lift the $7^{th}$ grade female pupils met the required standard ranging from 23 cm to 30 cm.

In the trunk & lift test, strength and flexibility of the trunk extensors were observed. The results showed that the $5^{th}$ grade probands achieved progressive shifts in the final testing, where the difference was confirmed as statistically significant at the significance level of 5 % ($t = -4.93$, $p < 0.05$). Despite the significant shift of the flexibility and backbone flexor strength level, the $5^{th}$ grade pupils did not meet the Fitnessgram standard in the trunk & lift test. The experimental group of girls did not meet the Fitnessgram standard in the mobility test, but in the trunk & lift test the standard was met and the shifts were reported as statistically significant ($t = 7.84$, $p < 0.05$) after the implementation of the experimental programme.

Based on the acquired results of our research the following observations and recommendations can we concluded: the implemented system of kinetic exercises showed positive effect on the change in backbone flexibility and strength and flexibility of the trunk extensors level in all grades. During the Physical education lessons, we recommend putting more emphasis on the health when exercising, in other words to observe and emphasise correct body posture. In pupils with a low kinetic ability level, we suggest increasing the attention of the teachers and the interest of the parents with the intention of observing and improving their children's further development.

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