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Physical Rehabilitation of Adolescents with Postural Disorders in the Sagittal Plane and its Relation to Neurophysiology

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Abstract: *The adolescents aged between 15 and 17 with postural disorders in the sagittal plane, who live in mountainous regions in the Carpathians, achieve less than their peers with similar postural disorders, who live in plain regions. The research aims to develop the comprehensive programme for correcting postural disorders in the sagittal plane among pupils, who live in mountainous regions in the Carpathians, using physical rehabilitation, and establish the links between empirical data of the experiment and neurosciences to develop methods of complex psychophysical and neurophysiological diagnostic and rehabilitation of adolescents with such disorders in further research. The research is based on a detailed observation of 319 adolescents aged between 15 and 17 from mountainous regions of the Ukrainian Carpathians and 94 pupils from plain regions with postural disorders in the sagittal plane. The research methods are the following: an analysis of the scientific and specialized literature; surveys and questionnaires; pedagogical tests; methods for determining the indicators of physical development, functional readiness and functions of the spine; methods of mathematical statistics, namely, the Ruffier-Dickson test, Otto test, Schober test, Thomayer test, Fleischmann test, Sedin test and spinal index, inclinometer measurements. The pupils who suffer from the stoop and round spine have shown a decrease in average values in the angles of lordosis and kyphosis curves; pupils who suffer from flat back – an increase in the angles of the sacral bone, lordosis and kyphosis curves; pupils who suffer from the round and concave back – a decrease in the angles of the sacral bone, lordosis and kyphosis curves. The implementation of the author's programme for physical rehabilitation has made it possible to achieve a statistically significant improvement in most of the analyzed indicators. Finally, the article extrapolates the results of the experiment to their neurophysiological and neuromedical application in terms of enhancing anamnesis and taking into account post-correction data in subsequent medical treatment.*

Keywords: *mountainous regions, Pilates, therapy exercise, the kinetic mode, aerobic training, strength training.*

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Introduction

As evidenced by the official data, the proportion of adolescents aged between 15 and 17 with chronic diseases has changed during the past 50 years. Thus, the number of chronically diseased children has increased by 72%, whereas the number of healthy individuals has decreased by 16 times. The first five ranks in the structure of morbidity among high school pupils (approximately 70% of all diseases) are respiratory, musculoskeletal, digestive, ophthalmological and endocrine diseases. The assessment of adolescent physical development has shown an increase in the number of obese (up to 17.53%) and underweight children, as well as children with disharmonious physical development (between 10 and 15% of mainly underweight adolescents) (Batrshin, Sadovoy, Mikhaylovskiy, & Sadovaya 2006; Behas et al., 2019; Sitovskyi et al., 2019; Vladzymyrskyi, & Popova, 2010; Vovkanych, & Hrynkiv, 2003; Zhylka, 2007).

The postural disorders among pupils from mountainous regions in the Carpathians have not been studied properly yet. Specific living conditions and unsatisfactory social conditions significantly affect any programmes for schoolchildren's rehabilitation, since they require simple and economically accessible methods, which should take into account the natural factors of the Carpathians (Byvalkevych, Yefremova, & Hryshchenko, 2020; Hrytsuliak, Hrytsuliak, & Bohachuk, 2007; Kaletnik, Zabolotnyi, & Kozlovskyi, 2011; Koziuk, Hayda, Dluhopolskyi, & Kozlovskyi, 2020; Kozlovskyi, 2010; Makoviichuk et al., 2020; Mykolaiskyi, 2006; Sebalo & Teslenko, 2020). At the same time, neurophysiological indicators of the analyzed disorders should be taken into account during physical rehabilitation. Indeed, there is an assumption about the difference between the main and accompanying symptoms of postural disorders in the sagittal plane, which should be confirmed by both functional indicators and medical diagnostic.

Based on the results of epidemiological studies conducted in different areas of Ivano-Frankivsk region, it has been found that adolescents aged between 15 and 17, who live in mountainous regions, are more expected to have postural disorders in the sagittal plane than their peers, who live in plain regions (72.5% vs. 42, 9%, $p<0.05$). The most common postural disorders among pupils from mountainous regions are the stoop and sway back (55.6% of pupils), round and concave back (22.7% of pupils), flat back (20,5 % of pupils). However, the approaches to correcting postural disorders among pupils from mountainous regions in the Carpathians have not been developed yet. Therefore, this problem should be studied,

scientifically and experimentally justified. The risk factors, which contribute to the occurrence and progression of these disorders, can be insufficient physical strength, chronic diseases, improper daily routine, poor nutrition, kinetic skill disorders, bad habits. It is also essential to take into account the neurophysiological specifics of motor activity of pupils living in mountainous and plain regions (differences in atmospheric pressure, loads during frequent ascents or descents from the mountain).

Pupils with postural disorders in the sagittal plane from mountainous regions achieve less than their peers from plain regions with similar postural disorders in terms of physical development (male and female pupils have different body weight, BMI, chest circumference, chest excursion, muscle strength in both hands and back, strength and dynamic endurance of abdominal muscles), functional (higher respiratory rate at rest, lower average indicators of inspiratory and expiratory breath-holding time and peak expiratory flow, higher heart rate at rest; 40.9% and 42.9% of male pupils in the main groups have poor physical ability, 8.6% – in the CG; 38.1% and 33,3% of female pupils have poor physical ability in the main groups, 14.7% – in the CG; $p < 0.05$) and physical strength (male pupils from mountainous regions achieve considerably less than their peers from plain regions in terms of strength and endurance; female pupils from mountainous regions achieve less than their peers from plain regions in terms of strength, endurance and flexibility; $p<0,05$). The reliable differences in a range of analyzed parameters between the groups of pupils with postural disorders (sway back, flat back, round and concave back; the state of the cardiovascular system; characteristics of vegetative reflexes) have been determined.

Postural disorders not only negatively influence appearance and body aesthetics but also the functional and physiological state of individual organs and systems. As a result, adolescents may suffer from disorders in physical development or the musculoskeletal system overload, which may cause various neurophysiological diseases, in particular visceral disorders (Aloshyna, Aloshyn, & Petrovych, 2009; Kashuba, & Zharova, 2006). Based on the results of many studies, the violations of spine biomechanics can initiate various visceral disorders (Falameeva, 2009; Khabirov, 2001; Kolisnyk, 2002; Slavik, 2008). Those children, who suffer from postural disorders, are characterized by reduced physiological reserves of respiration and blood circulation, failed adaptive reactions, which makes them susceptible to lung and heart diseases. For instance, increased thoracic kyphosis changes costal angle, which leads to decreased chest circumference and, consequently, decreased lumen capacity and cardiac disorders (Kolisnyk, 2002; Yarovoy, 1999). Due to increased lumbar lordosis, the

spine curves inward toward the abdomen, which leads to irregular diaphragm movements and, consequently, respiratory disorders. Besides, the location of internal organs in the abdominal cavity changes, which causes subsequent diseases. Constant spine congestion diminishes its physiological functions and causes chronic pathological conditions. These disorders are traditionally diagnosed when measuring neurophysiological and visceral parameters, rather than physical and functional ones, during a medical examination (Filak, 2009; Kashuba, & Zharova, 2006; Sloniak, & Tittinger, 2012).

The analyzed innovative technologies in physical education of pupils rarely focus on the formation of correct posture and prevention of its violations. In our opinion, such a situation can lead to further progression of the above-mentioned pathology among pupils and young people, which inevitably will affect their health in the future. Different aspects of the problem under study are covered in the works of many scholars (Bezliudnyi, Kravchenko, Maksymchuk, Mishchenko, & Maksymchuk, 2019; Gerasymova et al., 2019; Halaidiuk, et al., 2018; Maksymchuk, et al., 2018; Melnyk, 2019; Sheremet, Leniv, Loboda, & Maksymchuk, 2019).

The programmes for correcting postural disorders in the sagittal plane should be reconsidered and significantly improved, as well as adapted to particular living conditions of pupils, their lifestyle, nutrition, socioeconomic conditions and other factors. The combination of these factors is extremely specific in mountainous regions of the Carpathians.

Materials & methods

The research methods are the following: an analysis of the scientific and specialized literature; surveys and questionnaires; pedagogical tests; methods for determining the indicators of physical development, functional readiness and functions of the spine; methods of mathematical statistics, namely, the Ruffier-Dickson test, Otto test, Schober test, Thomayer test, Fleischmann test, Sedin test and spinal index, inclinometer measurements (Boichuk, Holubieva, Levandovskyi, & Voichyshyn, 2010; Boichuk, & Voichyshyn, 2012; Krutsevych, Vorobiov, & Bezverkhnia, 2011; Voichyshyn, 2011; 2012). The obtained data were verified to further include them in the complex neurophysiological and general therapeutic diagnostics of a musculoskeletal and cerebrovisceral nature and prevent neuropsychological and psychosomatic disorders.

The research consisted of four stages. During the first stage, Ukrainian and foreign literary sources were studied and analyzed, two questionnaires were designed to identify health disorders and reveal pupils'

harmful habits, an epidemiological study was conducted, which included questioning and inclinometer measurements of 659 pupils aged between 16 and 17 in five mountainous (Verhovynskyi, Kosivskyi, Nadvirnianskyi, Bohorodchanskyi and Rozhniativskyi) and three plain (Rohatynskyi, Tysmenytskyi, Tlumatskyi) regions. Based on the results of questioning and inclinometer measurements, pupils were randomly divided into groups for further observation. These groups included pupils with postural violations in the sagittal plane from both mountainous and plain regions.

Thus, the research is based on a detailed observation of 319 adolescents aged between 15 and 17 from mountainous regions of the Ukrainian Carpathians, namely, 171 male pupils and 148 female pupils, and 94 pupils from plain regions (37 male pupils and 57 female pupils) with postural violations in the sagittal plane.

The pupils from plain regions formed the control group (CG), involved in the programme of physical education for comprehensive schools. Their peers from mountainous regions were divided into two groups – the main group 1 (also involved in the programme for comprehensive schools) and the main group 2 (involved in the author's programme of physical rehabilitation).

During the second stage, anthropometric and physiological parameters were studied, as well as parameters of physical development, physical strength, functional state of the body, angular parameters of the spine and indicators of its functional state were identified. Based on the received data and their statistical processing, the results were evaluated and the programme of physical rehabilitation for adolescents aged between 15 and 17 with postural disorders in the sagittal plane in the Carpathian region was developed.

During the third stage, the developed programme of physical rehabilitation was verified based on the type of posture violation in the sagittal plane, and its correction was carried out based on individual characteristics of the body. The author's programme has been tested during an academic year.

After the programme was implemented, anthropometric and physiological parameters, parameters of physical development, physical strength, angular parameters and functional state of the spine were restudied.

During the fourth stage, the results of retesting were thoroughly evaluated and compared with the initial parameters. Besides, it became possible to take into account neurophysiological indicators to expand medical history and use them when planning individual neurophysiological correction and rehabilitation.

While developing the comprehensive programme for correcting postural violations in the sagittal plane, the authors of the article adhered to several requirements, namely, adequacy; regulation and proper distribution of physical loads; systematicity of physical activities; gradual expansion of those means required to ensure comprehensive influence on different muscle groups, joints and internal organs; selection of general and special corrective exercises according to a particular type of postural disorders in the sagittal plane and accompanying deformities; use of exercises required to strengthen and develop small muscle groups; organization of special training modes; improvement of student mental health.

The comprehensive programme of physical rehabilitation has been adapted to the current physical education curriculum for comprehensive schools and implemented into curricular and extracurricular activities. The programme has taken into account individual student characteristics (a type of postural disorder, accompanying diseases, test results, psychological peculiarities), as well as individual psychological (temperament, motivation) and neurophysiological (a lateral profile, a type of nervous system) features. Besides, it has been adapted to socioeconomic conditions of mountainous regions and, unlike most of the existing programmes of this kind, aims to correct postural disorders, develop physical skills, improve health level in general and mental health in particular, enhance motivation towards a healthy lifestyle.

Thus, the methods of the author's programme on physical rehabilitation have influenced three components of human nature, namely, physical, mental and social ones. They should contribute to general neurobiological perspectives of this disorder (neuropsychological, neurophysiological and neurosocial) in further research.

A comparative pedagogical experiment has been conducted to determine the effectiveness of the proposed comprehensive programme for correcting postural disorders in pupils from mountainous regions in the Carpathians.

The comprehensive programme lasted the school year (9 months) and consisted of three stages, namely, the preparation stage, the main stage and the supporting stage. Before the introduction of the programme, as well as after the completion of each stage, the basic functional systems of the pupils should be monitored. Also, it is essential to compile a neuropsychological profile for each pupil.

The control group includes pupils from plain regions, who participate in the programme of physical education for comprehensive schools. Their peers from mountainous regions were divided into two

groups – the main group 1 (also involved in the programme for comprehensive schools) and the main group 2 (involved in the author's comprehensive programme of physical rehabilitation).

Before the experiment, physical education teachers from mountainous regions in the Carpathians were familiarized with the peculiarities of the comprehensive programme, as well as the methods of pedagogical control.

The September-October period covered the preparatory stage of rehabilitation, the November-March and the April-May periods – the main and supportive stages of rehabilitation.

The preparatory stage of rehabilitation lasted two months and was characterized by a gentle mode. Its main tasks included mastering the proposed methods of posture correction in the sagittal plane, adjusting the cardiovascular and respiratory systems of the body to physical load, developing the pupils' physical skills, improving the pupils' endurance.

The main stage of rehabilitation lasted five months. It was characterized by a gentle training mode. Its tasks involved unloading the spine, strengthening the pectoral muscle sling, increasing the volume of movement in vertebral segments, correcting the existing postural disorders in the sagittal plane, correcting the associated deformities, improving the functional state of the cardiovascular and respiratory systems, further developing physical skills (strength, endurance, flexibility, coordination), mastering special kinetic skills adapted to living conditions.

The supportive stage of rehabilitation lasted two months. Training sessions were conducted based on the training kinetic mode. Its main tasks implied improving the functions of the systems reflecting the neurophysiological state (cardiovascular and respiratory systems); increasing physical activity and maintaining the reached level of physical performance; enhancing general and muscular endurance, coordination and flexibility; correcting the neuropsychological and psycho-emotional state; fixing the obtained results of rehabilitation.

The exercises incorporated in training sessions are aimed at forming a definite feeling in pupils about the individual body segments for all positions, as well as the tension of muscles if the posture is correct.

The morning hygienic exercises. Every day, the pupils did the morning hygienic exercises for 15-20 minutes before breakfast. It included simple exercises affecting all major muscle groups and joints. All exercises were performed at a slow and medium pace, with a gradually increasing range of movements, involving small, medium and large muscle groups. The morning hygienic exercises do not include static exercises since they cause

muscle tension and shortness of breath. According to each stage of rehabilitation, the pupils did a certain complex of the morning hygienic exercises.

Exercise therapy. Three times per week, the pupils did 10-15-minute general and special corrective exercises according to a type of postural disorders in the sagittal plane. The pupils with flat back did the exercises for deep back muscles, hip flexors and shoulder blades. The pupils with a sway back did the exercises to reduce the pelvic tilt. For this purpose, abdominal muscles were strengthened, flexor muscles were stretched, hip flexors were strengthened, posterior ligaments of the lower thoracic and lumbar spine and psoas muscles were stretched. The pupils with round and concave back did the exercises to strengthen the muscles of the extensors, stretch the muscles of the flexors of hip joints and the muscles of the front part of the thorax, strengthen the muscles of the lumbar spine and correct the position of shoulder blades. By increasing the angle of the pelvis, physical exercises helped to stretch the thigh muscles (the anterior muscle group), the paravertebral muscles of the lumbar spine, the quadratus lumborum muscle and the iliopsoas muscle and strengthen abdominal muscles and the back part of the hip. By reducing the angle of the pelvis, the muscles of the lumbar spine and the front part of the thighs were strengthened.

The following was done to lessen the excessive and intensify the moderate spinal curvatures and to create a natural correlation between them during training sessions: the weight of the head, the upper limbs and the torso causing postural defects at the excessive angle of the pelvis have been excluded; the influence of the angle of the pelvis on physiological curves of the spine has been eliminated; the local mobility of the spine has been improved for the next correction; those parts of the spine, in which curvatures are most apparent, have been especially influenced (local correction). These requirements are met by the exercises done in the initial lying position, with emphasis on the knees.

The winged shoulder blades were corrected using the isotonic and isometric exercises (trapezius and rhomboid muscles), as well as the exercises aimed at stretching the pectoral muscles.

The descent of the shoulder girdle was corrected through strengthening the neck muscles and the scapular compartment. Besides, the pupils did the complex of asymmetric and static low-amplitude exercises for the upper trapezius, rhomboid and subclavian muscles, as well as for the muscle raising the shoulder blade (on the side of the shoulder).

In the case of chest disorders, the back muscles, the muscles holding the shoulder blades in the corrected position and the respiratory muscles

have been primarily strengthened, taking into account that the violations of chest shapes are combined with postural disorders. The shape of the chest cannot be corrected unless the deviations of the spine have been corrected. Therefore, the authors of the article have chosen the simultaneous correction of the chest and spine shapes.

The effectiveness of using special exercises largely depends on the initial positions. The most effective positions for developing the pectoral sling and correct postural defects are the ones which minimize the load on the spine along the axis and the influence of the angle of the pelvis on the muscle tone. These include the position of lying on one's back, stomach, standing or resting on one's knees.

The complex of exercise therapy pays much attention to neurophysiological correction, namely, breathing exercises, which not only increase the functionality of the respiratory and cardiovascular systems but also contribute to the active correction of the spine and chest. Such exercise facilitates the educational effect and consolidates the skill of the correct posture.

To cultivate the feeling of the proper posture, one should stand at the wall, touching it with the occipital hump, shoulder blades, buttocks, shins and feet. After that, one should take a step forward without changing the position of the body and stand for 1-2 minutes.

The moving mode. Below are the basic rules of the moving mode, which were followed by the pupils of the second main group. The proposed mode aims to correct pathological curvatures of the spine and develop a feeling of the proper posture not only during training sessions but also in everyday life, as well as to consolidate the achieved effect.

It was suggested that the following recommendations should be followed: one should sleep on a hard bed with a small pillow; in the case of round and concave back, one should properly use the objects from everyday life such as a vacuum cleaner, brush or mop with a long handle; household appliances (a food processor, a microwave oven, a cooker, etc.) should be placed no lower than the belt; one should lift heavy objects by crouching and straightening one's back; when standing up, one should extend legs in the hip and knee joints; if one has a bag in one's hands, one should change hands at regular intervals (20-30 minutes); one should replace bags with a backpack or a cart with wheels; in the case of the excessive spinal curvatures in the sagittal plane, one should put on socks and shoes after putting one leg, bent at the hip and knee joints, onto the armchair, and lean forward without bending the thoracic spine; one should sit on rigid chairs, resting on the entire back, keeping one's feet on the floor, bent at the knee joints at an

angle of 90º; in the sitting position, one should strain abdominal muscles for 2-3 minutes; one should write, read and eat at the table, with one's elbows on it, with the straight back and the slightly tilted head (more importantly, the distance between the table and the body should be about 8-10 cm); the desk should be well lit; when talking on the phone or working on the computer, one should lean on the back of the chair or straighten one's back; in case of the round and round concave back, one should wash, brush one's teeth in the correct position, leaning forward without bending one's back in the chest; one should keep one's head straight when walking.

Pilates. The methodologies of Pilates in the complex programme of rehabilitation for postural disorders in the sagittal plane were used to strengthen the stabilizing spine muscles, namely, abdominal muscles, pelvic floor muscles and deep back muscles. They form a natural muscular torso. The Pilates training lies in observing the following eight principles: relaxation, concentration, alignment, breathing, centring, coordination, smooth movements, endurance.

The main neuropsychological aspect of correcting postural disorders in the sagittal plane was the use of the relaxation principle. In turn, the essence of the relaxation principle lies in the conscious release of unnecessary stress in certain parts of the body to further actively involve these parts in active work. The concentration principle aims to develop the kinaesthetic sensation of both the whole body and its parts and help to understand every movement and the processes taking place in the body. The alignment principle implies the gradual restoration of the muscular balance and, therefore, the correct position by consciously taking the correct posture of the body while standing, sitting, lying and especially, moving. Pilates uses chest breathing as well. All exercises are done in the following sequence: one inhales before doing the exercise, exhales holding one's stomach and performs the movement, after which the breath is relaxed and returns to the starting position. The centring principle involves creating a force belt by lifting the pelvic floor muscles to the spine from top to bottom. The coordination principle should be understood as the ability to perform the correct movements and control the posture and breathing at the same time. This skill is developed due to repetitions with a constant focus on the tasks. Pilates exercises are characterized by the obligatory smoothness of movements, whose essence implies the correct and graceful performance of quite ordinary mind-driven movements. Almost all movements are performed slowly, away from the strong centre. The endurance principle intends to gradually increase the intensity of training and move from the beginner programme to intermediate and higher than intermediate levels.

Pilates classes were conducted 3 times per week, with musical accompaniment, and lasted for 45-50 minutes initially and 50-60 minutes at the main and supporting stages. At each stage of rehabilitation, the Pilates exercises were changed to prevent the habituation effect.

Aerobic training. This type of rehabilitation, along with relaxation exercises, is extremely essential for changes in the neurophysiological state since there is a direct link between respiration, cardiovascular activity and neurophysiological regulation of the body. During aerobic training, the experimenters attempted to adhere to certain methodical rules: 1) to gradually increase the intensity and duration of loads; to gradually increase the exercise load (3-5% at each stage of training) by increasing the duration of training sessions (gradually increasing the duration of aerobic exercise from 30-40 minutes at the preparatory stage to 40-50 minutes at the main and supporting stages of rehabilitation); to increase the effectiveness of training sessions. During the first training sessions, the kinetic density corresponded to 45-50%; to the extent of the body's adaptation to physical activity, the experimenters increased it to 70-75% of the total training time. It was expedient to increase the intensity of training sessions; to gradually widen the range of the means to ensure a comprehensive influence on different muscle groups, all joints and internal organs; to increase the complexity and amplitude of movements; 2) to ensure the variety of tools. During the wellness training, the experimenters used aerobic exercises (walking, jogging, skiing) in combination with strength exercises for large muscle groups (flexing-extending hands in the lying position, pull-ups, press-ups, hyperextension, sit-ups, etc).

Aerobic training sessions included walking, jogging and skiing. Loads were determined based on the following three indicators: duration, distance length and movement speed.

Strength training. The comprehensive programme of physical rehabilitation involved dosed dynamic loads after aerobic exercises once a week. The duration of strength training was gradually increased from 15 minutes initially to 20-30 minutes at the main and supporting stages. The exercises were done using the repetition method, namely 2-3 sets of exercises up to 10 repetitions.

Results

Based on the results of epidemiological studies conducted in different districts of Ivano-Frankivsk region, it has been found that the adolescents aged between 15 and 17, who live in mountainous regions, are more expected to suffer from postural disorders in the sagittal plane than their peers, who live in plain regions (72.5% vs. 42,9%). However, pupils from both regions did not differ statistically by age or gender.

The most common postural disorders among pupils from mountainous regions are stoop, sway back, round and concave back, flat back. The risk factors, which contribute to the occurrence and progression of these disorders, can be insufficient physical strength, chronic diseases, improper daily routine, poor nutrition, kinetic skill disorders, bad habits, etc.

The pupils with postural disorders in the sagittal plane from mountainous regions achieve less than their peers from plain regions with similar postural disorders in terms of physical development (male and female pupils have different body weight, body mass index, chest circumference, chest excursion, muscle strength in both hands and back, strength and dynamic endurance of abdominal muscles).

The pupils from mountainous regions tend to have more pronounced deviations of neurophysiological and functional indicators, which characterize the respiratory system (the higher respiratory rate at rest, lower average indicators of inspiratory and expiratory breath-holding time and peak expiratory flow, $p<0.05$), as well as the cardiovascular vascular system (higher heart rate at rest, $p<0.05$).

Based on Apanasenko & Popova's (1998) evaluation of somatic health, it has been found that most male and female pupils with postural disorders in the sagittal plane from mountainous regions are characterized by low levels of somatic health and neurophysiological indicators. It must be noted that none of these pupils has approached higher levels. Male and female pupils with postural disorders, who live in plain regions, have different levels of somatic health. More than half of male pupils have average level, while almost half of female pupils have a low level. Also, 8,6% of male pupils tend to have an average level of somatic health, while none of the female pupils has eventually reached this level. Moreover, the Ruffier-Dickson test (Amosov, & Benet, 1989) indicates moderate neuropsychological deficiency (apathy, slow reaction, sluggish movements) in pupils living in mountainous regions. Indeed, the physical ability level of pupils from mountainous regions is much lower than that of their peers, who live in plain regions.

Male pupils, who live in mountainous regions, are considered inferior to their peers from plain regions in strength and endurance. One can observe quite a similar situation among female pupils from both regions. Besides, female pupils from mountainous regions are inferior to their peers from plain regions in flexibility.

Postural disorders in the sagittal plane cause significant functional disorders of the spine, namely, its limited mobility in the sagittal plane in both thoracic (based on Otto test) and lumbar (based on Schober test) sections, limited spinal flexion in general (based on Thomayer test), as well as its lateral (based on Fleischmann test) and overall mobility (based on Sedin test and spinal index) (Kashuba, 2002).

The results of inclinometer measurements prove that postural disorders in the sagittal plane (stoop, sway back, flat back, round and concave back) are more pronounced in the EG pupils. These changes are combined with significant chest deformity, pronounced decrease in strength of abdominal muscles, pelvic floor muscles, upper and lower back muscles, postural disorders stability with symptoms of its degenerative changes. Such data are valid for neurovisceral medical studies and serve as indicators for medical intervention.

The reliable differences in a range of analyzed parameters between the groups of pupils with postural disorders have been determined. They include sway back, flat back, round and concave back. Pupils of both sexes with flat back were characterized by larger stature (male pupils – 178.72±1.33 cm, female pupils – 164.31±1.12 cm, $p<0.05$), lower body mass index (BMI) (male pupils – 18,13±0.37 kg/m2, female pupils – 17.92±0.47 kg/m2, $p<0.05$) and higher shoulder index (male pupils – 93.27±1.13 cm, female pupils – 91.18±0,76 cm; $p<0.05$). Based on the parameters of functional strength, a reliable difference between the group of pupils with a flat back and that with a stoop, sway back, round and concave back has been set for the parameter of Shtange test (male pupils – 35.14±1.39 cm, female pupils –31.51±1.18 cm; $p<0.05$). Taking into account the indicators of physical strength, pupils with a flat back (male pupils – 5.3±0.8 cm, female pupils – 8.6±0.5 cm) have achieved less in flexibility test compared to their peers with a stoop, sway back, round and concave back ($p<0,05$). Based on the parameters of flexibility, pupils of both sexes with flat back are more likely to suffer from limited spine flexion and extension (Sedin test), as well as limited thoracic (Otto test) and overall spine mobility (Thomayer test and spinal index). The only indicator by which all three groups of pupils with different posture violations significantly differed ($p<0,05$) is the results of the Schober test. According to it, pupils with round and concave back are

more expected to suffer from limited mobility of lumbar spine than their peers with a flat back and stoop or sway back.

Thus, these pathological changes in the pupils from mountainous regions in the Carpathians have proved the need to develop the programme for correcting postural disorders in the sagittal plane.

After implementing the comprehensive programme, one could observe positive changes in the indicators of physical development (the percentage of male and female pupils with normal bodyweight has increased up to 85.7±4.1% and 90.5±4.1% respectively; that with low bodyweight has decreased down to 9.5±1.1% and 4.8±0.5% respectively; chest circumference, chest excursion and shoulder index have increased, too), neurofunctional strength (respiratory and heart rate at rest have decreased; inspiratory and expiratory breath-holding time has increased up to 51.71±1.35 sec and 27.81±1.50 sec respectively in male pupils, up to 50.52±1.92 sec and 35.71±1.17 sec in female pupils; peak expiratory flow and the level of physical ability significantly have increased, too).

Thus, the programme has enhanced the functions of the respiratory system, as evidenced by the absence of bronchial obstruction syndrome and the created prerequisites for improving pulmonary ventilation and lung capability.

The above-mentioned positive changes have influenced pupils' level of physical strength. Thus, the indicators have been optimized, which proves significant improvement of all physical skills of those pupils involved in the author's programme. A prerequisite for improving physical skills of pupils was a stable increase in the indicators of stationary and carousal dynamometry, muscular endurance of abdominal press and back ($p<0,05$). Positive dynamics of physical skills of those pupils who were involved in the traditional programme of physical education for comprehensive schools has not been recorded.

Optimizing the indicators of physical development and body functions after prolonged training by the programme proposed, it was possible to enhance pupils' somatic health. Thus, the percentage of male and female pupils with low levels of physical health has decreased considerably due to their transition to the average level gradation. Indeed, 4.8% of female pupils and 9.5% of male pupils involved in the author's programme have reached the above-average level of somatic health after the experiment. At the first stage, none of the pupils showed such results. The traditional programme of physical education does not provide an opportunity to positively influence the indicator of pupils' distribution according to the levels of physical health.

The pupils from the second main group were efficiently redistributed based on the results of Ruffier-Dickson test since they managed to significantly increase their neurophysiological and neuropsychological indicators (motivation; working capacity; stabilization of mental reactivity; decrease in the frequency of apathetic-depressive states). It must be noted that the above-mentioned positive changes have influenced their level of physical strength, too. Thus, the indicators have been optimized, which proves significant improvement of all physical skills of those pupils involved in the author's programme. Positive dynamics of physical skills of those pupils who were involved in the traditional programme of physical education for comprehensive schools has not been recorded.

The comprehensive programme has positively affected angular parameters of the spine in the examined pupils with various postural disorders based on the follow-up inclinometer measurements. Thus, pupils who suffer from the stoop and round spine have shown a decrease in average values in the angles of lordosis and kyphosis curves; pupils who suffer from flat back – an increase in the angles of the sacral bone, lordosis and kyphosis curves; pupils who suffer from the round and concave back – a decrease in the angles of the sacral bone, lordosis and kyphosis curves. The correction of spinal curves in pupils with postural disorders in the sagittal plane also included improving the functions of back and abdominal muscles (Krause-Weber test), eliminating the symptoms of asymmetrical blades, increasing the percentage of male and female pupils with normal posture (Mathias postural stability test), improving spinal movements in general (Sedin, Thomayer tests, spinal index calculation), as well as cervical spine movements (chest – chin test, chin – jugular notch test), thoracic spine movements (Otta test) and lumbar spine movements (Schober test). Besides, one could observe a significant increase in lateral spine mobility and an increase in the range of spinal movements when rotating about a vertical axis (Fleischmann test).

Discussion

The process of conducting this research has taken into account relevant ethical rules. First, all ethical requirements were considered before the implementation of this research. Next, the authors obtained approval from the ethical committee of the university. Then, the respondents were informed about the goals and objectives of the research and were interviewed. Most importantly, they were assured that the participation in

the research was voluntary, and they were entitled to leave it at any time so that they should not feel under pressure.

The article presents theoretical generalization and new solutions to the problem related to the correction and prevention of postural disorders in the sagittal plane in pupils who live in mountainous schools in the Carpathians. It proves the prevalence of postural disorders in the sagittal plane and peculiarities of angular spinal parameters of pupils who live in mountainous schools in the Carpathians, as well as compares them with the corresponding indicators of their peers who live in plain regions.

The article studies the indicators of physical development, functional and physical fitness, the level of somatic health and the peculiarities of functional spinal conditions of pupils with postural disorders in the sagittal plane. Besides, it compares the results with similar indicators of pupils with postural disorders in the sagittal plane, which who live in plain regions of Ivano-Frankivsk Oblast.

The article presents the author's complex rehabilitation programme for correction of postural disorders in the sagittal plane in pupils who live in mountainous regions, theoretically justifies the expediency of incorporating the elements of Pilates, athleticism and wellness tourism aimed at optimizing functional conditions of the spine, developing muscular corsets, physical skills and improving functional readiness of pupils.

It confirms the effectiveness of the author's complex of rehabilitation measures to improve functional conditions of the spine, physical development, functional and physical readiness, as well as the level of somatic health of pupils who live in mountainous regions.

The obtained results show close links between pedagogical and physical rehabilitation and medicine and neurosciences. Thus, an important neurophysiological indicator is the number of heartbeats. On the one hand, it is determined by the specifics (an increased respiration rate) in adolescents living in mountainous regions and, on the other hand, by the development of cerebral hypoperfusion activating the sympathetic system. In this regard, some scientists claim that such disorders are caused by the syndrome of postural tachycardia, which is the result of orthostatic intolerance in postural disorders in the sagittal plane (Cutsforth-Gregory, & Sandroni 2019, p. 429). Such disorders can be detected by measuring the heart rate when standing still for 10 minutes. If this frequency increases relative to the typical postural position by 30 beats or more, one can detect the symptoms of cerebral hypoperfusion, which indicates the complex neurosomatic nature of postural disorders in the sagittal plane.

Another neurophysiological indicator of postural disorders in the sagittal plane is ongoing postural-perceptual dizziness. Researchers from the University Hospital Centre in Zagreb studied about 150 patients with such symptoms (the median duration is 2 years). They found that 40% of patients suffered from vestibular neuritis and more than 10.5% of them from non-pathological dizziness (depending on a postural position) (Adamec et., 2020). These data indicate that adolescents with postural disorders in the sagittal plane need a complete and regular neurophysiological examination of their vestibular apparatus to identify complex (combined, concomitant) pathologies.

The practical value of the obtained results implies the development of the author's complex rehabilitation programme for correction of postural disorders in the sagittal plane in pupils living in mountainous regions, which can improve the level of physical development and functional and neurophysiological indicators by improving functional conditions of the spine.

The programme can serve as the basis for providing effective corrective and preventive work among pupils with postural disorders in the sagittal plane who live in mountainous regions. It can be introduced in professional activities of physical rehabilitation specialists, physical education teachers in schools and universities, coaches, as well as in the practice of rehabilitation centres, specialized institutions for children with postural disorders.

The problem of preserving and improving the health of the population continues to be one of the priority areas of Ukraine's social policy. The latter applies to young people, especially pupils. Indeed, the incidence rate of schoolchildren has increased by 1.8 times in the last 10 years (Popova, & Vladzymyrskyi, 2010). According to some statistics, the second place out of the five ranked ones in the structure of the incidence among high school students is occupied by musculoskeletal diseases, being second only to respiratory pathology. The incidence of musculoskeletal disorders in schoolchildren in secondary schools, especially in mountainous regions, remains an urgent problem of modern medicine (Apanasenko, & Popova, 1998; Batrshin, Sadovoy, Mikhaylovskiy, & Sadovaya, 2006; Popova, & Vladzymyrskyi, 2010), as well as physical education and physical rehabilitation (Aloshyna, Aloshyn, & Petrovych, 2009; Kashuba, 2002; Lazareva, 2012; Petrovych, Aloshyna, & Bychuk, 2007). Most programmes on physical rehabilitation of adolescents with postural disorders in the sagittal plane are quite complex, requiring special equipment that is impossible to implement given the logistics of mountainous regions. The

solution to this problem is to further improve and develop new programmes of physical rehabilitation that will be adapted to the conditions of mountainous regions in the Carpathians.

The research has verified the existing scientific views that the dissemination of musculoskeletal diseases among pupils in comprehensive schools, particularly in mountainous regions, remains an urgent problem of modern medicine (Apanasenko, 2005; Apanasenko, & Popova, 1998; Batrshin, Sadovoy, Mikhaylovskiy, & Sadovaya, 2006; Popova, & Vladzymyrskyi, 2010) and physical rehabilitation (Aloshyna, Aloshyn, & Petrovych, 2009; Lazareva, 2012; Petrovych, Aloshyna, & Bychuk, 2007). The importance of preventing and correcting postural disorders among pupils from mountainous regions in the Carpathians has been justified (Hulbani, & Kosa, 2010; Mykolaiskyi, 2006).

The main conceptual approaches to enhancing the influence of physical rehabilitation on physical development (Potapchuk, 2006), functional (Sedliar, 2011; Slavik, 2008) and physical strength (Furman, 1994; Plakhtii, Mukhin, Yevminov, & Kudel, 2006), the functions of the spine (Epifanov, & Epifanov, 2008; Doroshenko, 2009; Dubchuk, 2011) in case of posture violations in the sagittal plane have been further developed.

The article proves the views of such scholars as Lynets (2007), Miliukova & Evdokimova (2003), Plakhtii, Mukhin, Yevminov, & Kudel (2006), Ryzhenko (2006). They believe that the transformation of the ability to take the right position into the skill is achieved by the systematic repetition of exercises, constant control over holding the correct position and adherence to a special kinetic mode.

Specificity in angular parameters of the spine among pupils of the Carpathian region compared to the corresponding indicators of their peers from schools located in plain regions have been identified and described for the first time. The per cent correlation of various spinal disorders in the sagittal plane among pupils from mountainous regions in the Carpathians has been determined. The comprehensive rehabilitation programme for correcting posture violations in the sagittal plane has been developed for pupils from mountainous regions. The expediency of introducing the elements of pilates and athleticism into the programme has been theoretically justified. The programme has been adapted to educational and living conditions of pupils from mountainous regions, as well as economic, natural and social conditions in Ivano-Frankivsk region.

Also, the findings of the experiment can deepen neurophysiological aspects of rehabilitation for patients with postural disorders in the sagittal plane, including therapeutic and rehabilitation measures (Calmels, 2019) and

methods of neurostimulation of motor motility using electronic physiotherapy by (Jeunet, Glize, McGonigal, Batail, & Micoulaud-Franchi, 2019).

Finally, they can contribute to creating neuropathological anamnesis in the medical context of studying this particular problem and complement clinical studies associated with paired impulses and the so-called "virtual" (psychosomatic) damage to the cerebral system. Such synergy of data (combining the methods used in the article and neurofunctional measurements of motor control in patients with postural disorders in the sagittal plane) can generalize the role of parietal ligaments and ventral premotors of the cerebral cortex with postural disorders in the sagittal plane (Allart, Devanne, & Delval, 2019).

Conclusions

Based on inclinometer measurements, it has been found that postural disorders in the sagittal plane, such as stoop, sway back, flat back, round and concave back are more pronounced in pupils from mountainous regions compared with those in the CG. These changes also include severe chest deformity, a considerable decrease in strength of abdominal muscles, pelvic floor muscles, upper and lower back muscles, impaired postural stability with symptoms of degenerative changes, severe functional spinal disorders – limited mobility in the sagittal plane of thoracic (based on Otto test) and lumbar (based on Schober test) sections, limited spinal flexion in general (based on Thomayer test), as well as its lateral (based on Fleischmann test) and overall mobility (based on Sedin test and spinal index). Such changes act as symptoms for identifying a neuro- and somatopathological pattern of the underlying and accompanying diseases and, in extreme cases, medical correction or therapy.

The comprehensive rehabilitation programme for correcting postural disorders in the sagittal plane among pupils from mountainous regions, which includes some elements of pilates, athleticism and health tourism, is aimed at optimizing the functions of the spine, building muscular corset, developing physical skills and improving physical and functional strength of pupils, their somatic health. The programme is adapted to educational and living conditions of pupils from mountainous regions, as well as economic, natural and social conditions in Ivano-Frankivsk region. The programme is based on the differentiated approach to correcting various postural disorders in the sagittal plane. The complex nature of physical rehabilitation methods included in the author's programme is associated with simultaneous

influence on three components of the human nature, namely, physical, mental and social ones, which takes into account the neurophysiological profile of each individual.

Based on the comparison of the groups of pupils with different postural disorders, it has been proved that the author's programme has a differential influence on individual indicators of physical development (body weight, BMI, chest circumference, chest excursion), functional (Shtange test) and physical strength (flexibility and strength indicators test). One can observe the most pronounced optimization of these indicators among pupils with a stoop, sway back, round and concave back. The reliable differences between the above-mentioned groups of pupils and those pupils with flat back have been determined. The results of the tests for identifying the functional state of the spine indicate that the author's programme has a differential influence on the mobility of individual sections of the spine (Otto, Schober tests) and its overall mobility (Sedin, Thomayer tests, spinal index). Pupils who suffer from round and concave back, stoop and sway back have managed to make more progress in improving the functional state of the spine compared to their peers, who suffer from flat back.

So, the conducted studies on the effectiveness of the programme for correcting postural disorders in the sagittal plane involving a sufficient number of adolescents aged between 15 and 17 from mountainous regions in the Carpathians have turned out to be rather successful. Therefore, they can serve as the basis for the practical application of this programme, which ensures multi-aspect influence on the body.

The prospects for further researches consist in developing comprehensive programmes on inclinometer physical rehabilitation aimed at preventing and correcting various posture violations among pupils of different age groups adapted for mountainous conditions, as well as schools located in plain regions. The obtained data also show a direct correlation with neurophysiological and neuropsychological features of individuals with postural disorders in the sagittal plane. It is confirmed by the analysis of international neurophysiological discourse. Besides, it requires further research at the cross-section of correctional pedagogy, medicine and neuroscience.

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