



Physiological Features of Musculoskeletal System Formation of Adolescents Under the Influence of Directed Physical Training

RESEARCH

YAN GENG

SERGEI TRACHUK

XIAO MAN MA

YAN JIE SHI

XUE ZENG

*Author affiliations can be found in the back matter of this article

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ABSTRACT

Introduction: The musculoskeletal system plays an essential role in the performance of various movements and positioning of the body in space. Musculoskeletal diseases are an urgent problem of modern medicine. The investigation aims to determine the main pathologies of the musculoskeletal system and propose ways to avoid them.

Methods: For the analysis were used the data of 3 different research, were based on the data about 12–13 years old children. This is a retrospective study. Also was conducted anthropometric measurements, and correlation and comparison methods were used.

Results: It is shown that in adolescence, the musculoskeletal system is significantly reformed. Children experience rapid growth spurts, with girls having the growth spurt before boys. In addition, skeletal structures differ in adolescents of different sexes. It is noted that pain sensations that arise in adolescence persist in a more mature age and lead to various pathologies of the musculoskeletal system.

Conclusion: Modern adolescents have a tendency towards a deterioration of somatometric and somatoscopic indicators, which characterize the functional state of the spine. In case of disorders of the musculoskeletal system, rehabilitation should begin as early as possible using the appropriate therapeutic exercise techniques.

CORRESPONDING AUTHOR:

Yan Geng

Department of Theory and Methods of Physical Education, National University of Ukraine on Physical Education and Sport, Kyiv, Ukraine

yangeng03@outlook.com

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The state of the musculoskeletal system is one of the most important indicators of physical development and somatic health of people, children and adolescents in particular. The vertebral column and the arch of the foot act as structural links of the musculoskeletal system, forming a kinematic chain, which ensures rational and adequate performance of basic movements. Even insignificant functional disturbances of this kinetic chain can cause transformation of other musculoskeletal system links, which will certainly affect the state of somatic health (Vykhovanets, 2013). The skeletal formation is concluded only at the age of 20, and until this time it retains its elasticity, which, if the body is in the wrong position, leads to the impaired formation of the musculoskeletal system. Untimely identification and elimination of developmental disorders of the musculoskeletal system in adolescence, in turn, contributes to the development of a number of pathologies of other organs and systems in adults, in particular, secondary disorders of the cardiovascular, nervous, respiratory systems and other body systems (Kuprienko and Smirnova, 2015).

Moderate physical activity has a positive effect on the development of the musculoskeletal system in adolescents, contributing to the growth of bone mass (Dmytriiev, 2018; Latka et al., 2021). Low physical activity, on the contrary, negatively affects the formation of the skeleton. It is noted that insufficient physical activity is observed in 35–40% of primary school children and 75–85% of senior schoolchildren. As a result of insufficient motor activity, hypokinesia develops, which leads to hypodynamia. The latter condition is characterized by a number of negative structural and functional changes in many organs: muscular atrophy, general physical detraining, detraining of the cardiovascular system, decreased orthostatic stability, changes in water and salt balance, circulatory system disorders, bone demineralization, etc. As a result, there is a decrease in the functional activity of organs and systems, as well as the activity of regulatory mechanisms, which reduces resistance to adverse factors. In addition, there is a decrease in the intensity and volume of afferent information associated with muscle contractions, as a result of which there is disruption of movement coordination, decrease in muscle tone, endurance and strength parameters. Anti-gravity muscles (neck, back) are the most resistant to the development of hypodynamic states. In the abdominal muscles, atrophy develops quite quickly, which negatively affects the functional state of the circulatory, respiratory and digestive systems. With hypodynamia, there is a decrease in the force of heart contractions due to a decrease in venous return to the atria, weakening of the heart muscle, a decrease in the amount of circulating blood due to its stagnation in pools and capillaries. There is also a weakening of the arterial and vascular tone, a drop in blood pressure, development of hypoxia and general metabolic disorders.

Currently, the pathology of musculoskeletal system occupies a leading place in the structure of morbidity along with diseases of the organs of vision and diseases of the gastrointestinal tract. According to the GBD (Global Burden of Disease), approximately 1.71 billion people worldwide suffer from musculoskeletal system diseases (Cieza et al., 2020). The highest prevalence of these diseases is noted among the population of high-income countries — 441 million people, followed by the WHO Western Pacific Region with 427 million and the South-East Asia Region with 369 million. Musculoskeletal system pathologies also contribute significantly to disability of the population, which amounts to 149 million people (17%) worldwide (Hartvigsen et al., 2018). In Ukraine, musculoskeletal system diseases rank third after cardiovascular and oncological pathologies (sereda and Liannoy, 2013). Among adolescents, there is an increase in functional and chronic pathologies of the musculoskeletal system by 10–25%, scoliosis in particular (Mansurova et al., 2019).

Treatment and prevention of the development of pathologies of musculoskeletal system is the most difficult problem of modern orthopedics. First of all, it is necessary to identify problems with posture and spine at the right time and correct disturbances using various methods, including adequate physical activity for the successful treatment of these diseases. Basically, combined methods are used, which allow not only to correct posture and strengthen muscles, but also contribute to the overall improvement of the body of adolescents. Therefore, there are many methods and means of physical rehabilitation for posture disorders in schoolchildren, which include both traditional (round-the-clock observance of the orthopaedic regime, daily classes of corrective therapeutic gymnastics, therapeutic swimming, classical massage procedures, electrical muscle stimulation), and non-traditional — exercises on large inflatable

balls, therapeutic choreography, corrective gymnastics after daytime sleep and elements of acupressure. These methods and means are the basis for the development and implementation of physical rehabilitation programmes for students with postural disorders, taking into account their age.

The authors analyzed the results of 3 different studies, which were based on data on children 12–13 years old. This is a retrospective study. Anthropometric measurements were also carried out, and correlation and comparison methods were used. The problem of physical health of the younger generation is gaining importance in modern conditions. They include the development of pathologies of the musculoskeletal system. Adolescence is the period with the highest rates of physical development; therefore, this period is considered the most important for physical development. However, despite a large number of available methods, the study of the literature indicates a significant spread of functional disorders in the state of the musculoskeletal system. It is possible to conclude the insufficient development and implementation in practice of the system of measures for the prevention and treatment of pathologies of the musculoskeletal system in adolescence. The investigation aims to determine the main pathologies of the musculoskeletal system and propose ways to avoid them. Studying and reviewing various pathologies will add to the existing knowledge in this topic.

MATERIALS AND METHODS

Today, the main part of schoolchildren's school and leisure time is characterized by low physical activity, which is associated with a significant change in lifestyle in favor of passive pastime (Grankina, 2017). The latter is facilitated by the use of an elevator, cars, gadgets, interactive games, etc. According to research, 92% of children use gadgets instead of active games, 51% of teenagers do not spend time outdoors after school, 28% of schoolchildren do their homework for more than 3 hours, 12.8% — more than 4 hours, 4.4% — more than 5 hours a day, 73.7% of students continuously sit at their desk for more than 3 hours (Zolicheva et al., 2018).

There is evidence that poor posture at school can cause back and/or neck pain in adult working life. Ergonomic seating and correct positioning during certain work tasks are top priorities in the adult workplace, but are generally overlooked in school classrooms. The relationship between improper working posture and the development of neck and lower back pain has been extensively studied, but it is not known if this could be related to the school sitting posture. It has been suggested that in some adolescents, lower back pain may be associated with similar pain in adulthood. It is worth noting that there is no clear definition of posture in the ergonomics literature. Basically, the recommendations are reduced to sitting upright and not slouching. Yet the functional definition is a position taken in relation to a task being performed, therefore, the wrong posture can cause discomfort. To complete the basic tasks given to schoolchildren, it is required that they sit most of the time. The tasks in a seated classroom include reading, writing, listening and using the computer. Because some of these tasks typically use different postures (such as writing versus listening), the features of the chair and table may conflict with generally accepted safe seated postures. The factors influencing the posture of schoolchildren are varied. This can have consequences in adulthood. The epidemiology and etiology of pain in children and adolescents need to be studied, as it may contribute to a better understanding of the origin of pain problems in adults (Gheysvandi et al., 2019).

Taking into account the deterioration of the conditions for the development of musculoskeletal system in modern adolescents, it is very important to take adequate preventive and therapeutic measures aimed at eliminating postural deficiencies at the right time. In this area, there is a distinction between active and passive correction. Active correction includes physical therapy (therapeutic exercise), active posture straightening, adherence to work and rest regimen and other activities that are carried out with the active participation of the adolescent themselves. Passive correction involves use of special devices (wearing special corsets, orthopedic inlays, etc.). There is also a distinction between general and special correction. With the aid of general correction, health improvement is achieved through the use of various means of physical culture, and special correction contributes to the local improvement of defects in the musculoskeletal system (Bashkirin, 2005).

RESULTS

The musculoskeletal system of adolescents undergoes significant changes, which are primarily associated with growth changes. Growth in adolescence is often characterized by dramatic leaps and bounds. Significant physical growth occurs during school years: girls reach 65% of their height by age 4, while boys reach 60% of their height at the same age. Girls have a growth spurt at an earlier age than boys: girls reach 95% of their height by age 13, and boys do not reach the same percentage until age 15. The average height of boys in secondary school is 174.5 cm, and for girls it is 163.1 cm. In addition to height, adolescents of different sex also have differences in parts of the spine. In particular, in girls, the size of the thoracic spine differs from that of boys at the age of 13, and kyphosis of the thoracic spine is less common (Zheng et al., 2013). Somatoscopic and somatometric indicators are used to assess musculoskeletal system disorders. One study, which was conducted based on the Pereyaslav-Khmelnytsky gymnasium in the Kyiv region, involved 64 students aged 12–13 years. In order to study the state of prevalence of posture disorders among secondary schoolchildren, visual screening of body posture, anthropometric studies and questioning of students were carried out in the process of somatoscopy. Somatoscopy revealed postural deviations in the frontal plane (Table 1).

POSTURE	NUMBER OF PUPILS	%
Normal	10	10
Hyperkyphotic	9	15
Slouched	15	25
Hyperlordotic	2	3
Slumping posture (thoracic kyphosis)	2	3
Scoliotic (asymmetric shoulder blades)	7	12
Scoliotic (asymmetric shoulder girdle)	9	15
Scoliotic (asymmetric arrangement of the cervicobrachial angle)	2	4
Flat back	8	13

Table 1 Results of Examination of Pupils' Posture Disorders.

The study results are consistent with the data on disorders of posture in the organization of the educational process existing in literature (Afanasyeva, 2014; Voychyshyn, 2009). When clarifying gender characteristics of the distribution of posture pathology among the subjects, it was found that the prevalence of curvature of the spine in general among boys (42.2%) is lower than in girls (57.8%). Scoliosis affects more girls than boys. Using the results of the study, average anthropometric data indicators of the subjects were calculated:

- height: 164.5 ± 1.75 cm;
- chest circumference at rest: 82.1 cm;
- chest circumference when inhaling: 87.1 cm;
- chest circumference when exhaling: 78.8 cm;
- chest excursion: 8.1 cm;
- abdominal circumference: 67.6 cm;
- pelvic size (distance between the furthest points of the iliac crest): 23.6 cm.

Among the data obtained, the growth rate of pupils corresponds to the age standards and is more than 150 cm at this age. In the process of studying the somatometric indicators, it was found that the indicator of chest circumference (CC), both in boys and girls, was lower by an average of 7.0 cm and 5.2 cm, respectively, compared with healthy ($p < 0.01$) people. The data obtained indicate a significantly reduced static endurance of the muscles of the back and abdomen, which are involved in the formation of orthograde posture, which is one of the reasons for the development of posture disorders. The studies of the functional state of the respiratory organs indicate a decrease in the level of the actual vital capacity of the lungs (VC) by an average of 13.0% ($p < 0.001$) in boys and by 16.8% in girls ($p < 0.001$). The indicator of the ratio of VC to proper vital capacity of the lungs (PVC) was also reduced in boys by an average of 15.5% ($p < 0.001$) and by 10.5% in girls ($p < 0.001$).

Strictly defined limits and norms are missing for some indicators. These indicators are the circumference of the abdomen. At the same time, among the somatoscopic indicators in girls, the size of the pelvis plays an important role (the norm is 26 cm). A particularly dangerous problem for girls is the deviation from the norm in the size of the pelvis. The female pelvis should not be narrow, since the main purpose of a woman is reproduction, and serious complications can arise with narrow hips during pregnancy and childbirth. Among the surveyed girls, this indicator ranges from 20–25 cm (the average is 23.6 cm) (Stavitska, 2017). Thus, as a result of the experiment, it was found that there is a tendency towards deterioration in somatometric and somatoscopic indicators characterizing the functional state of the spine, which leads to poor posture in middle school students.

Spinal disorders are largely caused by improper seating, in which school furniture plays an important role. The selection of furniture of adequate size in adolescence allows one to form the correct posture and avoid problems with the musculoskeletal system at a more mature age (Castellucci et al., 2016). One study examined gender differences and their relationship to school furniture design and also performed anthropometric measurements. Statistically significant differences between boys and girls were found in 14 of 17 measurements carried out by Mououdi and Choobineh (1997) in their study of children aged 6–11 years in one of the provinces of Iran. However, these authors found no difference in seated height or body height between boys and girls. In contrast, a study of 1,248 Koreans aged 6 to 17 by Jeong and Park found that popliteal height was an important predictor of seat height. The researchers concluded that boys taller than 126 cm require taller tables and chairs than girls of the same height. Girls taller than 120 cm required more depth and width of the chair than boys of the same height. Hence, growth is an important factor when designing school furniture. Although Jeong and Park (1990) used anthropometric measurements similar to those of Mououdi and Choobineh (1997), it has not been established whether there is a relationship between these indicators and ethnic characteristics. Boys and girls have different requirements for the design of their classroom workplace. Significant gender differences are evident in the relationship between height and body size and are thus associated with furniture design (Wong, 2015).

Usually, musculoskeletal system disorders are associated with pain and discomfort in various parts of the spine. The epidemiology of pain in children and adolescents is not well documented, but the study has shown that many schoolchildren complain of low back pain. At the same time, 62% of children experienced back pain “sometimes” or “often”, and 9.5% “very often”. There was also a high level of complaints of back pain, which is closely related to the frequency of “non-standard” sitting at the desk (Knight and Noyes, 1999). The discrepancy between hip length and seat depth was found to be significantly associated with general seating discomfort, and the discrepancy between seated elbow height and table height was significantly associated with neck and shoulder pain. Muscle tension (especially in the neck and shoulders) during adolescence is a significant factor in the subsequent increased soreness in the neck. However, this study did not find a similar risk factor for low back pain (Parvez et al., 2018).

Another study noted that sitting height and asymmetry may be contributing factors to lower back pain during puberty. At the same time, for many adolescents, the discomfort in musculoskeletal system was associated with the use of a computer. Headaches and muscle fatigue can develop in the neck and upper back after just 20 minutes of using a computer, and the longer the duration of a task, the more discomfort the students experienced. 60% of students experienced discomfort when using a laptop and 61% experienced discomfort when carrying a laptop. Despite the uncertainty in the literature regarding the causative factor(s) of low back and neck pain in children, its prevalence appears to be high. Anthropometric deviations, possible adverse consequences for development during prolonged exposure to postural stress, and computer furniture are some of the important factors that must be taken into account in order to reduce the degree of pain in various parts of the spine (Grimes and Legg, 2004).

The pain associated with musculoskeletal system disorders can be reduced through physical activity. The importance of physical activity in maintaining an adequate musculoskeletal condition was confirmed in a Polish study in which students of music schools took part. Musicians represent a very specific professional group, which, due to some occupational risks, is subject to various health problems associated with playing instruments, musculoskeletal

disorders in particular. The aim of this study was to assess the correlation between the level of physical activity and the occurrence of musculoskeletal pain among young instrumentalists. 225 students of Polish music schools were examined. A moderate to high physical activity index was used to assess the level of physical activity of the study participants. To assess complaints of pain from the musculoskeletal system, the Nordic musculoskeletal questionnaire (NMQ), which is used worldwide, was used (Kahraman et al., 2016). The NMQ was supplemented with a visual analogue scale, which also allowed assessing the intensity of pain on a numerical scale from 1 to 10. The results of the study showed that pain localized in the neck, shoulders, upper and lower back was significantly more likely to be reported by participants who did not match the standard criteria for the recommended or minimum level of physical activity. The researchers concluded that performing the recommended health-oriented physical activity can reduce the severity of musculoskeletal pain (Nawrocka et al., 2014).

In case of disorders of musculoskeletal system, in addition to physical activity, rehabilitation is necessary. Another study examined the physical development and range of motion in certain parts of the spine in middle school students with poor posture. Experimental research work was carried out on the basis of a comprehensive stage I–III school No.7 in Lutsk during 2008/2009. The experiment involved 22 girls and 19 boys aged 12–13 years. The students who were found to have the musculoskeletal system disorders were engaged in physical education lessons and after the lessons underwent a developed experimental programme of physical rehabilitation in the PE hall. In addition, a course of physiotherapy and massage was prescribed. The developed programme for the prevention and correction of posture disorders by means of physical rehabilitation included three directions: courses during physical education class (twice a week), after-hours classes (three times a week) and independent courses at home. The level of physical development of schoolchildren 12–13 years old in conditions of poor posture at the beginning of the experiment and after its completion was determined by anthropometric indicators (Table 2).

SEX	N1	M1 ± SM1	P	N	M2 ± SM2	P
BODY LENGTH, CM						
Male	19	162.0 ± 2.30	>0.05	19	169.6 ± 0.64	<0.01
Female	22	158.0 ± 2.96		22	161.0 ± 0.56	
BODY WEIGHT, KG						
Male	19	48.8 ± 1.70	>0.05	19	54.8 ± 0.78	<0.001
Female	22	46.4 ± 2.13		22	59.4 ± 0.65	
PULSE IN A STANDING POSITION, BPM						
Male	19	81.1 ± 1.77	>0.05	19	78.1 ± 0.55	>0.05
Female	22	84.8 ± 2.27		22	84.8 ± 0.66	
BLOOD PRESSURE, MM HG						
Male	19	107/69 ± 2.73	>0.05	19	113/70.2 ± 2.52	>0.05
Female	22	107/69.3 ± 2.50		22	109/69.8 ± 2.13	
LUNG VITAL CAPACITY, L						
Male	19	3.2 ± 1.70	>0.05	19	3.5 ± 2.73	>0.05
Female	22	2.7 ± 1.41		22	2.9 ± 2.11	

Table 2 Height, Weight and Physiological Indicators of Secondary Schoolchildren in Conditions of Poor Posture at the Beginning and after the Experiment.

Note: M1 ± Sm1 – average data for the studied group at the start of the experiment; M2 ± Sm2 — average data for the studied group after the experiment.

Based on the anthropometric measurements, it was found that at the end of the school year, the indicators significantly differed from those at the beginning of the school year. A comparative analysis of these measurements showed that adolescents have grown significantly stronger during the year. Growth and weight indicators returned to normal. Boys on average per year grew by 2 cm (160.1 ± 0.62), gained 2.5 kg (51.8 ± 0.61) weight, girls, respectively, grew by 3 cm (159.5 ± 0.35) and gained 1 kg (50.7 ± 0.35). Pulse in a standing position (76–80 bpm) and blood pressure (BP) (105/60–110/70 mm Hg) began to correspond to the norm in both boys and girls. Vital capacity of the lungs (VC) in boys increased on average by 0.5 l, and in girls – by 0.6

l. Total movements of the entire spine of secondary schoolchildren at the beginning and at the end of the experiment are grouped in Table 3.

AMPLITUDE OF MOVEMENTS, DEGREES								
SEX	FLEXION		EXTENSION		FRONTAL PLANE		TURNS TO EACH SIDE	
	NORM (160°)	DEVIATION	NORM (45°)	DEVIATION	NORM (165°)	DEVIATION	NORM (120°)	DEVIATION
AT THE BEGINNING OF THE EXPERIMENT								
Male	45.2	54.8	39.9	60.1	38.7	61.3	43.6	57.4
Female	46.3	53.7	42.4	57.6	39.8	60.2	44.5	55.5
AT THE END OF THE EXPERIMENT								
Male	63.3	36.7	57.8	42.2	51.9	48.1	56.8	43.2
Female	64.6	35.4	59.7	40.3	53.1	46.9	58.4	41.6

Table 3 Indicators of Total Spinal Movements in Secondary Schoolchildren in Case of Posture Disorders at the Beginning and at the End of the Experiment, %.

As seen from Table 3, at the beginning of the experiment, the flexion of the entire spine was normal and amounted to 160° in 45.2% of girls and 46.3% of boys; deviations were found in 54.8% of girls and 53.7% of boys. Normal extension of the entire spine (145°) was observed in 39.9% of girls and 42.4% of boys; deviations, respectively – in 60.1% of girls and 57.6% of boys. The total range of motion in the frontal plane corresponded to the standard (up to 165°) in 38.7% of girls and 39.8% of boys; violations were observed in 61.3% of girls and 60.2% of boys. The total amplitude of turns in each direction, taken as the norm (up to 120°), was found in 43.6% of girls and 44.5% of boys; deviations, respectively – in 57.4% of girls and 55.5% of boys. Summarizing the results of this stage of the study, it can be noted that at the beginning of the experiment, the overwhelming majority of the subjects had serious deviations from the generally accepted norms of the range of motion in certain parts of the spine. As can be seen from Table 3, after the experiment, the total movements of the spine within the limits of flexion corresponded to the norm in 63.3% of girls and 64.6% of boys; deviations were observed in 36.7% of girls and 35.6% of boys. In terms of extension, the total movements corresponded to the norm in 57.8% of girls and 59.7% of boys; deviations were found, respectively, in 42.2% of girls and 40.3% of boys.

When comparing similar indicators of flexion and extension of the spine during the ascertaining experiment, significant positive changes were noted. After the experiment, the total range of motion in the frontal plane corresponded to the norm in 51.9% of girls and 53.1% of boys; deviations were observed, respectively, in 48.1% of girls and 46.9% of boys. The total amplitude of turns in each direction corresponded to the norm in 56.8% of girls and 58.4% of boys; deviations, respectively – in 43.2% of girls and 41.6% of boys. Thus, in the formative experiment, the total movements in the frontal plane and the amplitude of turns in each direction corresponded to the norm in more than 50% of girls and boys, in the ascertaining experiment, deviations were observed in more than 50% of adolescents. This is evidence of the positive effect of physical rehabilitation on the adolescent body with disorders of the musculoskeletal system. In the course of repeated courses in physical education class and after school hours, the students improved their health: their abdominal and back muscles strengthened, their physique improved (Krendeleva, 2009).

Chinese researchers studied the effect of a corrective functional exercise programme on postural thoracic kyphosis in adolescents. A simple, blinded randomized controlled trial was conducted at the Chinese Institute of Sport Science and three high schools in Beijing in students with a thoracic kyphosis angle (TKA) > 40° measured using SpinalMouse. A total of 181 people took part in the study; of these, 164 people were included in the analysis (experimental group, n = 81; control group, n = 83). The experimental group received a functional exercise programme designed to correct postural thoracic kyphosis, and the control group received an exercise programme designed in accordance with the curriculum. In this study, the following parameters were assessed: angle of thoracic kyphosis, angle of lumbar lordosis, sacral angle and trunk inclination, measured in an upright position; range of motion of the thoracic, lumbar and sacral spine, change in centre of gravity, measured in positions of forward flexion and

extension; and changes in the angle of thoracic kyphosis, angle of lumbar lordosis, sacral angle and trunk inclination, as measured by the Matthias test. These indicators are informative in assessing the state of the musculoskeletal system (Albertsen et al., 2018).

The results of the study showed that in both groups there were significant differences in the angle of the thoracic kyphosis before and after testing (intervention group: preliminary test 47.09 ± 5.45 , post-test 38.31 ± 9.18 , $P < 0.0001$; control group: preliminary test 47.47 ± 6.06 , post-test 43.59 ± 7.49 , $P < 0.0001$). After adjusting for sex and pre-test values, significant differences were found in post-test TKA, changes in sacral angle and TKA in the experimental group compared to the control group ($P < 0.05$) (Feng et al., 2018). In summary, the corrective functional exercise programme developed for this study improved severe thoracic kyphosis in adolescents.

Another study presents the “Alpha-Gravity” wellness method, the key element of which is gravity. This technique is used in the sports and health club “Patriot” in Vinnytsia along with exercise therapy, massage, physiotherapy, manual therapy and kinesitherapy. The difference between “Alpha-Gravity” and other types of physical activity is the compression on the spine and joints. This involves active work of the muscles during balancing in a suspended state with support on suspension cables, to which a person clings with the help of hands and feet (Grabovsky, 2020). The effects of this technique on adolescent musculoskeletal system are described. The study involved 20 children aged 5 to 16 years with various disorders of the musculoskeletal system. At the beginning of the observation, all showed a decrease in the amplitude of active movements in the area of the shoulders and spine, a decrease in muscle strength, and impaired posture and gait. After a year of physical exercises using the “Alpha-Gravity” method, the following results were noted: strengthening of the musculoskeletal system and the entire structure of the body: joints, spine, ligaments, tendons; restoration of mobility after injuries, fractures, dislocations, rupture of ligaments and strengthening of bone tissue; elimination of muscle cramps; increased body flexibility; improved blood circulation; stimulation of the brain; strengthening of the cardiovascular system; removal of mental and emotional stress (Kovtanyuk, 2018).

Thus, the positive effect of a complex physical technique was noted in almost 90% of patients, which is confirmed by clinical data. With regard to the effects on musculoskeletal system, positive changes in posture should be noted, an improvement in mobility when turning and bending in the spine area, an increase in possibilities with dosed physical activity, and in some cases, the diagnosis of “scoliosis” was changed to “scoliotic posture”, and there was also an improvement in the general functional state. Over the course of three years, more than 250 people underwent rehabilitation at the “Patriot” club and improved their health, 60% of them being children under 14 years of age. Additionally, the “Alpha-Gravity” system made it possible to speed up the healing process and install lasting results for a long period.

It has been shown that musculoskeletal system diseases are very common in modern adolescents. Basically, schoolchildren spend their study time, and often their leisure time, in a sitting position at the computer (Grankina, 2017; Zolicheva et al., 2018). At the same time, school furniture does not always correspond to the parameters of those who are seated, which leads to muscle strain, discomfort and pain (Grimes and Legg, 2004). The results of the study of somatoscopic and somatometric indicators of the state of posture showed that students have a significant decrease in the static endurance of the muscles of the back and abdomen, which take part in the formation of the orthograde posture, as a result of which the normal position of the back is disrupted. It was noted that the curvature of the back is more inherent in girls than boys. In general, adolescents of both sexes have a tendency towards a decrease in somatometric and somatoscopic indicators, which reflect the functional state of the musculoskeletal system (Stavitska, 2017).

DISCUSSION

Due to the fact that the skeleton is actively formed during puberty, it is very important to identify and correct disorders of the musculoskeletal system in time. It has been proven that in many respects the normal functional state of the musculoskeletal system depends on correct posture and balanced physical activity. And in cases of the musculoskeletal disorders, physical

rehabilitation is necessary. Studies have shown that with regular physical education both at school and during after school hours, students have improved their health. After physical education, their somatometric and somatoscopic indicators significantly improved compared to the values before training (Krendeleva, 2009).

In the case of the musculoskeletal pain, health-oriented physical activity can reduce the severity of pain. In addition, the implementation of appropriate physical exercises in adolescence contributes to the normalization of the functional state of the musculoskeletal system in adulthood (Nawrocka et al., 2014). Special corrective functional exercises can improve the condition of the spine in students with pronounced thoracic kyphosis (Feng et al., 2018). The “Alpha-Gravity” health-improving method, in turn, had a number of positive effects on the musculoskeletal system of adolescents with postural disorders (Kovtanyuk, 2018).

Thus, depending on the type of posture disorders, various methods of physical rehabilitation are used. For example, the technique for S-shaped scoliosis treatment consists of the need to combine massage with corrective gymnastics, that is, with special exercises that are aimed at correcting the curvature of the spine and strengthening the “muscle corset”. The course of treatment includes 12–16 procedures, of which the first 4–8 procedures are performed daily, and the subsequent ones – every other day (Greida et al., 2011). Another technique, proposed by L. Voychyshyn (2009), involves the distribution of tasks in different parts of a therapeutic corrective gymnastics class. The preparatory part of the lesson is carried out in the initial lying position (horizontal position of the spine) and, in order to prepare the muscles for active and effective work — in an upright position. The main part of the lesson includes dynamic and static exercises to strengthen the symmetrical muscles that support the spine. The final part of the lesson is carried out in an upright position (sitting, standing, walking, running) in order to consolidate the habit of correct posture in static poses and during dynamic movements. This programme of physical rehabilitation of children with scoliosis should include both traditional methods and means, as well as new, non-traditional ones. All the proposed methods solve the problem of unidirectional impact on the correction of the spine, but each method has its own specific action (Kuksa et al., 2014).

In modern rehabilitation and formation of correct posture special attention is paid to exercises on large bouncy balls, since they improve the function of coordination, balance and motor control, as well as strengthen the muscles. It is noted that the use of elastic balls improves the damping function of the spine, has a greater effect on its correction and contributes to the normal formation of its physiological curves (Bubela, 2002). To treat scoliosis, the A.V. Kondrashov massage method is widely used. The nature of the massage is determined by three main components: strength, pace and duration. A high pace (deep massage) promotes the development of inhibitory processes. Medium and low pace (surface massage) promote stimulating processes. A fast-paced massage increases the excitability of the nervous system, while medium- and slow-paced massage reduces it. However, without strengthening the abdominal muscles, gluteal muscles and back muscles in children, it is impossible to develop a stable stereotype of correct posture (Stavitska, 2017).

It is noted that the therapeutic effect of exercise is enhanced through massage. In particular, in the case of curvature of the spine, massage is used in the physical therapy method (therapeutic exercise) together with physical exercises and outdoor games (Peshkova and Avramenko, 2009). Physiotherapeutic treatment is also widely used in the complex of rehabilitation measures. The goal of physiotherapy is to provide a strengthening and corrective effect on the spine, improve blood circulation and musculoskeletal tissue, strengthen the muscles of the back and abdomen, normalize the functional state of the neuromuscular system, and reduce the load on the weak half of the spine (Sokolova, 2010).

Among the physical rehabilitation programmes for posture disorders in schoolchildren, one of the most effective is the comprehensive physical rehabilitation programme developed by O.S. Afanasyeva (2013). The specified programme contains a wide range of tools and includes three movement modes: *gentle*, *gentle training* and *training*. In the gentle mode, classes are conducted individually, in the gentle training and training modes the classes are conducted individually and using small-group methods, 3 times a week, for 8 months. The main form of motor regimen is therapeutic gymnastics with the predominant use of corrective exercises for the prevention of fixed posture disorders. In this case, preference should be given to symmetrical

physical exercises that eliminate the asymmetry of muscle tone, contribute to the correction of the asymmetry of the angles of the shoulder blades and reinforce the habit of correct posture. These exercises are performed three times a week for 45 minutes.

The defining feature of the programme is the use of fitballs, which contribute to the formation of correct postural habit, strengthening of the muscular corset and improvement of vestibular function. In addition, during therapeutic exercises, the use of Evminov board (Evminov prohilactor) is required to unload the spine and strengthen the deep muscles of the back. In addition, before morning exercises, a daily 10-minute massage should be performed: symmetric massage not only of the back, but also of the chest, and self-massage of the feet to strengthen the muscles of the foot, since the spine and feet are a single biokinematic chain. The effect of physical rehabilitation means can be enhanced by supplementing them with physiotherapy courses (Afanasyeva, 2013). The essence of a comprehensive physical rehabilitation programme for posture disorders in schoolchildren is as follows:

- gentle motor mode (1 month) of the programme involves self-massage of the feet, morning exercises (15 minutes, daily), and exercise therapy with fitballs (25% of the total amount of exercise in the main part of the lesson), breathing exercises according to the A.N. Strelnikova method (after therapeutic exercises for 15 minutes, the initial complex) (Ziborova and Miftakhov, 2016), a back and chest massage course (20 minutes, daily, 20 procedures), a course of paraffin therapy (before the application of massage, 15 procedures);
- gentle training mode (6 months) involves the above therapeutic exercise and introduces exercise on the Evminov board at an angle of 15°, gradually increased to 20° (50% of the total amount of exercise in the main part, including fitball exercise), a course of electrophoresis with euphyllin (10 procedures with the longitudinal arrangement of electrodes in the cervical and lumbosacral spine) and paraffin therapy (10 procedures before the application of massage);
- training mode (1 month) involves self-massage of the feet, morning exercises and therapeutic exercise with the use of fitballs and a Evminov board (75% of the total amount of exercise in the main part), breathing exercises according to the Strelnikova method (15 minutes of the main complex), back and chest massage course (20 minutes, daily, 20 procedures), a course of paraffin therapy (paraffin applications onto the paravertebral zone, 15 procedures) (Afanasyeva, 2014).

CONCLUSIONS

In the article, the authors identified the main pathologies of the musculoskeletal system and suggested ways to avoid them. Authors conclude that modern adolescents tend to a deterioration of somatometric and somatoscopic indicators, which characterize the functional state of the spine. In addition, in adolescents of both sexes, a decrease in chest circumference was noted, as well as a decrease in the level of actual vital capacity of the lungs. These indicators are informative in assessing the functional state of the musculoskeletal system.

The use of various methods, means and programmes of physical rehabilitation is necessary for students with postural disorders both in the educational process and at home. Various methods of rehabilitation of adolescents with musculoskeletal system disorders are described. Correct seating also plays a significant role during training, since most of the time students are in a sitting position. At the same time, it is important to take into account the gender characteristics of adolescents, since the musculoskeletal system develops unevenly in boys and girls. In case of disorders of the musculoskeletal system, rehabilitation should begin as early as possible using the appropriate therapeutic exercise techniques.

Therefore, there are many methods and means of physical rehabilitation for posture disorders in schoolchildren, which include both traditional (round-the-clock observance of the orthopaedic regime, daily classes of corrective therapeutic gymnastics, therapeutic swimming, classical massage procedures, electrical muscle stimulation), and non-traditional — exercises on large inflatable balls, therapeutic choreography, corrective gymnastics after daytime sleep and elements of acupressure. These methods and means are the basis for the development and

COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR AFFILIATIONS

Yan Geng  orcid.org/0000-0003-2193-3849

Department of Theory and Methods of Physical Education, National University of Ukraine on Physical Education and Sport, Kyiv, Ukraine

Sergei Trachuk  orcid.org/0000-0003-3071-5309

Department of Theory and Methods of Physical Education, National University of Ukraine on Physical Education and Sport, Kyiv, Ukraine

Xiao Man Ma  orcid.org/0000-0002-0831-7358

Department of Basketball, Beijing Sport University, Beijing, People's Republic of China

Yan Jie Shi  orcid.org/0000-0003-0000-8187

Department of Fitness and Recreation Health, National University of Ukraine on Physical Education and Sport, Kyiv, Ukraine

Xue Zeng  orcid.org/0000-0001-8068-0680

Students' Affairs Office, Fuxin Junior College, Fuxin, People's Republic of China

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