

Sensitive periods of flexibility development at school age Períodos sensibles de desarrollo de la flexibilidad en la edad escolar

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Abstract. The objective is to identify sensitive periods for the accentuated development of flexibility of schoolchildren. Methods: the scientific research was conducted on the basis of 60 schools in the city of Kirov, in Russia from September 14, 2022 to May 22, 2023. The pedagogical experiment involved 1,217 children (579 boys and 638 girls) from grades 1 to 11 of secondary school number 60 Kirov, Russia. Each lesson in the discipline "Physical education" lasted 40 minutes and took place 3 times a week. All students were engaged in the usual physical education program at school. All students took the tests at the beginning and at the end of the school year. The level of flexibility development was determined by the test "Leaning forward from a standing position on a gymnastic bench." Excel was used to process the results of the study, the Biostatistics-2022 program determined the reliability of the results of the T-Student study. Results: After the end of the study, the average indicators in each age group increased during the academic year. In the indicators of boys from the beginning to the end of the study, there was a significant and significant increase in flexibility indicators in the second grade (+15%), in the third grade (+17%) and in the fourth grade (+15%). In girls, a significant increase in the value is noted in the third grade (+16%), fifth grade (+14%) and sixth grade (+15%). In other age periods, there is not a significant increase in flexibility indicators ($p>0.05$). Conclusion: As a result of this large-scale study, it can be argued that the targeted development of flexibility should be in boys aged 8 to 11 years, and in girls aged 9-10 years, 11-12 years and 12-13 years.

Keywords: Physical exercises, Joint mobility, Muscle stretching, Physical education.

Resumen. El objetivo es identificar períodos sensibles para el desarrollo acentuado de la flexibilidad de los escolares. Métodos: la investigación científica se llevó a cabo sobre la base de 60 escuelas en la ciudad de Kirov, en Rusia, del 14 de septiembre de 2022 al 22 de mayo de 2023. El experimento pedagógico involucró a 1.217 niños (579 niños y 638 niñas) de los grados 1 a 11 de la escuela secundaria número 60 Kirov, Rusia. Cada lección de la disciplina "Educación física" duró 40 minutos y se llevó a cabo 3 veces por semana. Todos los estudiantes participaron en el programa habitual de educación física en la escuela. Todos los estudiantes tomaron las pruebas al principio y al final del año escolar. El nivel de desarrollo de la flexibilidad se determinó mediante la prueba "Inclinarse hacia adelante desde una posición de pie en un banco de gimnasia." Se utilizó Excel para procesar los resultados del estudio, el programa Bioestadística-2022 determinó la confiabilidad de los resultados del estudio T-Student. Resultados: Una vez finalizado el estudio, los indicadores promedio en cada grupo de edad aumentaron durante el año académico. En los indicadores de niños desde el principio hasta el final del estudio, hubo un aumento significativo y significativo en los indicadores de flexibilidad en el segundo grado (+15%), en el tercer grado (+17%) y en el cuarto grado (+15%). En las niñas, se observa un aumento significativo en el valor en el tercer grado (+16%), quinto grado (+14%) y sexto grado (+15%). En otros períodos de edad, no se observa un aumento significativo de los indicadores de flexibilidad ($p>0,05$). Conclusión: Como resultado de este estudio a gran escala, se puede argumentar que el desarrollo específico de la flexibilidad debería ser en niños de 8 a 11 años y en niñas de 9 a 10 años, 11 a 12 años y 12 a 13 años.

Palabras clave: Ejercicios físicos, Movilidad articular, Estiramientos musculares, Educación física.

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Introduction

In recent years, there has been a negative trend in the health of the population, especially schoolchildren (Hu et al., 2021; Oberle et al., 2020; Terrón-Pérez et al., 2021). There is a clear trend of deterioration in the health of children and adolescents studying in educational institutions. According to various authors, there are only 10-12% of practically healthy schoolchildren, about half of the children have minor morphological or functional abnormalities and up to 40% of schoolchildren have chronic diseases. Unfortunately, the data of medical examinations indicate that during the period of schooling, the health of children deteriorates 4-5 times. By the end of school, every third student has nearsightedness, impaired posture; problems with the cardiovascular system (Kholodov & Kuznetsov, 2018; Solodkov & Sologub, 2018; Matveev, 2021).

Over the past four decades, there have been ten times more obese children aged 5-19 in the world. This conclusion is made by the World Health Organization ().

Physical inactivity is a sedentary lifestyle and a disease of modern humanity of the twenty-first century. It is the result of getting rid of physical exertion and labor. Lack of physical activity has an extremely negative effect on the work of the myocardium (heart muscle) and blood vessels (Aliss et al., 2020; Mikaelsson et al., 2020; Di Maglie et al., 2022). The harmful effects of physical inactivity also affect metabolism, contributing to the development of obesity. Lack of movement negatively affects the activity of the brain, causing irritability, insomnia, decreased performance, and fatigue. People who lead a sedentary lifestyle have a high risk of gastrointestinal diseases, varicose veins, hypertension, joint diseases, and atherosclerosis. Thus, the motor abilities of schoolchildren deteriorate significantly (Heradstveit et al., 2020; Volmut et al., 2021).

The development of motor abilities of schoolchildren is one of the main tasks of physical education. The development of motor abilities contributes to the comprehensive and harmonious development of personality, the achievement of high body resistance to socio-environmental conditions, and the improvement of

adaptive properties of the body (Piñeiro-Cossio et al., 2021; de Bruijn et al., 2022). One of the most important conditions for the development of physical skills in school-age children is the correct and competent development of the flexibility of the growing body (Merino-Marban et al., 2015; Schwanke et al., 2016). Flexibility is the ability to perform movements with maximum amplitude in the joints (Muyor et al., 2014; Schwanke et al., 2016; Ospankulov et al., 2022). Flexibility can be active and passive. Active flexibility is the ability of a person to achieve large amplitudes of movements due to the contraction of muscle groups passing through the joint (for example, the amplitude of lifting the leg in balance "swallow"). Passive flexibility is the ability to perform movements with the greatest amplitude under the influence of external tensile forces, such as the partner's effort, external weights, and special devices. The range of motion in passive flexibility exercises is achieved more than in active exercises (Kholodov & Kuznetsov, 2018; Solodkov & Sologub, 2018; Matveev, 2021). Dynamic and static flexibility are also distinguished (Kholodov & Kuznetsov, 2018; Solodkov & Sologub, 2018; Matveev, 2021). The first manifests itself during movements, and the second – in poses (Moreira et al., 2012; Lopes et al., 2017; Mocanu & Dobrescu, 2021).

There is general and special flexibility. General flexibility characterizes mobility in all joints of the body and allows you to perform a variety of movements with a large amplitude. Special flexibility is the ultimate mobility in individual joints that meets the requirements of a specific type of activity and determines the effectiveness of sports or professionally applied activities (Mayorga Vega et al., 2014; Merino-Marban et al., 2015; Mărcuș et al., 2022).

Flexibility depends on a number of factors. The main factors determining joint mobility is anatomical. The limiters of movement are bones. The shape of the bones largely determines the direction and scope of movements in the joint (flexion, extension, abduction, reduction, supination, pronation, rotation) (Kamandulis et al., 2013; Ospankulov et al., 2022).

Flexibility is due to the central nervous regulation of muscle tone, as well as the tension of antagonist muscles. This means that the manifestations of flexibility depend on the ability to arbitrarily relax the stretched muscles and strain the muscles that carry out the movement, i.e. on the degree of improvement of intermuscular coordination (Pérez Vigo et al., 2022; Odintsova et al., 2023).

The flexibility indicators are significantly influenced by external conditions (Kamandulis et al., 2013; Lopes et al., 2017; Mărcuș et al., 2022):

- 1) Time of day (in the morning flexibility is less than in the afternoon and evening);
- 2) Air temperature (at 20-30 °C flexibility is higher than at 5-10 °C);
- 3) after a warm-up lasting 20 minutes, flexibility is higher than before the warm-up;
- 4) joint mobility increases after 10 minutes in a warm bath at a water temperature of +40 °C.

A factor affecting joint mobility is also the general functional state of the body at the moment: under the influence of fatigue, active flexibility decreases (due to a decrease in the ability of muscles to completely relax after a previous contraction), and passive flexibility increases (due to a lower tone of muscles that counteract stretching) (Kholodov & Kuznetsov, 2018; Solodkov & Sologub, 2018; Matveev, 2021; Pérez Vigo et al., 2022). Flexibility also depends on the gender of the person; usually girls and this quality is 20-30% more pronounced than boys. In general, the process of developing flexibility is individualized, and it is necessary to constantly develop and maintain flexibility (Mayorga Vega et al., 2014; Mocanu & Dobrescu, 2021).

In physical education at school, the main task is to ensure such a degree of comprehensive development of flexibility that would allow you to successfully master the basic vital motor actions and show other motor abilities with high efficiency, such as coordination abilities, speed, strength and aerobic (Schwanke et al., 2016; Ospankulov et al., 2022). The main means of fostering flexibility in children are gymnastic exercises associated with maximum muscle stretching (Moreira et al., 2012; Ospankulov et al., 2022).

It is known that at different periods of life a child is especially susceptible to certain influences of the surrounding world. Such periods are called "sensitive", in these age intervals of individual development, the child's ability to master or develop certain skills and abilities is the highest, but at other times this ability is significantly lower (Goldfield et al., 2012; Drouven & Grossmann, 2016; Kabanov et al., 2019; Matveev, 2021).

Training effects in sensitive periods are most effective. At the same time, there is a more pronounced development of physical qualities, strength, speed, endurance and adaptation reactions to physical exertion occur in the best way (Meinel & Schnabel, 1976; Martin, 1980; Volkov, 1986; Kholodov & Kuznetsov, 2018; Solodkov & Sologub, 2018). Sensitive periods for the development of various physical qualities manifest themselves in different ways. As for such a physical quality as flexibility, there are several studies that indicate one or another favorable period for the development of flexibility in boys and girls (Guzhalovskiy, 1986; Goldfield et al., 2012; Drouven & Grossmann, 2016; Solodkov & Sologub, 2018; Kabanov et al., 2019; Matveev, 2021).

Guzhalovskiy, the author of books on physiology, noted in 1986 that flexibility is most effectively developed at primary school age (7-10 years old), but after that there is another favorable period for the development of flexibility in girls (11-13 years old) and boys (13-15 years old) (Guzhalovskiy, 1986).

At the same time, other experts in the field of physiology note an increased increase in flexibility in girls aged 9-10 and 12-14 years, and in boys aged 10-11 and 14-15 years. (Solodkov & Sologub, 2018)

The authors of well-known books on the theory of physical culture and sports note a favorable period for the

development of flexibility under the age of 13-14 years in both boys and girls, while not differentiating the data into specific age segments (Kholodov & Kuznetsov, 2018).

In 2021, Matveev, a well-known specialist in the field of physical education and sports, author of hundreds of articles and books on the theory of physical education in Russia, systematized and summarized data on favorable periods of development of physical qualities. Thus, the author notes that the most suitable period for boys to develop flexibility will be 8-9 years and 12-13 years. And for girls, this is the age of 7-10 years, 11-13 years, 14-15 years and 16-17 years (Matveev, 2021).

There are data from earlier studies, where the authors emphasize the importance of realizing favorable periods during life and note a sensitive period for the development of flexibility at the age of 9 to 12 years for both boys and girls (Meinel & Schnabel, 1976; Martin, 1980; Volkov, 1986).

In some studies, the importance of favorable periods for the development of certain physical qualities is also emphasized, however, the authors do not cite specific age periods where targeted training for certain physical qualities will give maximum results (Goldfield et al., 2012; Drouven & Grossmann, 2016; Kabanov et al., 2019).

Thus, the literature review showed that there is no specific data on the issue of favorable periods for the development of flexibility, despite the fact that the authors emphasize the high importance of flexibility for everyday life and sports (Merino-Marban et al., 2015; Odintsova et al., 2023).

It is proved that knowledge of the specifics of sensitive periods of motor development by a sports teacher will increase the effectiveness of the educational process of schoolchildren. At the same time, despite some study of the issue of sensitive periods of flexibility development, it is clear that experts do not have a consensus on favorable periods for the development of flexibility. This contradiction determined the novelty and *purpose of the study* – to identify sensitive periods for the emphasized development of flexibility of schoolchildren.

Research objectives

1. Identify sensitive periods for the development of flexibility in schoolchildren from 7 to 18 years of age.
2. Compare the results based on gender.

Methods

Study participants

The pedagogical study involved 1,217 children (579 boys and 638 girls) from grades 1 to 11 of secondary school number 60 Kirov, Russia. There are about 31-32 students in each class. Number of students by class:

Primary and secondary school (grades 1-5 and 6-9) These are 5 streams of classes "A", "B", "C", "D" and "E" classes.

The senior level (grades 10 and 11), a set of only 3

streams, these are "A", "B" and "C" classes.

Inclusion criteria

1. Students who were healthy at the beginning of the school year and were admitted by the doctor to physical education classes in a regular group.

2. Students whose parents were aware of the study and gave their written informed consent for their children to participate in the study. It should be noted that according to the physical education program at school, children annually take flexibility tests. However, in addition, the parents of the students were warned that according to the results of the study, the test data will be taken into account in scientific research.

3. Students who do not engage in any kind of sport, as additional sports activities of students may affect the results of the study.

Exclusion criteria

1. Students who had illnesses and did not have a doctor's admission to physical education lessons in the main group.

2. Students whose parents refused to participate in the study.

3. Students who were engaged in sports or other active physical education activities that could affect the results of the study.

The research procedure

The scientific research was conducted on the basis of 60 schools in the city of Kirov, in Russia from September 14, 2022 to May 22, 2023.

Each lesson in the discipline "Physical education" lasted 40 minutes and took place 3 times a week. In the weekly schedule of schoolchildren, all physical education lessons were balanced and classes were held in one day. All students were engaged in the usual physical education program at school (Kainov & Kuryerova, 2019). The physical education program consists of the following sections: in September, children do athletics, October and November are the time for outdoor and sports games. In December and January, all students get up on skis, and in February they return to the gym for gymnastics and martial arts. March and April are the period for outdoor and sports games, and May is for athletics.

Despite the fact that all sections of the school curriculum are the same, children study more complex elements every year and consolidate previously studied exercises.

Control tests

All students took tests that show the level of development of physical qualities at the beginning of the school year (September 14, 2022) and at the end of the school year (May 22, 2023). Data on the development of flexibility were important for our study.

To determine the level of flexibility development, the world-famous test "Forward tilt from a standing position on a gymnastic bench" (hereinafter referred to as "forward

tilt") was used (Kainov & Kuryerova, 2019) This research method is well-known and reliable and informative in terms of measuring flexibility.

The test is performed from the initial position: standing on a gymnastic bench, legs are straightened at the knees, feet are parallel at a width of 10-15 cm. The participant performs the exercise in a sports uniform that allows the judges to determine the straightening of the legs at the knees (shorts). When performing the test at the command of the judge, the participant performs two preliminary tilts, sliding his fingers along the measuring ruler. At the third tilt, the participant bends as much as possible and fixes the result within 2 seconds. The amount of flexibility is measured in centimeters. The result above the level of the gymnastic bench is determined by the "-" sign, below the level of the gymnastic bench is determined by the "+" sign.

Errors that result in the test not being counted:

- bending of the legs at the knees;
- fixing the result with the fingers of one hand;
- no fixation of the result for 2 seconds.

Statistical analysis

Excel was used to process the results of the study, the

initial data were recorded, the arithmetic mean and standard deviation were determined, and the percentage increase from the beginning to the end of the study was determined. Using the Biostatistics-2022 program, the reliability of the results of the T-Student study was determined, the confidence level at $p < 0.05$ (Haynes, 2013; Mishra et al., 2019).

Results

Table 1 shows that the average figures in each age group increased during the academic year. It should be noted that the increase in indicators was different. If we consider the indicators of boys from the beginning to the end of the study, we see a significant and significant increase in flexibility indicators from 8 to 11 years old ($p < 0.05$). At the same time, in girls, a significant increase in flexibility values was observed at the age of 9-10 years, 11-12 years and 12-13 years ($p < 0.05$). The data obtained allow us to conclude that there are sensitive (favorable) age periods for the development of flexibility of schoolchildren. For a more detailed analysis, graphs by gender are presented.

Table 1.
Students' results in the flexibility test at the beginning and at the end of their studies

Class	Age	Gender	Amount of children	Before $M \pm m$	After $M \pm m$	p	Growth in %
I	7-8	Boys	59	3.8±0.9	4.0±1.0	>0.05	5%
		Girls	67	4.9±0.8	5.2±0.9	>0.05	6%
II	8-9	Boys	51	3.9±1.0	4.9±1.0	<0.05	15%
		Girls	68	5.3±1.0	5.6±0.9	>0.05	5%
III	9-10	Boys	56	4.6±0.9	5.4±0.8	<0.05	17%
		Girls	64	5.8±1.0	6.7±0.7	<0.05	16%
IV	10-11	Boys	58	5.3±0.7	6.1±1.0	<0.05	15%
		Girls	59	6.5±0.7	6.9±0.9	>0.05	6%
V	11-12	Boys	52	6.0±0.9	6.4±0.8	>0.05	6%
		Girls	64	7.0±1.0	8.0±1.0	<0.05	14%
VI	12-13	Boys	57	6.3±1.0	6.6±0.9	>0.05	4%
		Girls	62	7.7±0.7	8.9±1.0	<0.05	15%
VII	13-14	Boys	61	6.7±0.9	7.1±0.7	>0.05	6%
		Girls	54	8.4±1.0	8.9±0.8	>0.05	6%
VIII	14-15	Boys	56	7.1±0.9	7.5±0.8	>0.05	5%
		Girls	60	8.8±0.7	9.2±0.9	>0.05	4%
IX	15-16	Boys	59	7.5±0.7	7.7±0.9	>0.05	3%
		Girls	56	9.3±0.9	9.8±0.7	>0.05	5%
X	16-17	Boys	37	7.9±1.0	8.3±1.0	>0.05	5%
		Girls	41	9.8±1.0	10.4±0.8	>0.05	6%
XI	17-18	Boys	33	8.4±0.9	9.1±0.7	>0.05	4%
		Girls	43	10.2±0.7	10.6±0.8	>0.05	4%

M – Arithmetic average; m – Standard deviation

Figure 1 shows that boys have a sensitive period of flexibility development at the age of 8-9 years (+15%), 9-10 years (+17%) and 10-11 years (+15%), that is, from grades 2 to 4. Figure 2 shows that the following age

segments will be sensitive periods for girls to develop flexibility: 9-10 years (+16%) 3rd grade, 11-12 years (+14%) 5th grade, 12-13 years (+15%) 6th grade.

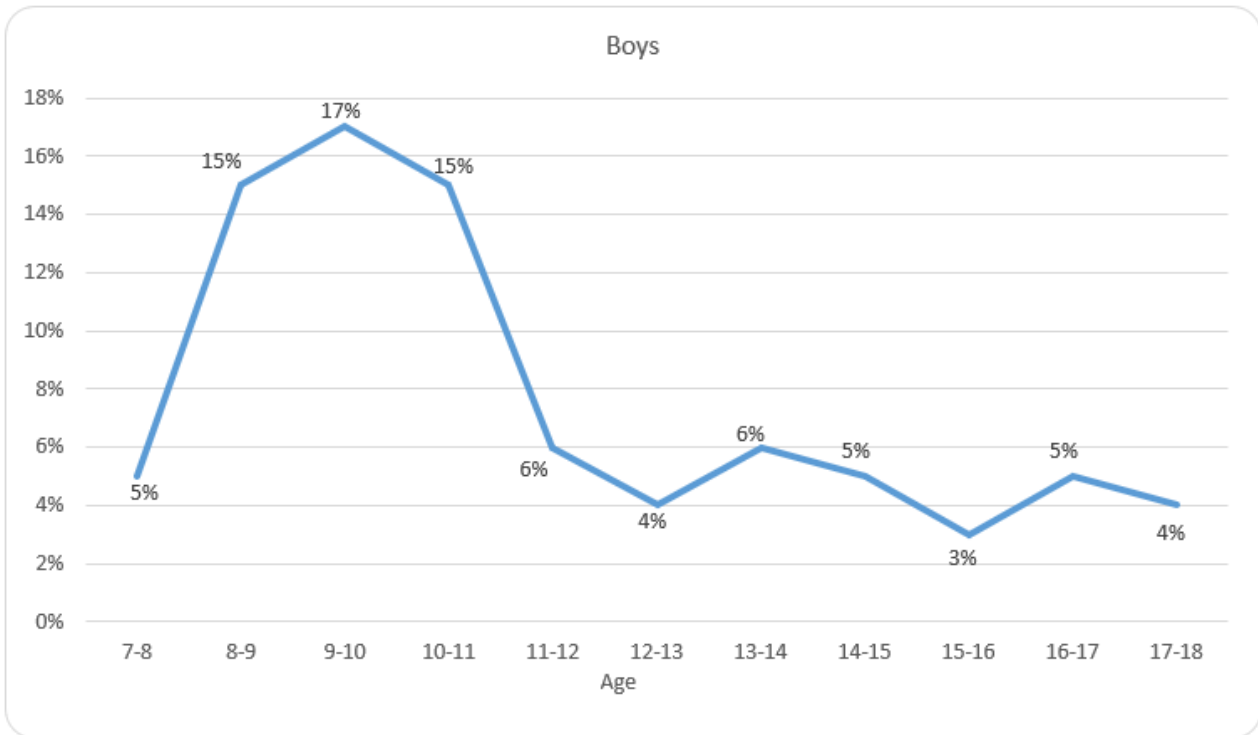


Figure 1. Favorable periods for the development of boys' flexibility

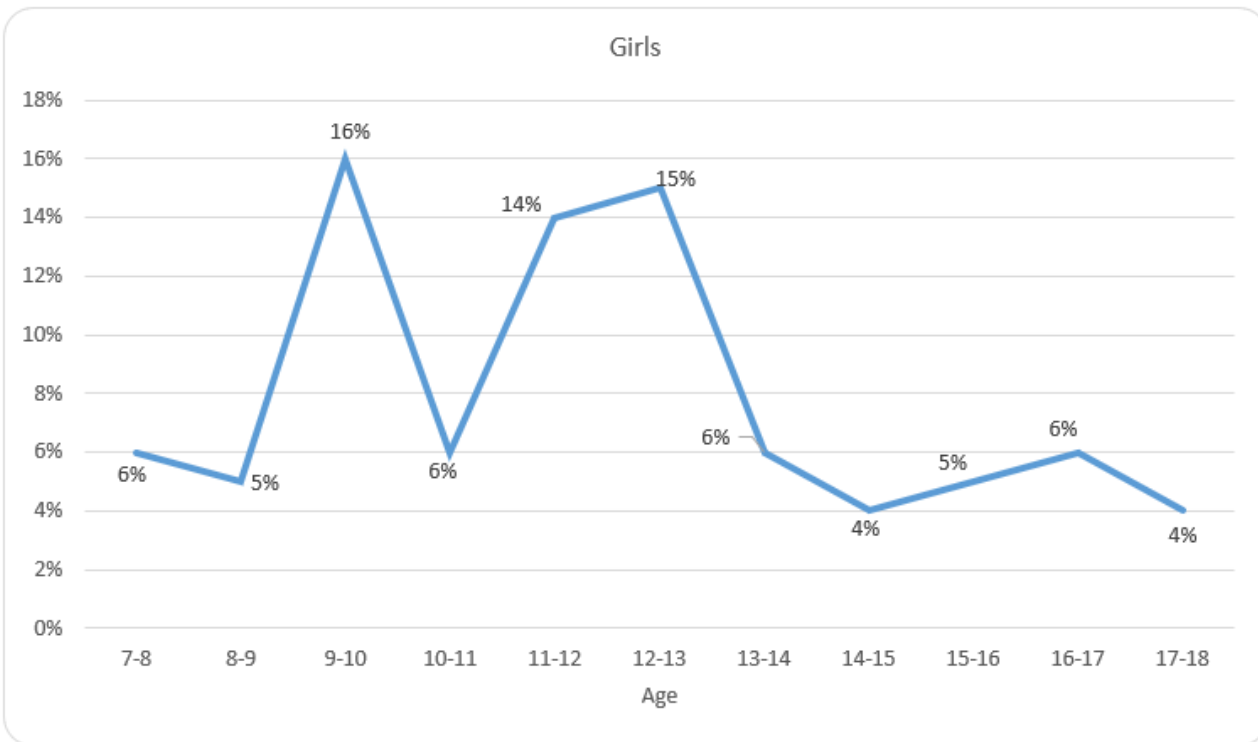


Figure 2. Favorable periods for the development of girls' flexibility

Discussion

The analysis of scientific literature has shown a negative trend in the health status of the population, especially children of different ages (Hu et al., 2021; Oberle et al., 2020; Terrón-Pérez et al., 2021). There is a sufficient

number of studies that highlight the importance of the problem of insufficient physical development of schoolchildren. Many authors describe in detail the consequences of such a modern disease as inactivity. The main method of combating physical inactivity is movement. A variety of physical activities and exercises that help

strengthen the muscular system, musculoskeletal system, and the entire body as a whole. There is an insufficient level of development of physical qualities in school-age children (Aliss et al., 2020; Heradstveit et al., 2020; Mannocci et al., 2020; Volmut et al., 2021; Di Maglie et al., 2022).

The development of motor abilities of schoolchildren is one of the main tasks of physical education. The development of motor abilities contributes to the comprehensive and harmonious development of the personality. Currently, it is customary to distinguish five basic physical abilities (qualities): strength (strength), speed (speed), coordination (dexterity and balance), endurance, flexibility (Piñeiro-Cossio et al., 2021; de Bruijn et al., 2022).

Flexibility as one of the main human abilities allows you to perform motor actions with the necessary range of movements (Moreira et al., 2012; Kamandulis et al., 2013; Mărcuș et al., 2022; Pérez Vigo et al., 2022). It characterizes the degree of mobility in the joints and the state of the muscular system. Insufficiently developed flexibility makes it difficult to coordinate movements, limits the possibilities of spatial movement of the body and its links. The development of flexibility to an optimal level and the constant maintenance of this level contributes to the comprehensive and harmonious development of personality, physical and mental performance, improvement of adaptive properties of the body, more creative realization of human creative forces (Merino-Marban et al., 2015; Schwanke et al., 2016; Mocanu & Dobrescu, 2021; Ospankulov et al., 2022; Odintsova et al., 2023).

A literature review has shown that during sensitive periods, the means and methods used in physical education achieve the best training effect. In subsequent periods, the same means and volumes of training loads do not provide such an increase in physical qualities (Meinel & Schnabel, 1976; Martin, 1980; Volkov, 1986; Kholodov & Kuznetsov, 2018; Solodkov & Sologub, 2018). Planning of physical education of schoolchildren should be based on knowledge about the stage-by-stage possibilities for the development of motor abilities in ontogenesis in various climatogeographic and socio-economic conditions, taking into account the individual typological characteristics of children and adolescents (Goldfield et al., 2012; Drouven & Grossmann, 2016; Kabanov et al., 2019, Matveev, 2021).

Thus, despite some study of the issue of sensitive periods of development of different physical qualities, we did not find data on the development of flexibility of schoolchildren in different age periods. As for the results of this pedagogical study, which involved 1,217 schoolchildren from grades 1 to 11, the results of the study allow us to draw some conclusions about favorable periods for the development of flexibility in boys and girls of school age:

The primary school age is grades 1-4 of schooling (7-11 years old). It is in this age period that there is a significant

increase in flexibility indicators as a result of the study. Thus, in boys aged 8-9 years, the indicators improved by 15%, 9-10 years by 17% and 10-11 years by 15% ($p < 0.05$). In all other age periods, there was an increase in indicators during the study period, but it was not significant from 3% to 6% ($p > 0.05$).

As for girls, a significant and reliable increase in indicators is noted in primary and secondary school age, namely, 9-10 years, indicators improved by 16% ($p < 0.05$), 11-12 years, indicators became 14% higher ($p < 0.05$) and at the age of 12-13 years, indicators improved by 15% ($p < 0.05$). In other age periods, the increase in flexibility indicators in girls ranged from 4% to 6% ($p > 0.05$).

If we compare the results of our study with the previously obtained results of other authors, then there is no unambiguous coincidence. For example, Matveev notes an increase in flexibility indicators for boys 8-9 years old and 12-13 years old, and for girls in junior, middle and high school age (Matveev 2021). Kholodov and Kuznetsov they note an increase in flexibility from birth to 13-14 years old, without specifying specific age periods for the purposeful development of flexibility in boys and girls (Kholodov & Kuznetsov, 2018). Guzhalovskiy notes an increase in flexibility from 7-10 years for all schoolchildren, as well as 11-13 years for girls and 13-15 years for boys (Guzhalovskiy, 1986). Solodkov and Sologub there is an increase in flexibility in boys aged 10-11 and 14-15 years, and in girls aged 9-10 and 12-14 years, which also partially coincides with the results of this study (Solodkov & Sologub, 2018).

Thus, to date, there is no definite general opinion regarding favorable periods for the development of flexibility at school age, despite some study of this issue. Therefore, the study is promising for further study of the issue of sensitive periods of flexibility, especially for schoolchildren. Probably, additional research should be conducted, which will include a much larger number of children, as well as several tests that determine the mobility of joints of different limbs.

Much attention in the modern scientific world is paid to the health of schoolchildren (Robles et al., 2023; Villodres et al., 2023), There is a problem of obesity (Lagunes-Carrasco et al., 2022). The solution to this problem can be solved partly with the help of physical education at school (Ferreira et al., 2022; Doskarayev et al., 2023).

Of course, the design of the study could be improved by adding additional tests to determine flexibility in schoolchildren, and it is also possible to study favorable periods for the development of other physical qualities in different age periods.

Limitations of the study

The study involved students who were healthy and admitted by a doctor to physical education classes. Children who did not engage in additional sports activities.

Conclusion

Knowing certain age periods for the development of certain physical qualities allows them to carry out targeted training and achieve better results. It is impossible to compensate for the lost time for an accentuated impact on physical abilities in the future. The study of the issue of sensitive periods is insufficient today, many experts give vague concepts of a specific age for the development of physical qualities in a certain age period, including flexibility. As a result of this large-scale study, it can be argued that the targeted development of flexibility should be in boys aged 8 to 11 years, and in girls aged 9-10 years, 11-12 years and 12-13 years.

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Conflict of interest

None. The authors declare no conflict of interest

Author contributions

Author Contribution: Study design; Data collection; Statistical analysis; Manuscript Preparation; Funds Collection – Georgiy Polevoy.

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