Original Article

Rehabilitation of children with muscle-skeleton disorders

Georgiy Polevoy

ABSTRACT

Objectives

Is to improve the function of the arch of the foot in primary school children who have flat feet by means of adaptive physical rehabilitation during classes using sets of physical exercises.

Methods

The study was conducted during the school year at a comprehensive school in Russia. The pedagogical experiment involved 88 elementary school children who are diagnosed with flat feet. All physical education classes were held according to the school schedule twice a week for 40 minutes. The control group studied according to the regular school physical education program, and the experimental group studied according to the experimental program, which included combined developing exercises, special exercises for corrective purposes for the arch of the foot, and outdoor games. Flat feet in children were determined using the Friedland index, jumping ability and fast muscle strength of legs were determined by the long jump, and muscle strength of the foot and lower leg was determined by the calf raise test. The reliability of differences in indicators was considered significant at the significance level of $p<0.05$.

Results

After the end of the pedagogical experiment, the indicators of children in the control group improved in the Friedland index from 26.93±0.3 to 27.29±0.5 ($p>0.05$), the strength of the foot and lower leg muscles increased by 7.9% ($p>0.05$), and the jumping ability and fast strength of the leg muscles increased by only 4.7% ($p>0.05$). In the experimental group, the Friedland index improved from 26.95±0.4 to 29.13±0.3 ($p<0.05$), the strength of the foot and lower leg muscles increased by 24.6% ($p<0.05$), and the jumping ability and fast strength of the leg muscles increased by 10.8% ($p<0.05$).

Conclusion

The experimental program proved its effectiveness. If special corrective exercises for the prevention or treatment of flat feet are used during each physical education class for 20 minutes, the results of podometry tests, calf raise and standing long jumps will improve significantly.

Keywords

Flat feet; Foot deformation; Child health; Physical exercises; Physical education.

INTRODUCTION

Currently, the problem of prevention and correction of deviations in the health of children of primary school age has acquired particular relevance, which is due to the growth and rejuvenation of various diseases[1-3].

The foot is the distal segment of the lower limb, when standing and walking it performs a supporting or pushing, spring, balancing function. From the point of view of biomechanics, a healthy foot has a functionally appropriate anatomical and physiological structure and the smoothness, ease of walking and energy efficiency depend on its condition[4,5]. The issue of prevention and correction of flat feet is acute. In this regard, for specialists, researchers and doctors there is a problem of finding new ways to prevent and correct flat feet in schoolchildren[6,7].

Flat feet can be longitudinal, transverse or combined. A healthy foot has two curvatures (two bends), and their flattening or absence is called flat feet[8,9].

Longitudinal flatfoot is accompanied by the lengthening of the foot due to the subsidence of the tarsal bones, which experience the greatest load under the influence of body weight. With longitudinal flatfoot, the legs quickly get tired not only when walking, but also when standing for a long time, especially when working standing, pain occurs in the gastrocnemial muscles and the arch of the foot. As a result, the spring function of the foot is disrupted, due to which the body does not experience jolts and shakes when walking, running and jumping[10,11].

When the transverse arch drops, the heads of the

Correspondence

Polevoy G.G. Department of Physical Education, National Research University of Electronic Technology «MIET», Moscow, Russia. E-mail: g.g.polevoy@gmail.com

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second and third metatarsal bones become supporting, and in this place a callus forms on the sole of the foot. With transverse flatfoot, the forefoot is spread out, which is one of the reasons for the deformation of the toes: the big toe begins to deviate obliquely towards the little toe[12,13].

Pain begins to manifest itself when the body cannot ensure normal and safe movement. It is because of flat feet that the ankle, knee and hip joints suffer, and pathological posture develops. Aa result of a violation of the support system, it can lead to arthrosis, scoliosis and many other diseases. Also, the development of varicose veins is associated with flat feet[14,15].

With flat feet, the entire load that the feet previously took on is forced to be compensated by the joints of the legs (hip, knee, and ankle) and the spine. The joints and spine are not designed for this, so they do not cope well with this function and very quickly fail. When flat feet in children are pronounced, lumbar lordosis increases. At the first signs of flat feet, it is recommended to consult a specialist[16,17].

Age-related features of child feet compared to adult feet[18,19].

1. The foot is shorter.
2. The foot is narrowed in the heel area.
3. The toes diverge (in an adult they overlap tightly)
4. The sole has well-developed plantar tissue, which fills the inner arch of the foot.
5. The range of motion of a child foot is greater due to the greater elasticity of the muscular-ligamentous apparatus.
6. The child foot has a more pronounced supinator position. When walking, children often place their foot not on the entire plantar surface, but on its outer edge. When growing, pronation of the foot is noted.
7. The child foot is less adapted to static loads (jumps, hops). With the indicated loads, the arch of the foot flattens somewhat after the load, and under the action of active muscle contraction it returns to its original position. In weakened, physically poorly developed children, the ligaments and muscles of the foot are systematically overstrained, stretched and lose their spring properties, therefore running, jumping, hopping are contraindicated, since the foot flattens, its inner arch drops and flat feet develop.

In preschool and primary school age, the foot is in the stage of intensive development. At this age, the body is highly flexible, so it is relatively easy to stop the development of flat feet or correct it by strengthening the muscles and ligaments of the foot[20].

It is possible to determine flat feet in a child only after the age of 5-6 years. This is due to the fact that the bone apparatus of the foot in a child is not yet strong enough and is mainly a cartilaginous structure. Diagnosis of flat feet in children over 6 years of age can be carried out using plantography[21] (Figure 1).

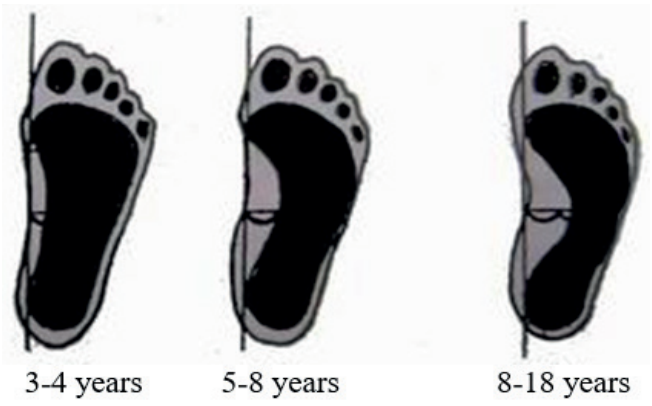

Figure 1 – Age-related changes in the longitudinal arch

When flatfoot is physiological, the longitudinal arches may not be fully formed, but the foot does not deviate inward. This deviation can be noticed if the axis of the shin and foot is evaluated. To do this, it is needed to mentally draw or mark through the dots the lines passing through the middle of the shin bone, the Achilles tendon and the center of the heel, in Figure 2 they are marked with dots and lines. Normally, it is a straight line (on the left). When flatfoot is noted, an angle open outward appears (on the right)[22].

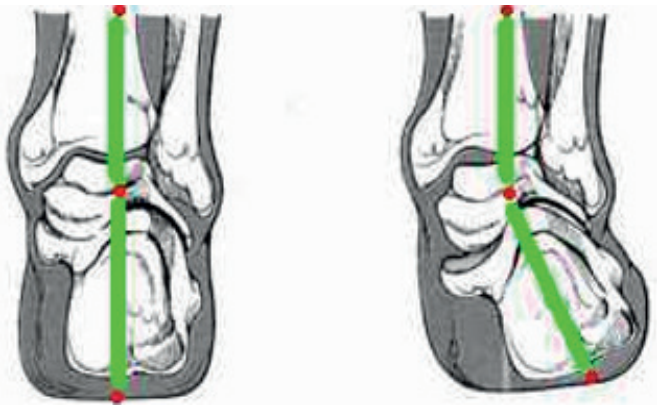

Figure 2 – Defining flat feet

It is important to note that it is possible to correct flat feet only in childhood, since the skeleton is not yet ossified. That is why it is very important to be able to recognize flat feet in children as early as possible[23,24].

Causes of flat feet[25,26]:

1. Congenital flat feet, approximately 3% of all cases.
2. Flat feet associated with bruises, fractures and sprains of the foot.
3. Specific diseases: rickets, poliomyelitis, diabetes.
4. Insufficient or excessive load on the legs.

Factors in the development of flat feet in children[27-29]:

- underdevelopment of the foot muscles;
- weakness of the muscular-ligamentous apparatus of the foot, may be the result of rickets;
- heavy physical exertion;
- excess weight;
- wearing improperly selected shoes;
- clubfoot;
- X-shaped legs;
- injuries to the foot, ankle;
- hereditary predisposition.

Prevention and correction of flat feet in children by means of physical education[30-32]:

1. Hygienic factors. Hygiene of footwear and its correct selection in accordance with the purpose. Hygienic washing of feet with cool water before going to bed, after walking barefoot.
2. Natural and health factors. Walking barefoot on natural country roads (grass, sand, pebbles), equipped in group areas in the warm season, on artificial roads in the cold season. Hardening procedures for feet in accordance with the individual characteristics of children and the absence of contraindications, subject to medical supervision.
3. Special sets of exercises aimed at strengthening the muscles of the foot and lower leg and forming the arches of the foot.

Physical exercises play a special role in the prevention of flat feet. School programs are filled with exercises that strengthen the musculoskeletal system of the lower extremities (walking, running, jumping, squatting, swimming, sports games). This helps to increase strength and endurance of lower extremities. However, in the school education system, they are not systematized and aimed at correcting or treating flat feet. Therefore, the use of special exercises during the lesson should be obligatory. The purpose of the study is to improve the function of the arch of the foot in primary school children who have flat feet by means of adaptive physical rehabilitation using exercise complexes.

MATERIAL AND METHODS

The study was conducted at the comprehensive school № 1327 in Moscow from September 16, 2024 to April 25, 2024.

A total of 88 primary school children (grades 1-4) diagnosed with flat feet took part in the pedagogical experiment. All physical education classes were held according to the school schedule, 2 times a week for 40 minutes.

The control group (44 students) studied according to the regular school physical education program.

The experimental group (44 students) studied according to the experimental program, which included combined developing exercises, special corrective exercises for the arch of the foot, and outdoor games.

The preparatory part of the lesson (15 minutes) included organizing the group for the lesson, lining-up. Various types of walking were used: walking on an inclined plane; walking on a gymnastic stick; walking on a mat; walking with raising straight legs, legs bent at the knees; moving in a squat; “frog jump”; “elephant walk”; walking on heels, on toes, on the outer edge of the foot; rolling from heel to toe; walking at different speeds and in different directions (snake, backwards). Short-term running. Breathing exercises.

The main part (20 minutes) of the lesson included special corrective exercises in various starting positions.

Physical exercises recommended for flat feet, performed in the starting position, lying on back:

1. Alternately and simultaneously pull the toes of your feet while simultaneously supinating them.
2. Bend legs, rest feet on the floor. Spread heels and bring them together. Relax after a series of movements.
3. Alternately and simultaneously lift heels from the support.

4. Bend legs at the knees and spread them apart, touching each other with the plantar surface. Abduction and adduction of the heels with focus on the toes.
5. Place bent leg on the knee of the other, half-bent leg. Circular movements of the foot in one direction and then the other. The same, changing the position of legs.
6. Sliding movements of the foot of one leg along the shin of the other, "embracing" the shin. The same with the other leg.

Exercises performed in the initial sitting position:

1. Legs bent, feet parallel. Raising heels simultaneously and alternately.
2. Dorsiflexion of the feet simultaneously and alternately.
3. Raising the heel of one leg with simultaneous dorsiflexion of the foot of the other leg.
4. Legs straight. Flexion and extension of the feet.
5. Place one leg with the foot on the knee of the other leg. Circular movements of the foot in both directions. Do the same with the other leg.
6. Grasping small objects with the toes and moving them to another place. Do the same with the other leg.
7. Sitting back, spread knees and pull feet up until the plantar surfaces are in full contact.
8. In the sitting back position, spread knees and pull feet up until the plantar surfaces are in full contact.

Exercises performed in the starting position standing:

1. Feet parallel, at a distance of a foot width, hands on the waist. Rise on toes simultaneously and alternately. Raise toes with support on heels simultaneously and alternately. Roll from heel to toe and back.
2. Half-squats and squats on toes, arms to sides, up, forward.
3. Feet parallel. Roll onto outer edges of the foot and back.
4. Toes together, heels apart. Half-squats and squats in combination with arm movements.
5. Feet parallel, hands on the waist. Alternate raising of the heels.
6. Standing on a gymnastic stick, feet parallel. Half-squats and squats in combination with arm movements.
7. The same, but standing on the rail of the gymnastic wall. Rise on toes and return to the starting position.
8. Standing on a wall bar. Rising up on toes and returning to the starting position.
9. Standing on a medicine ball. Squats combined with arm movements. As a rule, 3-4 exercises performed in different starting positions were used in one session.

Examples of tasks used in physical education lessons:

1. "Moon". Starting position - sitting, legs apart, hands behind you. Draw a semicircle several times with the right, left foot and both feet simultaneously.
2. "Sun". Starting position - the same. Draw a circle and rays extending from it several times with the right, left foot and both feet simultaneously.
3. "Cloud". Starting position - the same. Draw the outline of a cloud several times with the right, left foot and both feet simultaneously.
4. "Lightning". Starting position - the same. Draw lightning several times with zigzag movements with the right, left foot and both feet simultaneously.
5. "Rain". Starting position - sitting, legs bent apart, feet parallel, hands behind. Tap the floor with the toe of one foot, then the other foot and toes of both feet simultaneously, keeping heels firmly pressed to the floor. The same, only tap heels, and keep toes pressed firmly to the floor.
6. "Rainbow". Starting position - sitting, legs apart, hands in support behind. Draw a rainbow several times with the right foot, left foot and both feet at the same time.

In the final part of the lesson (5 minutes) relaxation exercises, slow walking, breathing exercises were used.

The following tests were used to assess physical fitness and determine flat feet:

1. Podometry (with determination of the Friedland index) - measuring the height of the foot (a vertical line drawn from the floor to the highest point of the foot in the area of the navicular bone, located at the distance of a transverse finger from the right angle of the ankle bend), to calculate the ratio between the length of the foot and its height[33].

Formula: B x 100/D, where B is the height of the foot, D is the length of the foot.

Index values:

31-29 - normal foot;

29-25 - flat foot;

<25 - severe flat feet.

2. Standing long jump - jumping ability and quick power were determined.
3. Calf raise – measuring the strength of the foot and lower leg muscles.

Method of execution: the student stands on a gymnastic bench, leaning on the front third of the foot and holding on to the gymnastic ladder with hands.

The number of calf raises in 20 seconds is measured.

Methods of mathematical statistics

The reliability of differences and indicators was considered significant at the significance level of $p<0.05$, which is recognized as reliable in pedagogical and medical-biological research.

Before and after the pedagogical experiment, all schoolchildren took control tests (Table 1).

Table 1. Comparative analysis of average group indicators for children of both groups during the study period

Tests	Groups	Before	After	p
Podometry (the Friedland index)	CG	26,93±0,3	27,29±0,5	>0,05
	EG	26,95±0,4	29,13±0,3	**<0,05**
	p	>0,05	**<0,05**	
Calf raises for 20 sec (number of times)	CG	6,3±0,5	6,8±0,4	>0,05
	EG	6,5±0,6	8,2±0,5	**<0,05**
	p	>0,05	**<0,05**	
Standing long jump (cm)	CG	118,3±3,9	123,9±4,3	>0,05
	EG	120,4±4,1	133,4±3,5	**<0,05**
	p	>0,05	**<0,05**	

* CG – control group; EG – experimental group.

Table 1 shows that before the start of the study, the average test scores between the groups did not differ significantly, which indicates the homogeneity of the groups.

However, after the end of the pedagogical experiment, changes occurred:

1) Changes in physical fitness indicators and the Friedland index have a positive trend, but they are insignificant ($P> 0.05$).
2) Changes in average data in the experimental group from the beginning to the end of the pedagogical experiment are significant ($P<0.05$) for all indicators.

Figure 3 shows the increase in indicators in both groups from the beginning to the end of the study.

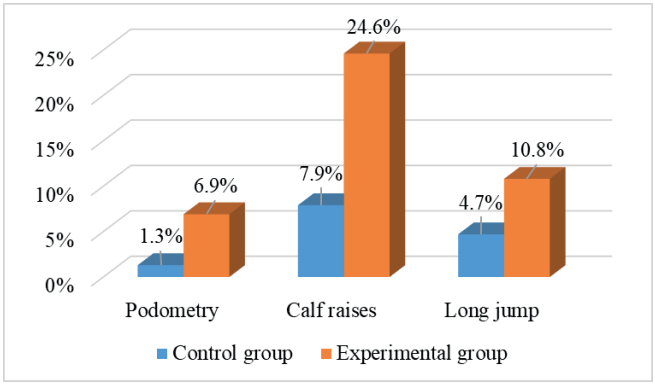

Figure 3. Increase in indicators of both groups during the study period

Figure 3 shows that the percentage ratio of average data for schoolchildren in the experimental group is significantly higher than that of children in the control group. Thus, the results obtained allow us to speak about the effectiveness of the active use of the adaptive physical rehabilitation program for the correction of flat feet in children of primary school age, which makes the process of correction of the disease more effective in the experimental group.

DISCUSSION

The subject concerning the health of primary school children is relevant, this is due to the fact that most of various diseases become chronic and hereditary, or manifest themselves at school age[34,35]. The problem of flat feet is addressed in many studies[5,8,13], there are various programs and methods for foot correction, medical centers offer using orthopedic insoles or shoes, but in most cases there is no systematic approach that will effectively and quickly solve the problem of flat feet at primary school age.

It is important that the state of the person's foot can directly affect his health. Disorders in the foot affect posture and the work of the whole organism. The arch of

the foot is supported and strengthened by the muscles of the lower leg, so its damping properties are determined not only by the anatomical features of its bones, but also by the active work of the muscles[11,14,18].

Methods of correction of flat feet in children of primary school age include exercises of adaptive physical rehabilitation, therapeutic gymnastics, massage and other methods[21,26]. The main means of adaptive physical rehabilitation are specially selected physical exercises. These exercises are used for the purpose of correction and prevention of flat feet in children of primary school age. They are capable of not only correcting foot deformation, but also preventing its occurrence[4,10,19].

In the process of studying the literature on the problem, the most effective physical exercises for correction of flat feet in children of primary school age by means of adaptive physical rehabilitation were identified and selected. These include therapeutic physical training, exercises of adaptive physical rehabilitation, therapeutic gymnastics, massage and other methods. These exercises have a positive effect on the patient's body, on their musculoskeletal system[7,32].

The effectiveness of the program for using sets of exercises for adaptive physical rehabilitation for the correction of flat feet in primary school children is developed and experimentally tested.

Before the start of the study, the average indicators in both groups for the Friedland index corresponded to "flat feet". However, after the end of the pedagogical experiment, the average data of children in the control group also corresponded to "flat feet", despite an improvement in indicators by 1.3% ($p > 0.05$). In the experimental group, the average indicators of the Friedland index improved by 6.9% ($p<0.05$) and amounted to 29.13±0.3, which corresponds to "normal feet". Thus, during the school year, using the experimental program, it was possible to normalize the arch of the foot of primary school children.

It should be noted that the experimental program is effective for developing jumping ability and fast muscle strength in the legs. Children who studied according to the experimental program were able to improve their long jump from 120.4±4.1 cm to 133.4±3.5 cm, the increase was 10.8% ($p<0.05$). At the same time, children of the control group who studied according to the standard physical education program at school only slightly improved their performance in the long jump test from 118.3±3.9 cm to 123.9±4.3 cm, the increase was 4.7% ($p>0.05$).

In the calf raise test, performance of the children in the experimental group improved from 6.5±0.6 sec to 8.2±0.5 sec, the increase in foot and lower leg muscle strength was 24.6% ($p<0.05$), while in the control group this performance improved on average from 6.3±0.5 to 6.8±0.4, the increase was 7.9% ($p>0.05$).

The obtained results of the study allow us to speak about the effectiveness of the program for using adaptive physical rehabilitation exercise complexes for the correction of flat feet in primary school children in the experimental group.

The scientific novelty lies in the development of an experimental adaptive physical rehabilitation program for primary school children with musculoskeletal disorders for the correction of flat feet. The difference of the program lies in the development of exercise complexes included in the preparatory part of the physical education lesson.

The practical significance of the study is that the program can be used in the prevention and control of flat feet in children of primary school age in different childcare institutions and correctional and preventive centers.

The theoretical significance of the study is to expand knowledge in the field of adaptive physical rehabilitation on the use of the developed program in the organization of physical education and health work with primary school students who have musculoskeletal disorders.

CONCLUSION

The experimental program, which included combined developing exercises, special exercises which have the focus on correcting the arch of the foot, and active games, proved its effectiveness. If special corrective exercises in various starting positions are used for 20 minutes during each physical education class at school, the indicators of podometry, calf raise, and standing long jump will improve significantly.

Practical recommendations

Some rules aimed at preventing and treating flat feet in children of primary school age[4-8,33]:

1. The foot is formed during the first 3 years, so it is necessary to monitor its development from early childhood.

2. In preschool and school age, it is necessary to include special exercises in daily morning exercises and physical education classes that strengthen the arch of the foot.
3. Using special exercises for the feet together with combined developing exercises for the muscles of the upper limbs, shoulder girdle, trunk, lower limbs, since flat feet often occur in weakened children.
4. The main types of exercises for flat feet should be plantar flexion (pulling the toes down) and supination of the feet (turning inward). Pronation of the feet should be avoided, since this movement intensifies the pathological condition of the ligamentous-muscular apparatus of the feet and shins.
5. Choose shoes wisely, and if you have flat feet, you need to use an orthopedic insole or shoes.
6. All physical exercises should be done barefoot

Conflict of interest: The author declares that he no conflict of interest.

AUTHOR'S CONTRIBUTION

Data gathering and idea owner of this study: Polevoy G.G.

Study design: Polevoy G.G.

Data gathering: Polevoy G.G.

Writing and submitting manuscript: Polevoy G.G.

Editing and approval of final draft: Polevoy G.G.

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