The effectiveness of the technology of physical therapy of flat feet in young athletes of all ages by means of taekwondo

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DOI: https://doi.org/10.34142/HSR.2019.05.04.02

Abstract
The purpose of this work was to develop technology for physical therapy of flat feet by means of taekwon-do and to check its effectiveness in students of all ages.

Methods: analysis of scientific and methodological literature; pedagogical observations; pedagogical methods; instrumental research methods (photometry methods using the BIG FOOT program, myotonometry and electromyography) methods of mathematical statistics. The survey involved 60 young athletes aged 8, 12 and 14 years with flat feet, who were engaged in the Taekwon-Do Sports Club in Ivano-Frankivs'k.

Results. After the study was the technology of physical therapy for flat feet in young athletes has been substantiated and developed, which is based on the didactic, general, organizational and methodological foundations of the process of correcting the vaulted apparatus of the foot and studying the state of muscles related to the anterior and posterior myofascial kinematic chains of the lower leg and foot. The technology of physical therapy provides for the use of taekwondo physical exercises, defines the goals, objectives and principles of corrective measures, forms and methods of conducting taekwondo classes, dosing principles and exercise parameters based on the creation of individual plans for young athletes of a particular age group. The developed technology of physical therapy provides for the implementation of appropriate measures at the preparatory, main and final stages.

Conclusions. Experimental verification of the developed technology of physical therapy for flat feet in young athletes of different ages with using anthropometric, instrumental (photo, myotonometric, electromyographic) research methods proved its efficiency, which was manifested in improving linear and angular characteristics of the foot, increasing the tone and amplitude-frequency characteristics of muscles, increasing physical qualities and improving methods and techniques of taekwondo.

Key words: schoolchildren; physical therapy; myo-fascial kinematic chains; vaulted apparatus of the foot.

Анотація
Данищук А.Т. Ефективність технології фізичної терапії плоскостопості в юних спортсменів різного віку засобами таеквондо.

Мета даної роботи полягає у розробці технології фізичної терапії плоскостопості засобами таеквондо і перевірці її ефективності у школярів різного віку.

Методи дослідження: аналіз наукової та методичної літератури; педагогічні спостереження; педагогічні методи; інструментальний метод дослідження (методи фотометрії з використанням програми «BIG FOOT», міотонометрії та електроміографії). Методи математичної статистики. В обсязі брали участь 60 юних спортсменів у віці 8, 12 і 14 років з плоскостопістю, яка базувалася на фізичній терапії при плоскостопості в юних спортсменів.

Результати. Після виконаного дослідження було обґрунтовано та розроблено технологію фізичної терапії плоскостопості в юних спортсменів, яка згрупкована на дидактичних, загальних, організаційних та методичних основах процесу корекції склепінчастого апарату стопи і вивчення стану м'язів, що відносяться до переднього і заднього міофасціального ланцюга голени і стопи. Технологія фізичної терапії передбачає застосування фізичних вправ таеквондо, що визначає мету, завдання та принципи корекційних заходів, форм і методів проведення занять з таеквондо, принципи дозування та параметри фізичного навантаження, що базуються на створенні індивідуальних планів для юних спортсменів окремою віковою групою. Розроблена технологія фізичної терапії передбачає впровадження відповідних заходів на підготовчому, основному і заключному етапах.

Висновок. Експериментальна перевірка розробленої технології фізичної терапії плоскостопості у юних спортсменів різного віку за допомогою антропометричних, інструментальних (фото-, міотонометричних, електроміографічних) методів дослідження довела свою ефективність, яка проявлялась в поліпшенні показників лінійних і кутових характеристик стопи, підвищеній тонусі та амплітудо-частотних характеристик м'язів, підвищенні фізичних якостей та удосконаленнях способів та прийомів таеквондо у якості корегуючого засобу фізичної терапії при плоскостопості.

Ключові слова: школярі; фізична терапія; міофасціальні ланцюги; склепінчастий апарат стопи.

Анотация
Данищук А.Т. Эффективность технологии физической терапии плоскостопия у юных спортсменов разного возраста средствами таэквондо.

Цель данной работы заключалась в разработке технологии физической терапии плоскостопия средствами таэквондо и проверки ее эффективности у школьников разного возраста.

Методы исследования: анализ научной и методической литературы; педагогические наблюдения; педагогические методы; инструментальные методы исследования (методы фотометрии с использованием программ «BIG FOOT», миотонометрии и электромиографии); методы математической статистики. В обследовании принимали участие 60 юных спортсменов в возрасте 8, 12 и 14 лет с плоскостопием, которое занималось на базе спортивного клуба «Таеквондо».

Результаты. После выполненного исследования была обоснована и разработана технология физической терапии плоскостопия у юных спортсменов, которая основывается на дидактических, общих, организационных и методических основах процесса коррекции сводчатого аппарата стопы и изучения состояния мышц, относящихся к переднему и заднему миофасциальному ланцюгам голени и стопы. Технология физической терапии предусматривает применение физических упражнений таэквондо, определяют цели, задачи и принципы коррекционных мероприятий, форм и методов проведения занятий по таэквондо, принципов дозирования и параметров физической нагрузки, основанные на создании индивидуальных планов для юных спортсменов отдельной возрастной группы. Разработанная технология физической терапии предусматривает внедрение соответствующих мероприятий на подготовительном, основном и заключительном этапах.

Вывод. Экспериментальная проверка разработанной технологии физической терапии плоскостопия у юных спортсменов разного возраста с помощью антропометрических, инструментальных (фото, миотонометрического, электромиографического) методов исследования доказала свою эффективность, которая проявлялась в улучшении показателей линейных и угловых характеристик стопы, повышении показателей тонуса и амплитудо-частотных характеристик мышц, повышении физических качеств и совершенствовании способов и приемов таэквондо.

Ключевые слова: школьники; физическая терапия; миофасциальные кинематические цепи; сводчатый аппарат стопы.
Introduction

The results of the analysis of data from literature sources [1-4] prove that in the complex of measures aimed at prevention and correction of flat feet in children of all ages, the leading place is occupied by the means of physical culture [5-7]. Within physical therapy programs, they are often combined with kinesiotherapy, reflexology, massage, physical, and other traditional and non-traditional factors [8-14]. Their advantage is that they are widely available therapeutic agents that effectively affect the various systems of the body, improving the harmony of physical development and increasing the level of somatic health [15-17]. However, despite the variety of correction programs, the question of improving the methods of correction of the vaulted apparatus of the foot relates to the urgent problems of modern branches of both physical culture and physical therapy [18-19].

This dictates the need to improve both the traditional and the introduction of new tools, forms and methods of exercise, which include the means and elements of taekwondo [20, 21]. At the same time, it remains important not only to apply them, but also to check the effectiveness of the results obtained. A key element in modern flat-foot correction programs for students is physical therapy, based on the role of physical activity and exercise in strengthening the muscles responsible for the formation and maintenance of the vaulting apparatus of the foot [22-24]. However, the accumulated experience in the organization of motor activity of children is not always used rationally, as evidenced by the increase in the number of pupils with flat feet [2, 3, 23-25].

According to Macieko et al [26], the muscular system plays an important role in the development of the infant body. This role is explained by the significant influence of the energy and plastic processes in the working muscles on the morpho-functional state of the vaulting apparatus of the foot [16].

The muscular system and the level of physical activity of the child determines its harmonious physical development and creates the possibility of existence of the child's organism in the conditions of pathological processes and conditions. Therefore, only with the systematic and rational use of basic physical therapy in children can the adverse effects of flatfoot be eliminated [2, 6, 13, 25], which include the reduction of muscle strength of the myofascial kinematic chains of the lower leg and foot. It is considered as one of the etiological factors of flatness, its further progression and development of various complications [4, 16, 26].

Based on the scientific literature on the morpho-functional state of the vaulted foot apparatus and factors affecting the nature and orientation of flatfoot correction, we have determined the purpose of the work – to develop technology for flatfoot physical therapy by means of taekwondo and to test its effectiveness in students of different ages.

Material and methods

Participants

The survey involved 60 young athletes aged 8, 12 and 14 years with flat feet who practiced at the Taekwondo sports club in Ivano-Frankivsk.

To determine the effectiveness of the developed physical therapy technology, flat-footed children who participated in previous studies were divided into main and control groups at the stage of the forming experiment. In these groups, the dynamics of indicators of instrumental research methods (measurements of length and body weight, photometry, myotonometry, electromyography), indicators of pedagogical research methods were analyzed.

The main group included children of 8 (n = 9), 12 (n = 10) and 14 (n = 11) years with flat feet, who were engaged in the proposed physical therapy program. In the control group, children of 8 (n = 10), 12 (n = 10) and 14 (n = 10) years with flat feet engaged in a conventional school physical education program.

Procedure

Based on the data from literature sources [1, 16, 19, 26] about the factors affecting the morpho-functional condition of the vaulting apparatus of the foot, we have developed a technology of physical therapy of flat feet in young athletes of all ages. According to the purpose of the research, this technology is based on didactic principles, organizational and methodological foundations of the process of physical therapy of such children (Fig. 1).

Common components of flatfoot physical therapy in young athletes of all ages include the purpose, objectives, and principles of exercise and taekwondo activities.

The organizational foundations of the technology were based on the construction of an individual physical therapy plan, consisting of a preliminary assessment of the morpho-functional state of the myofascial kinematic chains and the vaulting apparatus of the foot; definition of general
therapeutic and special therapeutic measures, including exercise and eekondo; creation of technology of physical therapy of flat feet; its implementation and final evaluation of its effectiveness for young athletes of all ages with flat feet [6, 15].

The methodological bases of the concept of physical therapy of flat feet include the means and principles of dosing, parameters of physical activity, methods and forms of conducting taekwondo classes [2, 6, 8] (Fig. 2).

The developed technology of the author envisaged the introduction of physical therapy measures at the preparatory, main and final stages. Their basis were individually selected and differentiated measures [21, 22].

Fig. 1. Flowchart of technology of physical therapy of flat feet in young athletes of all ages by means of taekwondo

Among them, there were exercises taekwondo, kinesiotherapy, massage, natural factors aimed at strengthening the vaulting apparatus of the foot, increasing the strength of myofascial kinematic chains of the lower leg and foot, improving the metabolic processes by enhancing circulation and lymphatic development, development of physical development and development.
Photometry using BIG FOOT, Myotonometry and Electromyography was used to evaluate the effectiveness of the developed methodology.

**Statistical analysis**

The following indicators were calculated: average values of angles in each of 10 frames; error of the mean, standard deviation, coefficient of variation. Data processing was carried out using computer programs - “EXCEL-2016”.

**Results**

According to electromyographic studies, it has been found that, following the use of physical therapy technology with the introduction of exercises and techniques, muscle strength related to the anterior and posterior myofascial kinematic chains of the lower leg and foot has improved. In the athletes of the main group, the electrophysiological activity in both types of muscles proved to be almost the same, since the frequency-amplitude characteristics coincide between the muscles of the anterior and posterior myofascial kinematic chains (Table 1, Fig. 3 (1) a, b).

**Table 1**

Comparative characteristics of the electromyographic excitability of the muscles of the anterior and posterior myo-fascial chains of the tibia of the main and control athletes after the experiment

| Group               | The name of the muscle | Statistical indicators |
|---------------------|------------------------|------------------------|
|                     |                        | $\bar{x}$   | $s$  | $m$  | $t$  | $p$     |
| Main, n = 30        | m. Tibialis anterior   | 201        | 2,46 | 0,73 | 3,6  | <0,05   |
| Control, n = 30     | m. Flexor hallucis longus | 147      | 2,05 | 0,61 | 4,2  | <0,05   |
| Main, n = 30        | m. Tibialis anterior   | 199        | 1,57 | 0,34 | 3,1  | <0,05   |
| Control, n = 30     | m. Flexor hallucis longus | 102      | 1,18 | 0,22 | 3,6  | <0,05   |

And, conversely, young athletes in the control group have a probable (p <0.05) irregularity of electrical excitability, which is manifested not only by varying degrees of decrease in total activity in both muscles (Fig. 3 (2) a, b), but also pronounced imbalance of muscle activity between the anterior and posterior myofascial kinematic chains of the lower leg and foot (see Table 1).

![Fig. 3. Interference electromyogram of the muscles that are part of the anterior (a) and posterior (b) myo-fascial kinematic chain of the tibia and foot and participate in the support of the vault apparatus of the athlete 14 years of the main group (1) and the athlete of 14 years of the control group (2)](image-url)

Such an imbalance, according to some authors [3, 8, 16, 25], can serve as a foundation for worsening the condition of the vaulting apparatus of the foot and the development of various complications of flat feet, on the other - an indicator for evaluating the effectiveness of a particular program of physical therapy.

It was also found (Table 2) that in young athletes of the main group the mean value of muscle tone in the isotonic state (A) was statistically significant (p <0.05) and increased on average by 6.9 $\pm$ 0.25%, muscle contractility (K1) - by 44.6 $\pm$ 3.44% (p <0.01), coefficient of "additional relaxation" (K2) - by 4.1 $\pm$ 0.18% (p <0.05).
Comparative characteristics of the muscle tone of the shin of the primary and control athletes after the experiment

| Group          | Indicator | Statistical indicators |    |    |    |    | Pririst, % |
|----------------|-----------|------------------------|----|----|----|----|------------|
| Main n = 30    | A         | x 87,3  S 2,96         | m 0.41 | t 4.4 | <0.05 | 6,9±0.25 |
| Control n = 30 |           |                        |    |    |    |    |            |
| Main n = 30    | K1        | x 15,9  S 2,80         | m 0.15 | t 2.9 | <0.01 | 44,6±3,44 |
| Control n = 30 |           |                        |    |    |    |    |            |
| Main n = 30    | K2        | x 0.98  S 0.06         | m 0.04 | t 3.3 | <0.05 | 4,1±0.18  |
| Control n = 30 |           |                        |    |    |    |    |            |

In our opinion, improvement in tonic and electromyographic indexes of the tibia and foot muscles had a positive effect on the likely improvement in the linear and angular characteristics of the young athlete's foot in all children in the main group (p <0.05). However, after the use of the author's technology of physical therapy, the expressiveness of the mold angle α and Friedland index were statistically significantly (p <0.01) improved respectively by 14.7 ± 0.81% and 11.1 ± 0.33% (Table 3).

Table 3

Dynamics of expressive indices of moldy foot angle (α) and Friedland index after experiment (x̅±S)

| Group          | The mold angle of the foot (α), degree | p | Increase, % |
|----------------|----------------------------------------|---|-------------|
| Main, n = 30   | 16,4±0.72                              | < 0.01 | 14,7±0.81 |
| Control, n = 30| 14,0±0.81                              |     |            |
| Friedland index|                                        | < 0.01 | 11,1±0.33 |

When analyzing the intergroup difference of indicators of the level of physical fitness (Table 4) of young athletes of the main group, statistically significant (p <0.01) increase of speed qualities was noted on average by 11.8 ± 0.53%, speed and strength – by 12.5 ± 0.87%, agility by 10.1 ± 0.45%, ability to static equilibrium by 23.1 ± 1.29%.

Table 4

Indicators of physical qualities of young athletes 10 years with flat feet after the experiment (x̅±S)

| N   | Indicators       | Main, n=11 | Control, n=10 |
|-----|------------------|------------|---------------|
| 1.  | Running 30m, s   | 6,4±0.57   | 6,1±0.51      |
|     | p (I-II)         | < 0.01     |               |
| 2.  | Long jump from place, sm | 129,9±4,31 | 140.4±4,22 |
|     | p (I-II)         | < 0.01     |               |
| 3.  | Shuttle running 4x9 m, s | 12,7±0.42 | 12,3±0.75    |
|     | p (I-II)         | > 0.01     |               |
| 4.  | Flamingo test, s | 11,1±0.56  | 8,3±0.21     |
|     | p (I-II)         | < 0.01     |               |

Analysis of the dynamics of methods and techniques of mastering kicks in young athletes of the main group shows that by 58.2 ± 1.46% statistically significantly increased the frequency of strokes outside the foot, almost a third (72.9 ± 2.61%) of them began to use alternate changes of right-left and
toe and heel parts of the foot - in 42.4 ± 1.88% of cases, which leads to a decrease in the load on the ankle joint and affects the efficiency of solving the motor problem when performing physical exercises in taekwondo.

**Discussion**

Our previous studies [20] and the works of other authors [3, 8, 22, 26] have become the basis for the substantiation and development of technology for physical therapy of young athletes and flat feet. It is based on general didactic, organizational and methodological principles of the process of restoration of the organism of children with orthopedic pathology [6, 16]. On this basis, the purpose, objectives and basic principles of recovery activities, forms and methods of taekwondo training were determined. It was the basis for the construction of an individual program of physical therapy, taking into account age parameters and principles of dosing of physical activity [2, 25].

When implementing physical therapy measures, the technology developed provided for the preparatory, main and final stages, which are based on the use of systematic physical exercises and means of taekwondo [11, 20, 21]. The program also included kinesitherapy in the form of additional morning hygienic and therapeutic exercises with the use of massage, natural factors (climatotherapy, balneological procedures) and orthopedic activities. Their inclusion in physical therapy programs is recommended by many authors [5, 9, 12-14].

According to the recommendations of individual authors [1-3, 19, 23, 26], a pantographic, a number of instrumental methods of research and testing of the level of fitness were used to experimentally test the effectiveness of the developed technology of physical therapy of young athletes and the age of 7-14 years. In such studies, electromyographic studies are of particular value [1, 15, 19].

Their conduct allowed us to establish that young athletes of the control group have a probable unevenness of electrical excitability, which is manifested by both different degree of tone decrease and pronounced imbalance of muscular activity between the anterior and posterior myofascial kinematic chain.

Such an imbalance, according to some authors [3, 8, 16, 25], can serve as a foundation for worsening the condition of the vaulting apparatus of the foot and the development of various complications of flat feet, on the other - an indicator for evaluating the effectiveness of a particular program of physical therapy [25, 26].

Our opinion is supported by data from other authors [5, 7, 16, 27], who also believe that improving the tonic indexes of the leg and foot muscles has a positive effect on the likely improvement in the linear and angular characteristics of the foot. This provision is confirmed by our electromyographic studies.

The results obtained proved the effectiveness of the developed program of physical therapy, which was manifested in improving the tone of the leg and foot muscles and improving the level of fitness.

**Conclusions**

1. In the development and implementation of flat-footed physical therapy technology, we used effective tools, forms, methods, and principles of physical therapy that, in their unity, made it possible to realize the corrective and healing functions of the means and taekwondo within the framework of the proposed technology, ensuring their relationship with the training of young people. athletes of all ages and the formation and correction of the condition of the vaulting apparatus of the foot.

2. The results of the studies indicate that the use of means and elements taekwondo within the framework of the developed technology of physical therapy, contributed to the achievement of individual plans for the correction of the condition of the vaulting device of the foot in flat feet in young athletes of different ages, which was reflected in their statistically significant status motor, physical development and physical fitness, as well as ways of owning techniques taekwondo.

Prospects for further studies include the study of the functional parameters of the cardio-respiratory system to improve the technology of physical therapy of flat feet in athletes of different ages using modern research methods.

**Conflict of interest**

Authors state that there is no conflict of interest.
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Received: 16.11.2019

Принята в редакцію: 16.11.2019