Influence of lower leg myofascial kinematic chains on flat feet development of children 7-14 years old

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Abstract
The aim of the work is to study the biomechanical properties of the myo-fascial kinematic chain "foot-shin" of children of 7-14 years old with non-fixed and clinically expressed flat-footedness.
Material and methods. The study involved 14 children with flat-footedness of grades I-II and 6 children with flat-foot deformity of the foot and 20 children who only had functional disorders of the foot. An anthropometric study of the foot was carried out, electrophysiological indicators of the muscles of the leg were determined, and plantograms were analyzed.
Results. The study found a correlation between the indicators of the anatomical and functional state of the foot and the imbalance of the frequency-amplitude indices of the ipsi and contralateral muscles within one link of the myofacial kinematic chain, may be important as one of the factors that contribute to the development of flatfoot. This is confirmed by other indicators and indicate a decrease in the height of the longitudinal arch, a decrease in the metatarsal and heel angles of the arch of the foot. Such changes have a pronounced relationship with age. The results of the work indicate that a possible cause of flattening of the vaulted apparatus of the foot is not only the weakness of its joint-ligament-muscular system, but also above the located kinematic segment - the tibia. The correlation analysis revealed the relationship between the indicators of the development of the anatomical and biomechanical components of the foot and the characteristics of the electromyographic indicators of the muscles of the leg in children 7-14 years old. As a result of a comprehensive study, it was found that during this period of ontogenesis in the formation of flatfoot such electromyographic indicators as frequency-amplitude characteristics of action potentials of motor units of the long and posterior tibial muscles, as well as their tone imbalance, take on major importance.
Conclutions. Experimental studies have established that the registered changes in the articular components of the foot of children 7-14 years old lead to a change in the electromyographic parameters of the muscles of the leg, which are involved in the formation of the initial sections of myo-fascial kinematic chains.
Key words: foot, electromyography, plantography, children of school age.

Анотація
Данищук А.Т. Вплив міо-фасціальних кінематичних ланцюгів гомілки на розвиток плоскостопості у дітей 7-14 років
Мета роботи – вивчити біомеханічні властивості міо-фасціального кінематичного ланцюга "стопа-гомілка" дітей 7-14 років з нефіксованою і клінічно вираженою плоскостопістю.
Матеріал і методи. У дослідженнях взяли участь 14 дітей, що мають плоскостопість I-II ступеня важкості і 6 дітей з плосковальгусною деформацією стопи і 20 дітей, у яких виявлені тільки функціональні порушення стопи. Проведено антропометричне стопи, визначали електрофізіологічні показники м'язів гомілки, аналізували плантограми. **Результати.** У дослідженні виявлений кореляційний взаємозв'язок між показниками анатомо-функціонального стану стопи і дисбалансом частотно-амплітудних показників іпсі- і контрлатеральних м'язів в межах однієї міо-фаціальної кінематичної ланки, що може мати значення як один з факторів, який сприяє розвитку плоскостопості. Це підтверджується іншими показниками, що свідчать про зниження висоти поздовжнього склепіння, зменшенням плеснового і п'яткового кутів склепіння стопи. Такі зміни мають яскраво виражений взаємозв'язок з віком. Результати роботи вказують, що можливою причиною сплощення склепінчастого апарату стопи є не тільки слабкість її суглобово-зв'язково-м'язового апарату, але й вище розташованого кінематичного сегменту – гомілки. Проведений кореляційний аналіз виявив залежність між показниками розвитку анатомо-біомеханічних компонентів стопи та особливостями електроміографічних показників м'язів гомілки у дітей 7-14 років.
Висновки. Експериментальними дослідженнями встановлено, що зареєстровані зміни суглобових компонентів стопи дітей 7-14 років призводять до зміни електроміографічних показників м'язів гомілки, які приймають участь у формуванні початкових ділянок міо-фасціальних кінематичних ланцюгів.
Ключові слова: стопа, електроміографія, плантографія, діти шкільного віку.

Аннотация
Данищук А.Т. Влияние мио-фасциальных кинематических цепей голени на развитие плоскостопия у детей 7-14 лет
Цель работы – изучить биомеханические свойства мио-фасциальной кинематической цепи "стопа-голень" детей 7-14 лет с нефиксированной и клинически выраженным плоскостопием.
Материал и методы. В исследованиях приняли участие 14 детей, имеющих плоскостопие I-II степени тяжести и 6 детей с плосковальгусною деформацией стопы и 20 детей, у которых обнаружены только функциональные нарушения стопы. Проведено антропометрическое исследование стопы, определяли электрофизиологические показатели мышц голени, анализировали плантограммы.
Результаты. В исследовании обнаружена корреляционная взаимосвязь между показателями анатомо-функционального состояния стопы и дисбалансом частотно-амплитудных показателей ипси- и контрлатеральных мышц в пределах одного звена мио-фациальной кинематической цепи, может иметь значение как один из факторов, который способствует развитию плоскостопия. Это подтверждается другими показателями и свидетельствуют о снижении высоты продольного свода, уменьшением плюсневого и пяточного углов свода стопы. Такие изменения имеют ярко выраженную взаимосвязь с возрастом. Результаты работы указывают, что возможной причиной уплощения сводчатого аппарата стопы является не только слабость ее суставно-связочно-мышечного аппарата, но и выше расположенного кинематического сегмента - голени. Проведенный корреляционный анализ выявил зависимость между показателями развития анатомо-биомеханических компонентов стопы и особенностями электромиографических показателей мышц голени у детей 7-14 лет.
Выводы. Экспериментальными исследованиями установлено, что зарегистрированные изменения суставных компонентов стопы детей 7-14 лет приводят к изменению электромиографических показателей мышц голени, которые принимают участие в формировании начальных участков мио-фасциальных кинематических цепей.
Ключевые слова: стопа, электромиография, плантография, дети школьного возраста.

Introduction

The first place among the pathologies of the lower extremities in children is occupied not by the flat foot itself, but by various functional disorders of the foot, the frequency of which, according to a number of authors [1, 2], ranges from 35.1 to 63.8%. Many researchers have found that non-fixed foot disorders or mobile flat feet over time can lead to serious changes throughout the body and cause flat feet and flat feet, as a separate nosological unit [3].

First of all, flat feet and flat-footed foot are characterized by pronounced deformation of the foot, which is manifested in a decrease in the height of the longitudinal arch, combined with pronation of the heel and supination contracture of the anterior foot [4]. Violations of the support-depreciation function of the foot in children 7-12, it is very difficult to detect because these changes are hidden and do not cause pain for some time. At the same time, a slight aching or mild character remains only a subjective feature, which is often left unattended by parents [5].

One of the reasons for the flattening of the longitudinal arch of the foot is the weakness of the musculoskeletal system, not only the foot itself, but also the muscles of the shin [6]. Together, they form the first link in the so-called myo-fascial kinematic chains (IFLC). The theory of their existence and decisive role in the biomechanics of the human body has recently become widespread relevance and is the subject of much attention, especially in the preparation of physical therapists [7].

Experimental studies [8] found that in violation of the vaulted apparatus of the foot in parallel there is a decrease in the depreciation properties of the lower extremity and impaired spinal function of the spine. This is due to the biomechanical features of the foot-spine kinematic pair, as one of the three existing elastic segments of the human body (the third element is myo-fascial kinematic chains [7]). Each of them provides mechanical shock absorption in at least two mutually perpendicular planes [9]. The importance of correct and consistent, in space and time, the functioning of these three elements of the musculoskeletal system is difficult to overestimate, since the violation of at least one of them on the one hand causes a direct proportional exhaustion of the reserve capacity of the other two, and on the other - is the cause of pathology above and below the kinematic links of the human body. Therefore, it is very important to study the first components of the myo-fascial kinematic chains (in our case, these are the tibia muscles), the development of which will largely depend on the condition of the vaulted foot apparatus [8].

The above was the basis for an in-depth study of the biomechanical properties of the skeletal muscles of the tibia of children of all ages who have I-II degree of flat feet or flat-mouth deformity of the foot compared with children who have only found functional changes in the foot, which are located in SA.

The aim of the study is to study the biomechanical properties of myo-fascial kinematic chain of the foot-tibia of children 7-14 years with unfixed and clinically pronounced flat feet.

Material and methods

The analysis and theoretical generalization of the specialized scientific literature, pedagogical observation, anthropometry [10], electromyography, video computer foot analysis, statistical data processing ("Statistics 6") have been carried out.

Electromigraphy was performed using the Neuro-EMG-Micro computer-based electromyrographic complex manufactured by Neurosoft (Russia). The muscles involved in the lateral (long tibia) and dorsal (posterior tibia) of the myo-fascial kinematic chains of the right and left tibia were examined.

Video-computer analysis was performed with the help of the system for determining the functional state of the locomotor system "DIERS FAMUS" (Germany), which allowed to perform quantitative analysis of the planograms of the foot in static position and dynamic load during walking (Fig. 1). The study involved 14 children with flat feet I-II severity and 6 children with flat-foot deformity of the foot (experimental group 1) and 20 children with functional disorders of the foot (experimental group 2).

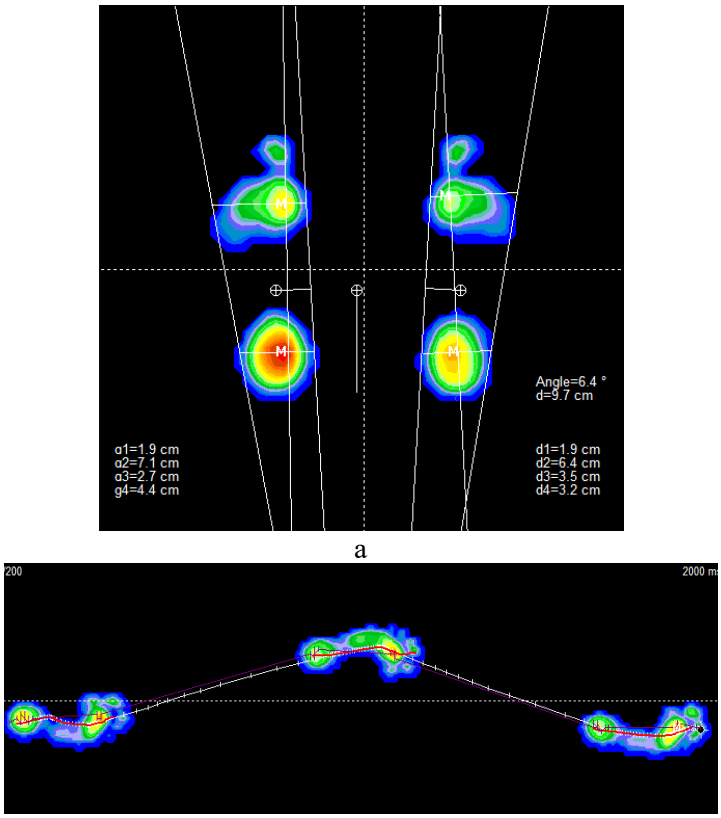


Fig. 1. General view of the computer planogram analysis page in static (a) and dynamic (b) planograms using DIERS FAMUS (Germany)

All children are engaged in the Taekwon-to-Ivano-Frankivsk section for 2-7 years. In the images of the foot in different planes, using the ImageJ program (USA), in addition to the linear dimensions, the angular characteristics of the CAC were measured: the mold angle α (characterizing the spring properties of the foot associated with the retention of the active components of the muscles) and the heel angle β (characterizes the spring properties associated with the passive components, due to the peculiarities of bone junction and the ligamentous apparatus of the foot).

Results

As a result of comparative examination, it was found that the children of the first experimental group had statistically significant differences ($p < 0.05$) in height of the vaulted apparatus of the foot (Fig. 1).

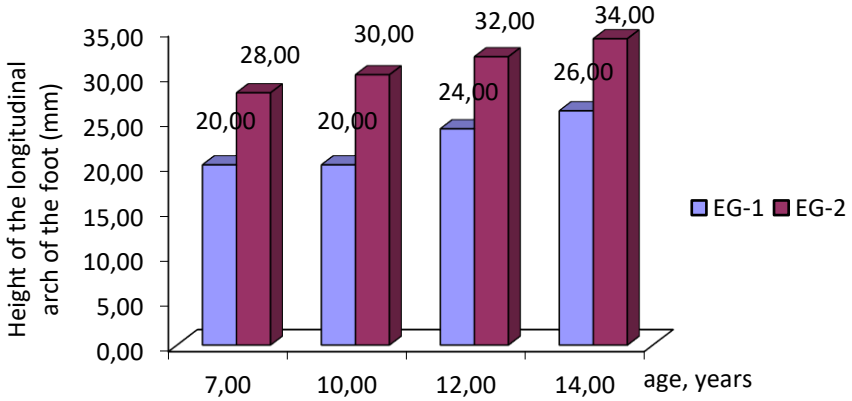


Fig. 1. The height of the longitudinal arch of the foot in children with fixed flat feet and flat feet of the I-II degree at the age of 7-14 years:
EG-1 is experimental group 1
EG-2 is experimental group 2

The analysis of the results showed that the decrease in the musculoskeletal properties of the feet of schoolchildren is accompanied by a decrease in the performance of the motor units of the muscles under study according to electromigraphy. Against this background, the asymmetry of muscle tone, which belongs to one myo-fascial kinematic chain, is revealed. This was reflected in the higher values of the frequency-amplitude characteristics of the action potentials of the motor units of the long tibial muscle and the decrease in the electromigraphic indices of the posterior tibial muscle (Fig. 2).

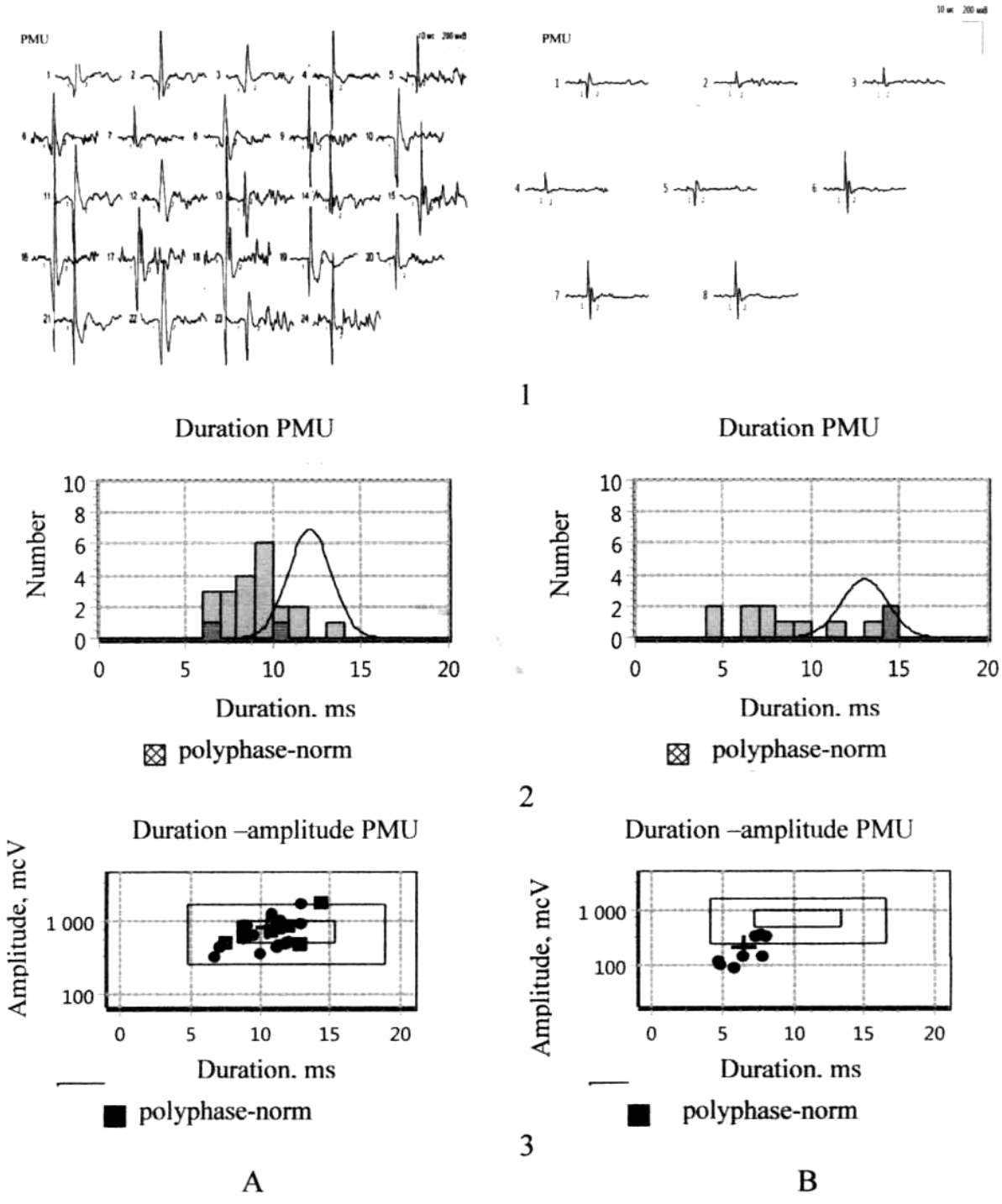
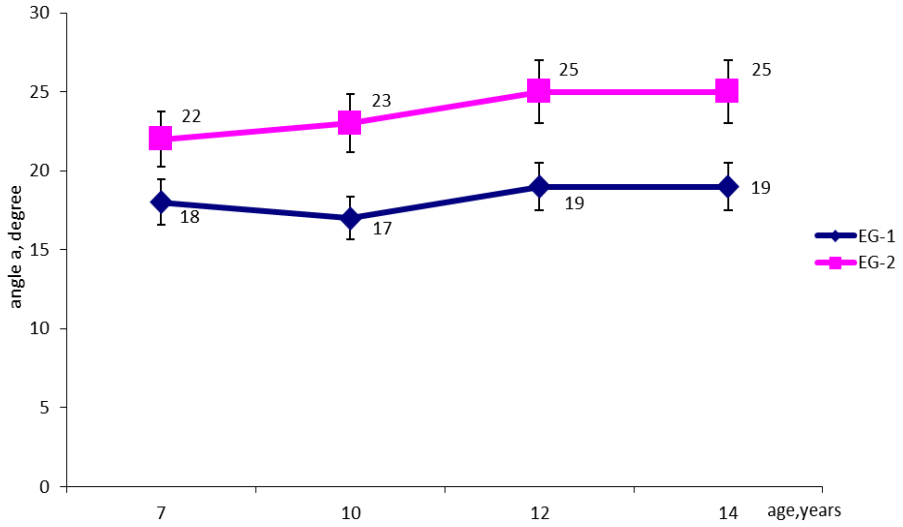
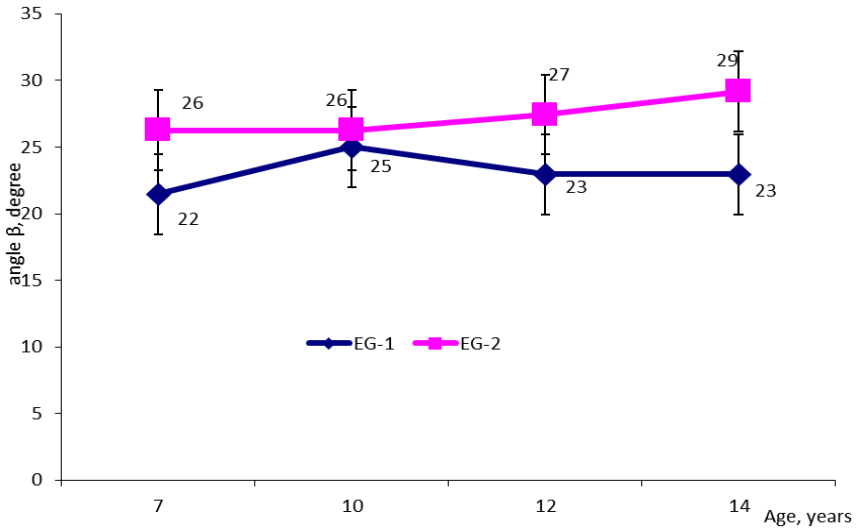


Fig. 2. Qualitative (1) and quantitative (2, 3) electromyographic indexes of the long tibial muscle (A) and posterior tibial muscle (B) in a 10-year-old child with flat-footed I-II severity

Significant differences were observed when comparing the angular characteristics of the foot. In all children, experimental group-1 mean mold angle was 1.1-1.5 ° less than in experimental group 2 (Fig. 3).



a



b

Fig. 3. The magnitude of the angle α (a) and the angle β (b) in children with unfixed flat feet (EG-2) and flat feet I-II severity (EG-1), depending on age:
EG-1 is experimental group 1
EG-2 is experimental group 2

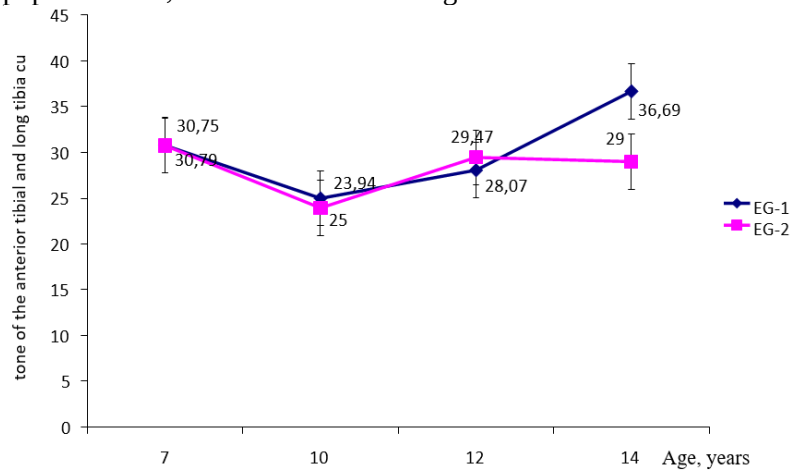
Changing the height of the vaulting device of the foot as the age of children in both groups, as a rule, is accompanied by a significant increase in the tone of the long tibial muscle by an average of 4.0% and the anterior tibial muscle - by 6.8% per year, which is manifested first of all, by increasing the amplitude of the action potential of the motor unit (Fig. 3). The dynamics of change in tone of the studied muscles of the lower extremities is wavy. The greatest increase in the tone of the muscles under investigation is from 7 to 8 years and from 10 to 12 years.

As a result of correlation analysis it is established that the index of the height of the arch of the foot has a certain relationship with the linear dimensions of the foot itself and the geometry of its articular formations: the length of the foot ($r = 0,58$, $p < 0,05$), the length of the supporting part of the arch of the foot ($r = 0.56$, $p < 0.05$), the height of the arch of the foot ($r = 0.75$, $p < 0.05$), the height of the rise of the foot ($r = 0.83$, $p < 0.05$), as well as the value of the metatarsus ($r = 0.80$, $p < 0.05$) and heel ($r = 0.84$, $p < 0.05$) angles.

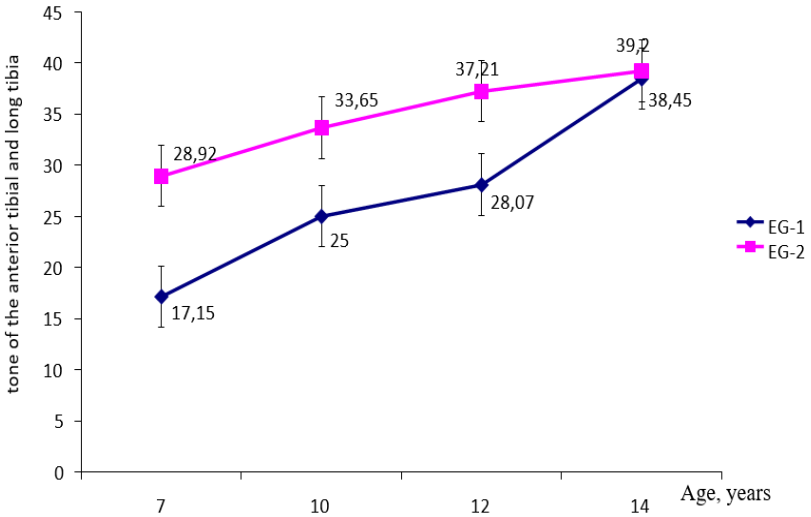
Discussion

Features of biomechanics of the foot, which is the most important link in the general myo-fascial kinematic chains, largely determine the biomechanics of movements of the lower extremities, spine and human body as a whole [11, 12, 13].

One of the main features of this fairly sophisticated design is that the cushioning ability of the foot, contrary to popular belief, is determined not so much by tendons and ligaments, but by the dynamic performance of a large group of foot and leg muscles [3, 14, 15] . However, according to many authors [5, 16, 17], the most effective correction of flatfoot is possible only at the age of 12 years, since by this age the vaulted apparatus of the foot is finally formed. Therefore, in our study, we chose the age range of children under 14 to test the effectiveness of physical therapy after 12 years and to identify or deny their effectiveness at that age.



A



B

Fig. 4. Indices of anterior tibial and long tibial muscle tone of children 7-14 years: A - children with flat-foot deformity of the foot; B - children with not fixed flat feet:
EG-1 is experimental group 1
EG-2 is experimental group 2

To date, the causes and mechanisms of development (etiopathogenesis) of flat foot and flat foot in children have not been sufficiently studied [2]. There are many theories about the occurrence of this pathology, each of which has the right to exist. However, the only theoretical basis characterizing these stato-dynamic disturbances has not yet been formed [11, 18, 19].

Therefore, we propose our own vision of this problem, which is based on a theoretical and practical basis on the unity of anatomic-biomechanical factors, which is clearly presented in the theory of myo-fascial kinematic chains. According to this theory [7, 20, 21], all groups of the leg muscles and their own muscles of the foot are involved in the formation and retention of the vaulted apparatus of the foot [2].

Together they represent the first link of myo-fascial kinematic chains. Prevents valgus (deviation of the foot outward) deformation of the foot, mainly the posterior group of the leg muscles. Conversely, the lateral group of the tibiae muscle raises the lateral edge of the foot (pronation), while participating in the formation of flat-valvular (combination of valgus and flatfoot) deformity of the foot [4]. Therefore, in our work we investigated the EMG activity of the muscles of these two groups. The revealed asymmetry of the amplitude-frequency characteristics of these muscles in DG-1 children confirms the opinion of some authors [1, 3, 6], about the significant role of the initial links of IFLC in the formation of the correct SAS. On the other hand, he argues that the lag in their development (primarily power characteristics) against the background of the tonic imbalance of these muscle groups plays the function of a trigger factor for the development of flat foot and flat-foot deformity of the foot. This approach will allow you to review the views on the treatment and prevention regimens of such foot defects and to apply non-traditional physical exercises for the development of power, while restoring the symmetry of muscle tone in the ipsi and contralateral structures of one myo-fascial kinematic chain. Such exercises can be a training complex and taekwon-do, which has movements that simultaneously develop the flexibility, coordination and strength of the muscles of the lower extremity.

The quantitative changes we found in the anthropometric parameters of the vaulted apparatus of the foot indicate a significant difference, especially in relation to the height of the arch and its angular characteristics, between children with severe pathology and functional disorders of the foot. Therefore, they should be used to monitor the effectiveness of physical therapy, as they objectively reflect the real condition of the osteoarticular component of the vault of the foot.

In addition, we also found age dependence between changes in various indicators, indicating a greater sensitivity of the vaulting device of the foot in 7-8 years, compared with older age. This is probably due to the fact that, at a younger school age, his reserve capacity is determined more by a ligament than by a muscular element [2, 6]. Then, as the latter naturally develops at an older age. It is this pattern that explains the presence of a large group of surveyed children with functional disorders of the foot and substantiates the need for early development of reserve capabilities to prevent the development of flat feet.

Conclusions

1. The analysis of the scientific literature shows that with age, the percentage of cases of violation of the vaulting apparatus of the foot of different types decreases: from 53.7 to 72.9% - in boys 7-9 years, from 46.2 to 59.1% - in 10-12 years and from 40,1 to 55,3% - 13-14 years. The possible reason for flattening of the foot vault is not only the weakness of its articular-ligamentous-muscular apparatus, but also the tibia above the kinematic segment.

2. The correlation analysis revealed a correlation between the development of the anatomic-biomechanical components of the foot and the features of the electromyographic parameters of the tibia muscles in children 7-14 years. As a result of a comprehensive study it was found that during this period of ontogeny in the formation of flatness of the leading value such electromyographic parameters as the frequency-amplitude characteristics of the action potentials of the motor units of the long tibial ($r = 0.87$, $p < 0.05$) and posterior tibial ($r = 0.81$, $p < 0.05$), as well as imbalance in their tone.

3. Experimental studies have found that recorded changes in the joint components of the foot of children 7-14 years lead to changes in the electromyographic parameters of the tibia muscles, which are involved in the formation of the initial sections of the myo-fascial kinematic chains.

The prospects of further research should be directed to the study of other problems of the influence of myo-fascial kinematic chains on the biomechanical properties of the foot and their role in forming conditions for the development of flat feet and other deformities of the foot.

Conflict of interest

Authors declare that there is no conflict of interest.

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