Danyshchuk Andrii, Ivanyshyn Iryna. Effectiveness of a program of the comprehensive correction of foot arch disorders in young athletes aged 7-8 years specialised in taekwon-Do I.T.F. Journal of Education, Health and Sport. 2020;11(1):400-411. eISSN 2391-8306. DOI http://dx.doi.org/10.12775/JEHS.2021.11.01.040
https://apcz.umk.pl/czasopisma/index.php/JEHS/article/view/JEHS.2021.11.01.040
https://zenodo.org/record/5750656

The journal has had 5 points in Ministry of Science and Higher Education parametric evaluation. § 8. 2) and § 12. 1. 2) 22.02.2019.

The authors declare that there is no conflict of interests regarding the publication of this paper.

Received: 03.01.2021. Revised: 28.01.2021. Accepted: 31.01.2021.

Effectiveness of a program of the comprehensive correction of foot arch disorders in young athletes aged 7-8 years specialised in taekwon-Do I.T.F.

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Abstract

Introduction. A number of scientists have proven the positive effect of taekwon-Do I.T.F. on the physical state of people of all ages, the state of their musculoskeletal system. However, in the scientific literature there is no data on the effectiveness of taekwon-Do I.T.F. use in the programs of correction of foot arch (FA) disorders of young athletes. Similarly, no studies have been conducted on the effect of taekwon-Do I.T.F. exercises on the development of myofacsical kinematic chain (MFKC) of the lower limb and its role in the foot maintenance and correction in foot arch disorders. **The purpose** is to experimentally test the effectiveness of a comprehensive program for the foot arch disorders correction of young athletes by means of taekwon-Do I.T.F. **Material and method.** The following instrumental methods were used in the work: plantography (baropodograph using computer device “DIERS FAAMUS” (Germany)); electroneuromyography ("Neuro-EMG-Micro" made by "Neurosoft" (Russia)); photometry; myotonometry; formative consistent pedagogical experiment; methods of statistical data processing (Statistics 6.0 (StatSoft, USA)). Young athletes aged 7–8 with FA disorders and a normal foot took part in a 12-month formative experiment**. Results.** The value of the Friedland index, which characterizes the functional foot reserves, increased statistically significantly among EG1 young athletes who practiced according to the program developed by us, compared with those who were training according to the traditional program – by 6.48% against 3.85%, respectively. **Conclusions.** Analysis of FA morphological parameters of young athletes aged 7-8 years shows that the positive changes are statistically significantly more performed in young athletes who were training in the sports center "Taekwon-Do I.T.F." on a program of comprehensive correction, which is confirmed by FA changes.

Key words: taekwon-do; juniors; foot arch disorders

Introduction

According to E. Doroshenko [11], the athlete health, especially his musculoskeletal system (MSS), is closely interrelated with the problem of the effectiveness of long-term

sports training process. According to WHO statistics [28], research data V.O. Kashuba in co-authorship [12, 13], A.I. Alyoshyna and in co-authorship [2] every year the number of children with various forms of MSS disorders increases significantly, 70% of which are foot disorders. This has a negative effect on the training process, as children with foot arch disorders get tired quickly, and therefore have low physical performance.

The problem of prevention and correction of FA functional disorders in children of different ages were investigated by a number of authors [4, 12, 24, 33]. When developing correction programs, many authors paid attention to different types of motor activity [4, 7, 10, 31] and so on.

At present stage of sports development in different countries of the world martial arts, in particular, taekwon-Do, are becoming more and more popular among children and youth. The popularity of it is expressed in more than 50 million people involved from 206 countries according to statistics in 2015 [21] and is due to its entertainment, diverse impact on motor, mental and volitional qualities of person [22]. In the scientific literature, the positive effect of taekwon-Do classes on the musculoskeletal system of people of different ages has been proven [18, 22, 27, 29, 30, 32].

However, there is no data on the effectiveness of taekwon-Do use in the programs of FAA disorders correction of young athletes.

The purpose is to experimentally test the effectiveness of a comprehensive program for the correction of foot arch disorders of young athletes by taekwon-Do means.

Material and methods

Plantographic measurements were performed on a baroplantograph with a computer device "DIERS FAAMUS" (Germany) for the purpose of visual foot diagnosis in statics and dynamics (walking, running, jumping). Electroneuromyographic examination (ENMG) was performed using a computerized electroneuromyographic complex "Neuro-EMG-Micro" ("Neurosoft", Russia) to determine the temporal, amplitude and frequency muscle contraction parameters, which are part of the MFKC of foot shin. The photometry method was used to calculate linear (foot length; maximum foot arch height; lift height) and angular (metatarsal angle α, calcaneal angle β, foot arch angle γ) foot parameters based on the coordinates of 11 anthropometric foot points in the sagittal plane. The method of myotonometry was used to determine the indicators that characterize the biomechanical properties (elasticity, contractility, additional relaxation) of skeletal muscles that are part of the various MFKC of lower limb [25]. The formative consistent pedagogical experiment included a study of the impact of foot arch disorders correction program of young athletes engaged in taekwon-Do I.T.F., on its state and evaluation of developed program effectiveness. The methods of statistical data processing in the study were used to verify the sample for compliance with the law of normal distribution using the Shapiro-Wilk test (W); to determine the probability of differences between individual samples and indicators; to determine the effectiveness of the implementation of developed comprehensive correction program [9]. Statistical processing of the study results was performed on a personal computer using MS Excel 2010 tables and the application package Statistics 6.0 (StatSoft, USA).

To determine the effectiveness of the developed comprehensive correction program, all young 7-8 year-old athletes with FA disorders were assigned by us to EG1 (n = 18) and EG2 (n = 15). EG1 was engaged in our proposed program of correction of FA disorders, EG2 and the reference group (n = 15) were engaged in the traditional taekwon-Do program. The analysis of the obtained results, their comparison with the initial data and evaluation were performed 12 months after the beginning of the author's program of FA disorders correction, that allowed to evaluate the effectiveness of a comprehensive foot correction program of young athletes with FA disorders.

Results

The increase in the average foot length indicators of the studied groups EG1, EG2 and RG during the experiment was 2.97%, 3.21% and 3.11%, respectively (Table 1).

Thus, after the experiment there were no statistically significant changes ($p > 0.05$) in foot length values of young athletes who belonged to EG1, EG2 and RG. The average foot length increase was 6.3–6.8 mm, which corresponds to the age norms and indicates the FA stabilization and absence of signs of its stratification after the experiment.

After the experiment, a statistically significant improvement in foot arch height value in young athletes EG1 by 1 mm (6.85 %) ($t = 2.16$; $p < 0.05$), while in EG2 the increase in this indicator was only 0.3 mm (2,12 %) ($t = 0.64$; $p > 0.05$), and the reference group - 0.9 mm (6.02 %) ($t = 1.79$; $p < 0.1$).

Changes analysis in the values of the height of the navicular bone upper edge above the support (navicular height) shows a statistically significant increase in young EG1 athletes by 9.47% ($t = 2.33$; $p < 0.05$), while in young RG athletes growth rates were 6.93% ($t = 1,65$; $p < 0.1$), and in EG2 only 2.25% ($t = 0.55$; $p < 0.05$).

Table 1 – **Change in the indicators of foot support-spring properties of young athletes aged 7-8 years with FA disorders in the sagittal plane during the experiment, $\bar{x}(m_x)$**

Experimental groups	Indicators		p before-after
	before experiment	after experiment	
Foot length, mm			
EG1 (n = 18)	208.9(2.45)	215.2(2.30)	< 0.1
EG2 (n = 15)	208.6(2.35)	215.4(2.41)	< 0.1
RG (n = 15)	208.4(2.33)	215.3(2.51)	< 0.1
Foot arch height, mm			
EG1 (n = 18)	14.1(0.37)	14.9(0.28)	< 0.05
EG2 (n = 15)	14.0(0.31)	14.3(0.35)	> 0.1
RG (n = 15)	14.5(0.41)	15.4(0.29)	< 0.1
Height of upper edge of a navicular bone, mm			
EG1 (n = 18)	35.2(1.04)	38.7(1.08)[2]	< 0.05
EG2 (n = 15)	35.1(1.05)	35.9(1.02)[1]	> 0.05
RG (n = 15)	36.2(1.11)	38.8(1.12)	< 0.1
Metatarsal angle (α), grad			
EG1 (n = 18)	11.2(0.66)	13.1(0.59)	< 0.05
EG2 (n = 15)	11.1(0.95)	12.3(0.79)	> 0.05
RG (n = 15)	11.6(0.74)	13.4(0.64)	< 0.1
Calcaneal (heel) angle (β), grad			
EG1 (n = 18)	18.3(0.51)•••	22.3(0.55)***	< 0.001
EG2 (n = 15)	18.2(0.44)•••	19.3(0.48)•••	< 0.1
RG (n = 15)	21.0(0.52)	22.8(0.55)	< 0.05
Foot arch angle (γ), grad			
EG1 (n = 18)	153.2(2.14)[1]	142.5(1.98)**	< 0.01
EG2 (n = 15)	154.0(2.16)[1]	150.7(2.11)••	> 0.05
RG (n = 15)	138.2(2.53)	132.2(2.21)	< 0.1

Notes: 1 – differences are significant compared to indicators in the reference group at the statistical tendency level; 2 – differences are significant compared to the indicators in EG2 at the level of statistical tendency;* – differences are statistically significant compared

to the indicators in EG2 (** – $p < 0.01$, *** – $p < 0.001$); • – differences are statistically significant compared to the indicators in the RG (•• – $p < 0.01$, ••• – $p < 0.001$)

Estimation of metatarsal angle (α) dynamics value according to Kozyrev showed that this indicator have not improved in young EG2 athletes – 12.3±0.79° after the experiment against 11.1±0.95° before the experiment ($t = 0.97$; $p > 0.05$), while in young EG1 athletes, who were engaged in our correction complex program, there were probably significant changes in the metatarsal angle (α) by 15.64% – from 11.2±0.66° to 13.1±0.59° ($t = 2.15$; $p < 0.05$). Approximate growth rates were also observed in RG – 14.40% ($t = 1.84$; $p < 0.1$).

Similar changes occurred in heel angle (β) indicator, where the growth rate was 19.70% ($t = 5.33$; $p < 0.001$) in young EG1 athletes, 8.22% ($t = 2.38$; $p < 0.05$) in RG athletes and 5.87% in EG2 ($t = 1.69$; $p < 0.1$).

The same was characteristic of the foot arch angle (γ) values. Thus, in young EG1 athletes the value of the angle improved statistically significantly from 153.2±2.34° to 142.5±1.98° ($t = 3.49$; $p < 0.01$), at statistical tendency level there was an improvement in this indicator in RG – from 138.2±2.53 to 132.2±2.01 ($t = 1.86$; $p < 0.1$), in EG2 this indicator value, having a positive tendency, was still insignificant (by 2.32%).

One of the indicators that reflects the real FA state and characterizes the functional foot reserves is known as a Friedland index. The statistically significant this indicator value increased in young EG1 athletes, who were engaged in the program developed by us (Table 2).

Table 2 – **Change in Friedland index values in young athletes aged 7-8 years during the experiment, $\bar{x}(m_x)$**

Experimental groups	Indicators		p before-after
	before experiment	after experiment	
EG1 (n = 18)	25.4(0.45)•••	27.1(0.30)•••[1]	< 0.01
EG2 (n = 15)	25.5(0.41)•••	26.5(0.35)•••	< 0.1
RG (n = 15)	28.7(0.51)	29.8(0.33)	< 0.1

Notes: 1 – differences are significant compared to the values of indicators in EG2 at the level of statistical tendency ($p < 0.1$); • – differences are statistically significant compared to the values of indicators in the RG (••• – $p < 0.001$)

Thus, the Friedland index value increased in this group by 6.48% ($t = 3.14$; $p < 0.01$), while in EG2 only by 3.85% ($t = 1.86$; $p < 0.1$). Approximately the same growth rates were in RG – 3.76% ($t = 1.81$; $p < 0.1$). It should be noted that during the experiment, the indicator value in EG1 was statistically significantly different from the same in RG.

Thus, the analysis of FA morphological indicators in young athletes aged 7-8 years shows that the positive changes are statistically significantly more performed in young athletes who were training in the sports center "Taekwon-Do I.T.F." according to the developed comprehensive correction program, confirmed by changes in FA disorders degree (Fig. 1).

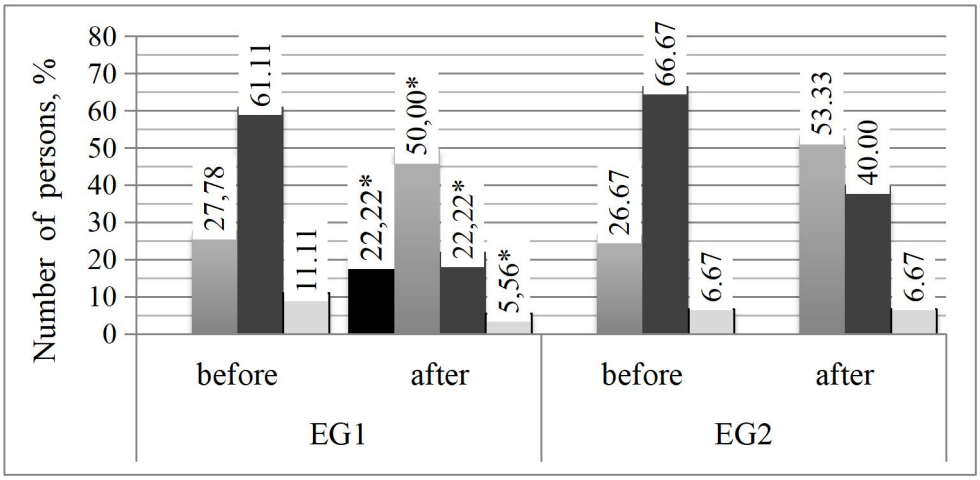

Fig. 1. Change in the distribution of young 7-8 year-old athletes by type of foot arched apparatus according to the Friedland index after the experiment ■ – normal arch; ■ – moderate flat foot; ■ – flat foot; ■ – severe flat foot

To determine the impact of a comprehensive correction program on the functional state of tibia MFKC muscles, the myotonometry indicators comparative analysis in young athletes of three groups was performed (Table 3).

Table 3 – **Changes in myotonometry of the tibial muscle MFKC in young athletes aged 7-8 years engaged in taekwon-Do I.T.F., $\bar{x}(m_x)$**

Experimental groups	Myotonometry indicators, units					
	A		K1		K2	
	before	after	before	after	before	after
Calf muscle						
EG1 (n = 18)	76.7(2.11)	82.3(2.35)^{3}	6.3(1.23)	9.7(1.12)*	0.96(0.02)	0.98(0.02)
EG2 (n = 15)	76.8(2.96)	80.2(4.44)	6.2(0.97)	7.6(1.25)	0.96(0.02)	0.96(0.02)
RG (n = 15)	–	82.2(2.26)	–	10.6(1.07)	–	0.99(0.01)
Tibialis posterior muscle						
EG1 (n = 18)	78.6(3.25)	89.6(2.75)$^{*\bullet 1}$	9.2(0.82)	12.4(0.92)^{*2}	0.97(0.02)	0.99(0.02)
EG2 (n = 15)	78.8(4.32)	82.0(2.44)	9.5(0.87)	10.1(0.84)	0.97(0.02)	0.98(0.02)
RG (n = 15)	–	96.1(2.17)	–	13.9(1.97)	–	1.01(0.02)
Tibialis anterior muscle						
EG1 (n = 18)	84.5(2.11)	90.2(2.24)^{1,3}	8.6(1.52)	12.3(1.88)^{3}	0.96(0.02)	0.98(0.02)
EG2 (n = 15)	84.1(2.93)	86.7(2.43)	8.4(1.57)	10.9(1.75)	0.96(0.02)	0.97(0.02)
RG (n = 15)	–	96.1(2.55)	–	15.9(1.97)	–	0.98(0.02)
Long tibialis muscle						
EG1 (n = 18)	77.0(2.33)	85.5(1.23)$^{***\bullet}$	6.3(1.02)	9.7(1.03)$^{*\bullet\times 3}$	0.95(0.02)	0.97(0.02)
EG2 (n = 15)	75.3(2.57)	80.1(2.08)	6.5(0.87)	8.8(0.58)*	0.94(0.02)	0.95(0.02)
RG (n = 15)	–	92.5(2.32)	–	12.2(0.83)	–	0.97(0.02)
Long flexor toe						
EG1 (n = 18)	80.1(2.15)	85.3(1.25)*	9.6(1.49)	13.2(0.86)$^{*\bullet 2}$	0.96(0.02)	0.99(0.02)
EG2 (n = 15)	80.2(2.32)	81.2(1.34)	9.7(1.66)	10.6(1.23)	0.97(0.02)	0.97(0.02)
RG (n = 15)	–	86.7(2.31)	–	12.5(1.79)	–	0.99(0.02)

Notes: 1 – differences are significant compared to indicators values in RG at the statistical tendency level; 2 – differences are significant compared to indicators values in EG2 at the statistical tendency level; 3 – differences are significant compared to indicators values before the experiment at the statistical tendency level; * –- differences are

statistically significant compared to indicators values before the experiment (*– $p < 0.05$, ** – $p < 0.01$, *** – $p < 0.001$); • – differences are statistically significant compared to indicators values in EG2 after the experiment (• – $p < 0.05$); × – differences are statistically significant compared to indicators values in the RG after the experiment (× – $p < 0.05$)

In the process of calf muscle myotonometry indicators studying in young EG1 athletes there was observed an increase in myoton in isotonic stress state (A) at the level of statistical tendency ($t = 1.77$; $p < 0.1$), the contractility coefficient (K1) ($t = 2.04$; $p < 0.05$), as well as "additional relaxation" (K2).

Changes in calf muscle myotonometry in young EG2 athletes were less pronounced and no statistically significant improvement was found.

Biomechanical properties analysis of posterior tibialis, long tibialis and long flexor toe, the tone and strength characteristics of which determine the FA support and damping function, also revealed positive changes in their elastic properties under the influence of a correction comprehensive program in young EG1 athletes.

Thus, the posterior tibia muscle tone index value in the state of "isotonic tension" (A) increased statistically significantly – by 14.00% ($t = 2.58$; $p < 0.05$) and the coefficient "K1" – by 34.78% ($t = 2.60$; $p < 0.05$), while in EG2 these increases were only 4.06% and 6.32%, respectively.

Appropriate changes were observed for the long tibial muscle namely the tone indicators in "isotonic stress" state statistically significant increased (A) by 11.04% ($t = 3.23$; $p < 0.001$) and the coefficient "K1" by 53.97% ($t = 2.35$; $p < 0.05$). It should be noted that in EG2 also significantly increased the coefficient "K1" value by 35.38% ($t = 2.20$; $p < 0.05$).

All studied indicators of the long flexor toe tone of young athletes aged 7-8 years also had statistically significant positive changes, namely the tone value in the state of "isotonic stress" (A) increased by 6.49% ($t = 2.09$; $p < 0.05$), and the coefficient "K1" – by 37.50% ($t = 2.09$; $p < 0.05$), while in EG2 by 1.24% and 9.28%, respectively.

When studying of myotonometry indicators of the anterior tibialis muscle in young athletes EG1 revealed an increase in myotonus in "isotonic stress" state (A) by 6.75% ($t = 1.85$; $p < 0.1$) and "contractility coefficient" (K1) на 43.02% ($t = 1.87$; $p < 0.1$). In EG2 representatives such changes were not observed even at statistical tendency level..

It was found that after an annual taekwon-Do I.T.F. classes cycle according to sports training center standard program for young EG2 athletes, electrophysiological activity improves and becomes almost the same between the muscles of the anterior and posterior MFKC, but they have a slight difference in frequency and amplitude characteristics and as a result certain difference in the strength characteristics of these muscles. Analysis of EMG studies in young EG2 athletes showed that the muscle tone imbalance decreased by an average of 56.71%, which is expressed in lateral tone decrease and muscle tone increase of posterior foot-limb MFKC. A characteristic pattern of muscle tone recovery in young EG1 athletes is a parallel increase in muscles overall activity of the anterior and posterior foot-limb MFKC, as well as the average frequency-amplitude balance restoration between them. EMG data, which characterize the excitability state and frequency-amplitude characteristics of motor units, show the lack of asymmetry of foot-limb muscles electrophysiological parameters, which belong to the joint MFKC.

This was expressed in a decrease of frequency-amplitude characteristics range of motor units potentials action of long tibialis muscle and their increase in the posterior tibialis muscle in 88.89% of young EG1 athletes and 60.00% in EG2 (Fig. 2).

Stabilographic data analysis showed that the indicators values of general CG standard deviation in the sagittal plane in young EG1 athletes by 18.31% ($t = 1.99$; $p<0.1$)

lower than before the experiment, while in EG2 the deviation decreased only by 6.94% (Table 4).

The same tendency was observed for the values of the standard deviation of the body gravity centre (BGC) in the frontal plane – they were on average 31.97% ($t = 4.93$; $p < 0.001$) in EG1 and 20.60% ($t = 2.80$; $p < 0.05$) in EG2 smaller than before the experiment.

It should be noted that in EG1 this indicator values were close to the values in RG, while in EG2 they were statistically significantly higher ($t = 2.08$; $p < 0.05$). It was also found that the value of BGC displacement speed in the sagittal plane in young EG1 athletes decreased by 26.40% ($t = 2.93$; $p < 0.01$) and differed from that in the RG by 7.38% ($p > 0.05$). In EG2, the value of this indicator also had a positive tendency that is decreased by 14.86% ($t = 1.45$; $p > 0.05$).

Thus, the data obtained indicate that young EG1 athletes have significantly improved the tone and contractile ability of foot-shin MFKC muscles, which are responsible for FA maintenance.

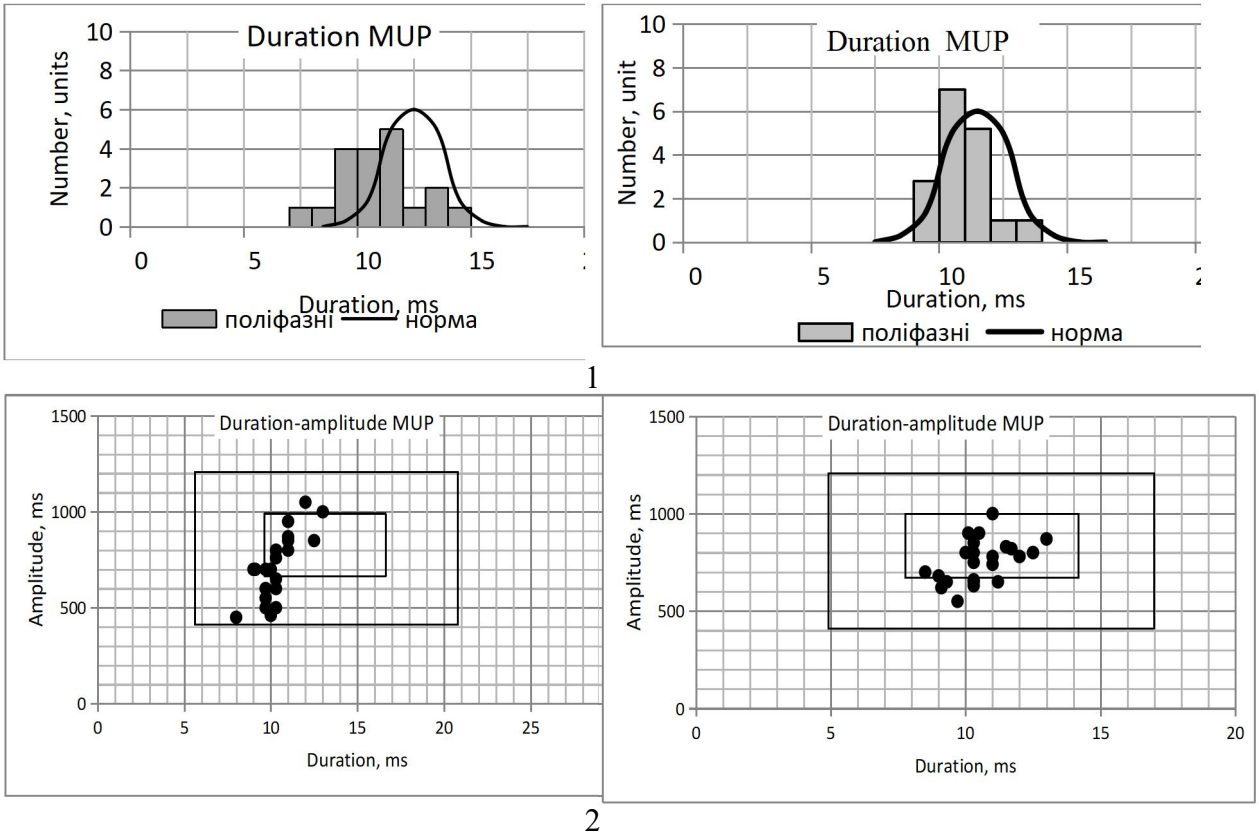

Fig. 2. Quantitative (1, 2) electromyographic indicators of the long tibialis muscle of young 7-8 year-old athlete of EG1 before (a) and after (b) the FA program of comprehensive correction implementation

Table 4 – **Indicators of deviation and velocity of body gravity center of young 7–8 year-old athletes before and after the complex correction program implementation, $\bar{x}(m_x)$**

Indicators	EG1 (n=18)		EG2 (n=15)		RG (n=15)
	Experiment stages				
	before	after	before	after	
BGC standard deviation in the frontal plane, mm	7,1(0.53)	5,8(0.38)$^{1\bullet}$	7,2(0.48)	6,7(0.23)$^{\times}$	5,4(0.62)
BGC standard deviation in the saggital plane, mm	26,9(1,41)	18,3(1,03)^{***2}	26,7(1,52)	21,2(1,24)$^{*\times}$	17,3(1,41)
BGC displacement velocity, mm·s^{-1}	17,8(1,54)	13,1(0.45)$^{**\bullet}$	17,5(1,63)	14,9(0.74)$^{\times}$	12,2(0.96)

Notes: 1 – differences are significant compared to the indicators values before the experiment at the level of statistical tendency; 2 – differences are significant compared to the indicators values in EG2 at the level of statistical tendency; * – differences are statistically significant compared to the indicators values before the experiment (*– $p < 0.05$, ** – $p < 0.01$, *** – $p < 0.001$); • – differences are statistically significant compared to the indicators values in EG2 after the experiment (• – $p < 0.05$); × – differences are statistically significant compared to the indicators values in the RG after the experiment (× – $p < 0.05$)

This, in its turn, indicates of positive impact of the proposed comprehensive correction program using physical training and taekwon-Do elements.

Discussion

A comprehensive program of foot arch correction of young 7-8 year-old athletes with its disorders after experimental testing proved its effectiveness and manifested a statistically significant improvement in foot arch morpho-functional state. Our data correlate with A.V. Valkevich [5] and K.M. Sergienko [24], research results, which also testified to the positive changes under the influence of experimental programs of the ankle joint height in boys.

In addition, the author noted an increase in the tone of m. tibialis anterior by 5.4%, that is consistent with our myotonometry results, according to which there was a statistically significant improvement in tone in the state of isotonic stress (A) and the coefficient K1 of the posterior tibialis muscle, long tibialis muscle, long flexor digitorum.

Analysis of stabilographic data showed that CG standard deviation values in the sagittal and frontal planes in young athletes EG1 have improved by 18.31% ($p < 0.1$) and 31.97% ($p < 0.001$) respectively.

In the course of the research we confirmed the data [1, 4, 8, 10, 4, 14, 23, 31] on physical training positive effect on body of young athletes aged 7-8 years with FA disorders; The obtained data confirm and supplement the opinion of a number of researchers [6, 15, 16, 19, 26] that exercises is an important method of prevention and correction of foot-shin MFKC muscles myotonic imbalance in children of different ages. This is also testified by dynamic podometry results, which indicate that after the experiment there is a decrease in double support time with increasing isolated support time during walking [17]; there is an increase in walking pace with the reducing of half step length and time, the step base, whole step length and time, which indicates the effectiveness of the author's correction program; data [28] on FA disorders frequency and nature, according to which one of the common pathologies in childhood is static flat feet (about 80% of cases).

Conclusions

1. The formative experiment results confirmed the feasibility of the developed comprehensive program, which made it possible to achieve individually planned results of FAA correction of young athletes aged 7-8 years with foot arch disorders by means of taekwon-Do, manifested a statistically significant improvement in:

– foot arch morpho-functional state: the foot arch height by 6.85% ($p < 0.05$), the value of the metatarsal angle (α) by 15.64% ($p < 0.05$), heel angle (β) – by 8.22% ($p < 0.05$), decreasing of the foot arch angle (γ) – by 7.23% ($p < 0.01$), the Friedland index value increased in this group by 6.48% ($p < 0.01$);

– tone of isotonic stress state (A) and the coefficient "K1" of the posterior tibialis muscle – by 14.00% ($p < 0.05$) and 34.78% ($p < 0.05$) respectively, the long tibialis muscle – by 11.04% ($p < 0.001$) and 53.97 % ($p < 0.05$) respectively, the long flexor toe by 6.49% ($p < 0.05$) and 37.50 % ($p < 0.05$) respectively;

– values of BGC standard deviation in the sagittal and frontal planes in young athletes under the experimental program improved by 18.31% ($p < 0.1$) and 31.97 % ($p < 0.001$) respectively.

2. Analysis of FAA morphological indicators of young athletes aged 7-8 years showed that the positive changes are statistically significantly more pronounced in young athletes engaged in the sports training center "Taekwon-Do I.T.F." using a comprehensive correction program, testified by changes in FAA disorders degree: the number of people with severe flat feet decreased by 5.56%, while in the group engaged in standard program, this indicator had not change; with a flat foot by 38.89% against 22.67%, with moderate flat foot it increased by 22.22% against 26.66%, but in this group 22.22% of people achieved a normal foot state.

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