ORIGINAL ARTICLE

Feet structure in young capoeira athletes versus untrained peers

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Abstract

Background & Study Aim. In the literature a lot of space is devoted to research on the effects of practicing martial arts on the functional performance and muscle strength. In contrast, few scientific papers quite generally address the problem of the impact of this forms of activity on the formation of the foot, especially in children and adolescents at the developmental age. The present study aimed is selected features of the construction of the foot in capoeira athletes and peers who did not undertake regular physical activity.

Material & Methods. The study group comprised 74 boys aged 8-10 years, including 38 capoeira athletes attending "*UNICAR*" Capoeira Academy in Rzeszow and 36 health peers who did not train in any sports and did not regularly participate in any physical exercises apart from attending obligatory physical education classes at school. The CQ-ST podoscope was applied as the main research tool. In order to evaluate differences in average level of tested variables, between capoeira athletes group and controls we used Mann-Whitney U test.

Results. Average value of Clarke's angle at capoeira athletes oscillated around the lower limit of the norm and in case of the left foot were significantly lower compared to the untrained controls. Average value of Wejsflog index (W) in both feet of the martial arts athletes achieved significantly lower values compared to the controls.

Conclusions. Young capoeira athletes in comparison to their peers who did not undertake regular physical activity showed lower longitudinal arch of the left foot and lower transverse arch in both feet. In the training process, especially at its initial stages, special attention must be paid to the skilfully dose exercises and elements of combat with excessive overloading of the forefoot, and take into account the impact of exercises designed to strengthen the muscles of foot arch.

Key words: foot • jogo • martial arts • spinning kicks

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INTRODUCTION

Capoeira – ***noun*** a martial art and dance form, originally from Brazil, that is used to promote physical fitness and grace of movement [30].

***Jogo* (game)** – a ritual fight in which two capoeira athletes enters the circle and exchange blows with each other to the rhythm of Brazilian instruments.

Capoeira is a martial art originating from ritual dances of African tribes and Brazilian tradition. For Brazilian slaves it was on the one hand a form of manifestation of their cultural identity and on the other – fun, allowing to forget about misery. In the thirties of the twentieth century in Brazil, the first academy teaching this art was set up. In 1937 capoeira gained the status of a national sport of Brazil. Currently, it is performed by two and a half million Brazilians, mostly in schools, universities and military academies [1-4].

In Poland capoeira was imported in 1994. The first classes were held in Dąbrowa Górnicza in "*UNICAR*" group. The essence of capoeira distinguishing it from other martial arts, are elements of a smooth yet dynamic dance, combined with acrobatic evolutions, sweeping kicks and undercuts, evasion and takedowns. Capoeira is a *jogo* (game) – a ritual fight in which two capoeira athletes enters the circle and exchange blows with each other to the rhythm of Brazilian instruments. This interesting and at the same time spectacular martial art is becoming increasingly popular in Poland.

Doing capoeira requires mastering the basics of movement (*ginga* – to swing in Portuguese) and the techniques of defence and attack, as well as proper fitness preparation and well-developed coordination, praxis and concentration. Therefore, training is based on strength, high-speed, flexibility training with elements of acrobatics, and sensomotor coordination, and learning capoeira techniques (kicks, transitions, dodge, takedowns). Systematic, targeted training allows to master the adaptation of the body to the requirements of the environment and the use of upper and lower limbs in combat. In the literature a lot of space is devoted to research on the effects of practicing martial arts on functional performance and muscle strength [5-11].

In contrast, few scientific papers, quite generally address the problem of the impact of this type of activity on the formation of the foot in children and adolescents at the developmental age. It should be emphasized that a human foot is a significant static and dynamic part of the musculoskeletal system. It reduces the unit of body weight pressure, acts as a lever during the rebound and absorbs rotations of individual segments of the lower limb in the loading phase [12]. Halabchi et al. [13] emphasized the importance of genetic conditioning, both in the context of the inheritance of a specific type of skeletal structure and the inherent tendency for certain behaviours (e.g., active or sedentary lifestyle) that may affect the development of the foot. In addition, due to its delicate structure, the foot is susceptible to environmental factors which may favourably or destructively influence the process of its construction and performance formation.

Many authors claim that physical exercises are powerful in modelling of this part of the musculoskeletal system. Górska-Kłęk et al. [14] observed a decrease of longitudinal feet arch in long-distance runners. In turn, Walaszek et al. [15] showed higher values of Clarke's angle in female sprinters compared to non-training women, although in both cases these values were within normal limits. In terms of transverse arch, the authors did not notice statistically significant intergroup differences. Grabara [16] based on results of boys playing football noticed certain decrease of longitudinal and transverse arches and toe deformities, proportionate to training experience. The author concluded that the shape and capacity of football player feet are affected by individual predispositions and various external factors, such as the type of footwear used in this sport discipline and the kind of playing surface on which sportsmen play in varying atmospheric conditions. Cain et al. [17] found out that training effort and simultaneous excessive overload of the musculoskeletal system during trainings and indoor football games negatively affect the foot shape and result in gait pattern pathologies. Aydog et al. [18] observed tendency to decrease of the longitudinal foot arch in adolescent basketball players. These changes were proportional to the training period.

The literature lacks studies on the effects of capoeira training on the feet construction. Therefore, we assumed that every research on the impact of training on the structure and efficiency of the feet can be a source of knowledge for coaches and trainers, responsible for the development and implementation of training programs, and above all valuable clue how to choose exercises and dose training loads to improve technical capacity and motor skills, in terms of eliminating the risk of overloading the musculoskeletal system.

The above mentioned facts decided that the present study aimed is selected features of the construction of the foot in capoeira athletes and peers who did not undertake regular physical activity.

MATERIAL AND METHODS

Participants

We examined 74 boys aged 8-10 years, including 38 capoeira athletes (fourteen 8-year-olds, twelve 9-year-olds and twelve 10-year-olds) attending "*UNICAR*" Capoeira Academy in Rzeszów, Poland. The control group included 36 health peers (fourteen 8-year-olds, ten 9-year-olds and twelve 10-year-olds) who did not train in any sports and did not regularly participate in any physical exercises apart from attending obligatory physical education classes at school. The following inclusion criteria were applied: age range of 8-10 years, dominating right hand and right leg determined on the basis of the *Waterloo Handedness and Footedness Questionnaire – Revised* [19] and a written informed consent to participate in the study. In case of capoeira athletes additional inclusion criterion was a 2-year training practice and attending classes regularly. The exclusion criteria for both groups were signs of orthopaedic disease, pathology of the lower limb and previous orthopaedic surgery.

Capoeira trainings were held 2 times a week. Each training session lasted 1.5 hours. Classes were held in the gym by qualified instructors. Capoeira athletes practiced in loose uniforms (abada trousers and T-shirts) and bare feet. The training included general fitness, flexibility, high-speed, strength exercises with elements of acrobatics, stretching, movement, learning the techniques of defence and attack (kicks, transitions, evasion). In addition, once a week capoeira athletes attended classes on the history of capoeira, Brazilian culture, Portuguese and the ability to sing capoeira songs and play instruments (drums, tambourine, berimbau, atabaque, pandeiro). An essential element of these activities was the confrontation of techniques with other participants (sparring). The subjects declared in the interview that apart from capoeira they did not take part in other sports sections.

Studies design

The CQ-ST podoscope (manufactured by Electronic System) was made use of as the main research tool. The following indicators were measured: foot length (D) and width (S), both in cm; Clarke's angle, the Wejsflog (W) index (i.e. ratio of the length to the width of the foot), hallux valgus angle (α), and the fifth toe various deformity angle (β); all angles are expressed in degrees. The procedures for calculating the feet structure indices are shown in Figure 1.

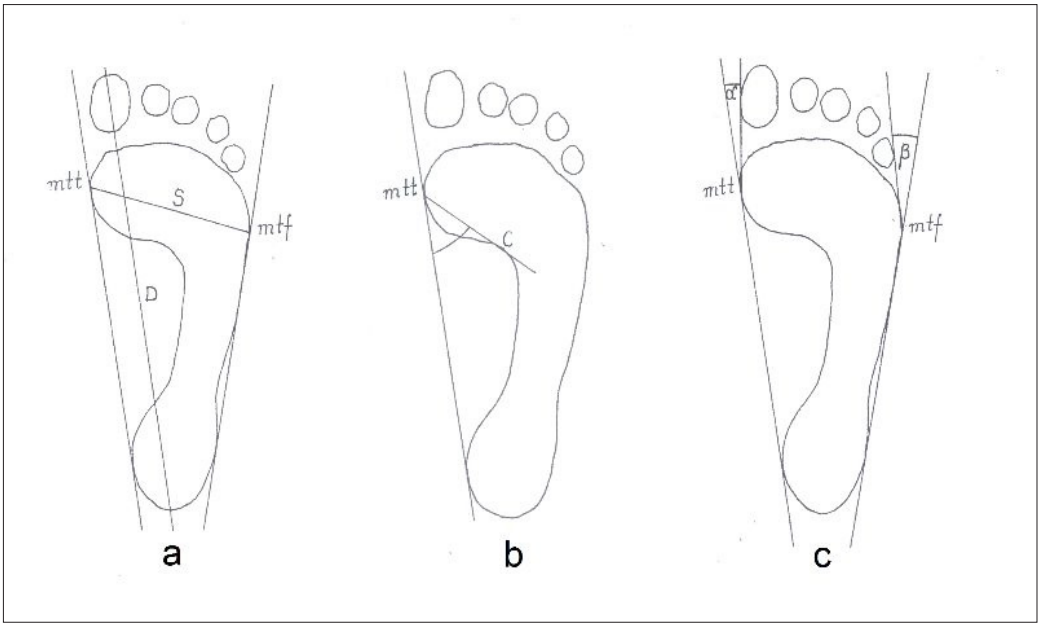

Figure 1. Procedure for determining the feet structure indices: a) foot length (D), foot width (S) and the Wejsflog (W) index; b) Clarke's angle; c) hallux valgus angle (α) and the angle of the varus deformity of the fifth toe (β).

Body weight and height of the subjects were measured by means of the following devices: medical scales, with accuracy of 0.1 kg and an anthropometer using Martin's technique with accuracy of 0.1 cm (Table 1).

The study was approved by a local academic Ethics Review Committee of the Rzeszow University. All procedures were carried out in full compliance with the Declaration of Helsinki. In order to ensure the integrity of the research process, all tests were carried out in the morning, using the same measuring instruments operated by the authors. The measurements were carried out in a gym, boys were wearing their gymnastic uniforms without shoes. All participants, their parents or legal guardians received detailed information concerning the aim and methodology used in the study and signed written consent.

Statistical analysis

In order to analyse the gathered research data, the basic measures of descriptive statistics were calculated. The consistency of the values with the normal distribution was verified by means of the Shapiro-Wilk test. For evaluate differences in average level of tested variables between capoeira athletes group and controls we used Mann-Whitney U test. The results were considered statistically significant, if the probability level of the test was lower than the predetermined significance level $p \leq 0.05$. The Stat Soft STATISTICA software (version 10.0) was used to process the test results.

RESULTS

Data indicates that the length of the foot in boys qualified for the respective age groups was similar (Table 2). The values for the width of the right foot and the left side were higher in capoeira athletes, statistically significant differences were found in boys aged 9 and 10 years. Average Clarke's angle matched the standard range developed by Lizis [20] for each age group, but capoeira athletes were close to the lower limit, while in the control group reached a level closer to the upper limit. In the case of the left foot, the values of this index were statistically significantly lower in capoeira athletes. Average value of Wejsflog index (W) was in the middle of the range between 2 and 3 [21], although both in case of the right and left foot in different age groups these values were significantly lower in capoeira athletes.

The average value of the hallux valgus angle (α) fluctuated around the lower limit of the norm [20]. There were no statistically significant differences in the values of this index between capoeira athletes and their peers not taking up regular physical activity. The values of the varus angle of the V toe (β) in the right and left foot both in young capoeira athletes and in their inactive peers exceed the upper limit of the norm [20], so in the individual age categories there are no statistically significant intergroup differences (Table 3).

DISCUSSION

Scarce studies on the impact of combat sports and martial arts on the construction of the foot demonstrate that they may have different influence on the formation of longitudinal, transverse arches and the frontal support area. Mikołajczyk et al. [22] based on the research on boys aged 9-13 years, who regularly practiced judo three times a week for 90 minutes, claims that judo training exerted a positive effect on the height of the longitudinal foot arch. A positive impact of martial arts on the longitudinal foot arch was confirmed by Andrzejewska et al. [23]. Average means of Clarke's angle in 20-year-old judokas who had been practicing judo for 10 years were within the normal range. Zvonar et al. [24] analysed the shape of the longitudinal arch and the

Table 1. Somatic characteristic of the capoeira athletes (age/n: 8/14; 9/12; 10/12) and untrained controls (8/14; 9/10; 10/12).

Age [years]	Body weight [kg]		Body height [cm]	
	Capoeira athletes	Untrained controls	Capoeira athletes	Untrained controls
	$\bar{x} \pm SD$			
8	29.78 ±6.70	29.17 ±5.75	130.07 ±7,11	129.94 ±6.65
9	31.75 ±5.71	31.40 ±4.30	135.67 ±5.19	135.30±5.08
10	34.42 ±4.78	33.50 ±4.93	139.67 ±5.18	138.92 ±4.96

Table 2. Comparison of length, width and transverse and longitudinal foot arch indictors between capoeira athletes (age/n: 8/14; 9/12; 10/12) and untrained controls (8/14; 9/10; 10/12).

Age [years]	Capoeira athletes (n = 38)			Untrained controls (n = 36)			U	p
	$\bar{x}$ ±SD	Me	QR	$\bar{x}$ ±SD	Me	QR		
Foot length (rf) [cm]								
8	19.41 ±0.95	19.65	1.50	19.71 ±1.35	19.90	2.10	76.5	0.329
9	20.29 ±0.48	20.20	0.55	20.18 ±0.36	20.10	0.30	47.5	0.417
10	21.58 ±0.99	21.75	0.70	21.34 ±1.84	21.25	2.85	67.0	0.799
Foot length (lf) [cm]								
8	19.45 ±0.87	19.65	1.60	19.81 ±1.32	20.00	2.30	78.0	0.376
9	20.32 ±0.50	20.20	0.60	20.26 ±0.37	20.20	0.40	52.0	0.628
10	21.64 ±0.94	21.75	0.55	21.47 ±1.93	21.25	3.10	66.5	0.755
Foot width (rf) [cm]								
8	7.69 ±0.51	7.85	0.80	7.38 ±0.73	7.25	1.40	73.5	0.265
9	8.07 ±0.39	8.10	0.40	7.57 ±0.50	7.50	0.70	26.0	0.025*
10	8.65 ±0.78	8.50	0.70	7.83 ±0.73	7.75	1.40	35.0	0.033*
Foot width (lf) [cm]								
8	7.58 ±0.52	7.55	0.80	7.46 ±0.63	7.45	1.20	88.0	0.667
9	8.08 ±0.46	8.00	0.15	7.61 ±0.45	7.50	0.70	25.0	0.020*
10	8.66 ±0.58	8.70	0.70	7.71 ±0.68	7.70	1.05	21.0	0.002*
Clarke's angle (rf) [°]								
8	33.07± 7.43	33.50	13.00	35.43 ±7.26	38.00	8.00	82.5	0.482
9	34.17± 9.22	38.50	10.00	40.90 ±12.40	43.00	14.00	36.0	0.123
10	37.50 ±4.36	38.50	4.50	37.58 ±8.87	38.00	13.00	66.0	0.755
Clarke's angle (lf) [°]								
8	30.64 ±5.41	30.00	6.00	36.71 ±10.62	38.50	8.00	45.0	0.014*
9	30.50±10.42	33.00	13.50	42.70 ±11.67	43.50	18.00	25.0	0.020*
10	33.00 ±8.41	36.00	10.00	39.42 ±8.76	41.50	11.00	38.5	0.051
The Wejsflog (W) index (rf)								
8	2.53 ±0.12	2.51	0.09	2.68 ±0.16	2.62	0.22	37.5	0.004*
9	2.52 ±0.13	2.54	0.14	2.66 ±0.18	2.66	0.16	27.5	0.030*
10	2.50 ±0.14	2.53	0.10	2.73 ±0.11	2.73	0.10	8.5	<0.001*
The Wejsflog (W) index (lf)								
8	2.57 ±0.11	2.55	0.12	2.66 ±0.13	2.64	0.13	64.5	0.125*
9	2.54 ±0.15	2.58	0.12	2.67 ±0.15	2.66	0.18	30.0	0.050*
10	2.51 ±0.10	2.48	0.13	2.79 ±0.13	2.77	0.16	4.0	<0.001*

rf – right foot, lf – left foot, * p≤0.05

Table 3. Comparison of the of forefoot loading area between capoeira athletes (age/n: 8/14; 9/12; 10/12) and untrained controls (8/14; 9/10; 10/12).

Age [years]	Capoeira athletes (n = 38)			Untrained controls (n = 36)			U	p
	$\bar{x}$ ±SD	Me	QR	$\bar{x}$ ±SD	Me	QR		
Hallux valgus angle (α) rf [°]								
8	2.50 ±3.46	0.00	6.00	3.43 ±2.14	3.50	3.00	69.0	0.193
9	3.58 ±3.42	3.50	5.50	3.20 ±4.64	2.00	4.00	51.5	0.582
10	3.83 ±2.95	4.00	5.00	3.17 ±3.79	2.00	5.50	59.0	0.477
Hallux valgus angle (α) lf [°]								
8	2.21 ±3.14	1.00	3.00	3.36 ±3.69	1.50	8.00	83.5	0.511
9	4.92 ±4.03	4.50	7.00	3.40 ±3.72	3.00	5.00	46.0	0.381
10	4.83 ±4.24	4.00	8.00	3.92 ±4.14	3.00	7.00	63.0	0.630
The angle of the varus deformity of the fifth toe (β) rf [°]								
8	13.21 ±6.77	12.00	7.00	10.50 ±5.67	10.50	6.00	70.5	0.210
9	13.08 ±4.54	13.50	7.50	10.20 ±5.55	10.50	5.00	38.5	0.159
10	13.58 ±6.43	12.00	6.00	11.00 ±8.52	12.50	15.50	64.5	0.671
The angle of the varus deformity of the fifth toe (β) lf [°]								
8	12.28 ±6.09	12.50	1.00	13.00 ±8.86	16.00	15.00	91.0	0.769
9	13.83 ±4.57	14.50	7.00	15.20 ±7.22	17.50	7.00	46.0	0.381
10	10.92 ±4.83	11.00	7.00	11.42 ±7.22	12.50	12.00	67.5	0.799

rf - right foot, lf - left foot

influence of type of training ground on the distribution of pressure forces in the foot of karate athletes. The results did not give a clear answer whether activity on soft mats or a hard surface had more favourable influence. Błaszczyk et al. [25] concluded that the feet of young taekwondo-do ITF students aged 8-13 years, with 2.5 years of training practice experience are at risk of deformation. The authors emphasized that a necessary condition for admission of a child to taekwondo-do classes needs to be a positive result of foot arch tests and exercises to strengthen the muscles responsible for its architecture should be a regular part of the training.

In our study, the average Clarke's angle in the determined age groups of capoeira athletes oscillated around the lower limits of the norm. Transverse arch in the left foot was significantly lower compared to the controls. It should be emphasized that for the clarity of the results, right-handed and right-legged athletes were selected for the study.

Studies by Sterkowicz et al. [26] on a group of 15-year-old judo athletes showed that the handedness and footedness significantly correlate with the choice of preferred attack directions in combat situations. Similar conclusions reached Sogabe et al. [27] in the study of adult men and women practicing judo. Therefore, it can be concluded that in the martial arts, dominating lower limb has manipulating function (kicks), and the left one is for support. Hence the noticeable reduction in the longitudinal arch of the left foot in our study. This indicates the correlation between dominating limb with the direction of the movements and thus the tendency to load one of the limbs. As the essence of martial arts is to win and therefore special emphasis placed on effective asymmetric fighting techniques, which are enhanced by multiple repetition of certain movements leading to perfection. In addition, from the beginning of the training, the coaches concentrate on the mobility potential of the sportsmen and on improving their innate motor predisposition (usually asymmetrical movements), which are the uniqueness of the later champion.

The analysis of literature indicates that most authors focused on the assessment of longitudinal foot arch and less frequently on transverse

arch and toe settings. Demczuk-Włodarczyk et al. [28] stated that the training typical of martial arts does not interfere with the architecture of the longitudinal arch, however, it changes the distribution of compressive forces in the forefoot. Hence contestants feet are susceptible to disturbances in the transverse arch and forefoot loading area. The authors found greater pressure on the heads of the fourth and fifth metatarsal bones and plantar side of the fourth and fifth toes and resulting deformity of the V toe.

On the basis of our research, we found that the angles of hallux valgus (α) did not deviate from the norms and were similar for the right and left foot. In turn, the average values of the varus angle of V toe (β) both in the capoeira athletes and the controls, with both feet exceeded the upper limit of the norm. The trend towards a more varus setting of V toe may be due to the increased load of the side edge of the foot and lack of statistically significant intergroup differences in individual age categories seems to exclude the impact of capoeira on this kind of disturbances in the forefoot loading area.

Nowak [29] underlines that wrestling models massive foot with wider forefoot. Our study showed that capoeira athletes feet are wider and laterally flatter compared to their peers who did not take up physical activity regularly. Referring this results to the studies of authors who have dealt with the issues of the impact of martial arts on the feet structure, it can be considered that overload of forefoot during training and fights can cause flattening of the transverse arch of the foot. In the case of capoeira training, particularly dangerous for the feet are spinning kicks (e.g. *rabo de arraia* – stingray's tail in Portuguese), during which the axis of rotation is in the forefoot. Frequent training of such elements leads to stretching of soft-tissue structures, and as a consequence – transverse platypodia. The impact of jumping exercises performed on hard surfaces without shoes should be also considered. Under the influence of these activities, overload especially in the beginner capoeira athletes can occur as a result of the disproportion between the strength of the arch muscles and requirements, which they must cope.

Awareness of these issues can emphasize clearly that the martial arts, including capoeira absolutely cannot be regarded as a panacea for excessive obesity or weakened by sedentary lifestyle muscular system which is typical of modern civilization. The results of the research and their analysis indicate the need to make a careful selection of candidates to the capoeira academy to minimize permanent adverse changes in the musculoskeletal system, resulting from the significant training loads. In the selection process, the final decision on the qualification to groups should be taken based on the results of the construction and function of the musculoskeletal system, including feet, the analysis of weight-growth indicators, and the capacity of individual muscle groups. Instructors in the training process, especially at its initial stages should skilfully dose exercises and elements of combat with excessive overloading of the forefoot, and take into account the impact of exercises designed to strengthen the muscles of foot arch. In case of children and adolescents at the developmental age, martial arts should not be the only form of activity. They should be complemented by activities in water which in a unique, specific and beneficial way acts on the motor organ, mitigating overload. The analysis of literature related to the subject discussed showed that most authors focused on assessing the formation of the longitudinal foot arch.

This paper is an attempt of a comprehensive analysis of foot shape in young capoeira athletes. Efforts were made to select the groups to be uniform, particularly in terms of age (data were analysed separately for 8-, 9- and 10-year-olds) lateralization and sex. At the same time it should be emphasized that any report on this issue undertaken in the work is a valuable contribution supplementing scarce publications on the evolution of the foot under the influence of techniques and training loads in martial arts.

CONCLUSIONS

Young capoeira athletes in comparison to their peers who did not undertake regular physical activity showed lower longitudinal arch of the left foot and lower transverse arch in both feet. In the training process, especially at its initial stages, special attention must be paid to the skilfully dose exercises and elements of combat with excessive overloading of the forefoot, and take into account the impact of exercises designed to strengthen the muscles of foot arch.

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