The assessment of the effect of strength training of lower limbs on arching and force distribution of the sole in young men

Ocena wysklepienia oraz rozkładu sił nacisku podeszwowej strony stóp młodych mężczyzn pod wpływem treningu siłowego kończyn dolnych

Marta Bibro[1,*], Aleksander Drwal[2], Agnieszka Jankowicz-Szymańska[1]

[1] *State Higher Vocational School in Tarnow, Institute of Health Sciences, Poland*
Państwowa Wyższa Szkoła Zawodowa w Tarnowie, Instytut Ochrony Zdrowia

[2] *State Higher Vocational School in Tarnow, Institute of Health Sciences, Poland (student of physical education)*
Państwowa Wyższa Szkoła Zawodowa w Tarnowie, Instytut Ochrony Zdrowia (studia na kierunku wychowanie fizyczne)

Article history:
Otrzymano/Received: 15.12.2018
Przyjęto do druku/Accepted for publication: 06.01.2019
Opublikowano/Publication date: Styczeń 2019/January 2019

Abstract

Introduction: The human foot is an important element of the dynamic-static musculoskeletal system, therefore its structure and function are often discussed in the literature. Many authors claim that the morphological structure of the foot adapts to some extent to its regular activity. There is an ongoing research of the effect of particular sports disciplines on the pattern of arching and loading of the foot. It has not been sufficiently documented whether a short intensive activity negatively affects existing abnormalities of the positioning of the feet.

Aim of the study: The aim of this research was the assessment of the effect of a 60-minute intensive strength training on the arching of the feet and the load of lateral and medial side of the forefoot and hindfoot among young men.

Material and methods: The research was carried out among 60 students between 19 and 26 years of age divided into 2 groups. The main research tool for assessing the arching and loading of particular parts of the foot was the BTS P-WALK baroresistant platform. The measurements were conducted in the span of 30 seconds and contained the analysis in the static conditions after which it was repeated 60 minutes later. During that time group 1 was carrying out a strength training including lower limb exercises, while group 2 was spending their time passively, in a seated position.

Results: According to both measurements in the experimental group the side and central part of the foot were symmetrically loaded, however the loading of the forefoot significantly changed, especially in the forefoot centre. An hour long activity slightly affected the height of the arching of both feet, however for some of the participants there was an increase and among some a lowering of the middle long arch. These changes were not observed in the control group.

Conclusions: An isolated, intensive strength training affects both the foot loading pattern and the length-wise arching of the feet.

Keywords: foot, foot arching, ground pressure of the foot, strength training

Introduction

The human foot performs an important static-dynamic function within the musculoskeletal system. Its morphological structure, in particular the correct shape of the longitudinal and transverse arches condition its proper efficiency [1, 2]. It is important that the foot is one of several links in the proprioceptive kinematic chain, therefore disorders in the shape and functions of its individual segments may be the cause of dysfunction in other segments of the musculoskeletal system [3]. The efficient functioning of the foot depends not only on the condition of the muscular-ligament system and bone structure, but also on the specifics of the movements performed, their duration and the loads it is subjected to in everyday activities. Many authors believe that the morphological structure of the foot to some extent adapts

* Adres do korespondencji/Address for correspondence: martabibro@poczta.fm

to regular effort. One of the increasingly more popular forms of physical activity, both among young people and adults, is strength training [4]. Strength training that is skilfully planned and carried out not only shapes the mass, strength and endurance of muscles, but also causes many positive changes in the body that can protect against diseases related to contemporary civilisation [5,6]. However, it should be remembered that it often involves significant overloads of the musculoskeletal system. The feet are also subject to considerable pressure, among others due to their distal location and direct contact with the ground. Scientific reports covering the problem of shape of the feet of people practising various sports focused most often around the impact of systematic training loads on the morphofunctional state of the feet. Few authors have undertaken the problem of assessing the direct impact of one-time physical exercise

The aim of the study was to assess the effect of 60 minutes of intense strength training on arching of the feet and the load on the lateral and medial side of the forefoot and hindfoot of adult young men.

Material and methods

The study involved 60 men in the 19–26 age range. Using the scaled anthropometer and the TANITA weight scales, the subjects' height and weight were measured, then the BMI index was calculated and the body weight status was determined. People with abnormal BMI and musculoskeletal system deformities (scoliosis, other permanent posture defects, skeletal deformities resulting from previous illnesses or injuries) were excluded from the research. The main measurement tool used to assess the arch and load of individual foot zones was the BTS P-WALK baroresistant platform enabling the analysis of static force density distribution during standing. The measurement lasted 30 seconds, was performed in silence in an isolated room and was repeated after 60 minutes. The Arch Index value (ratio of the surface area of the central part of the foot print to the area of the entire foot without toes [%], correct value 21–28%), pressure exerted on the lateral and medial side of forefoot as well as lateral and medial side of hindfoot [Kpa].

The surveyed men were divided into two groups of 30 people. Group 1, subjected to training, carried out training in the gym including lower limb exercises within 60 minutes. The training consisted of seven complex exercises performed in accordance with the principles of strength training. Exercises were performed in a strictly defined order, starting with straightening the knees on a machine, squat with a barbell on the shoulders, squats on a hack squat machine, bending the knees while sitting on the machine, bending the knees kneeling on the machine, deadlift with straight legs and ending with calf raises when standing. The weight selection was individual, the repetition range was from 8 to 12 maximum repetitions, performed in 3 or 4 series. Breaks between series were about 3–4 minutes.

Group 2, control group, spent the time between consecutive examinations passively, in a sitting position.

Statistica v10 was used for statistical analysis. Basic descriptive statistics, the Shapiro-Wilk test (testing the distribution normality) and Levene's test (testing the equality of variance) were used. Intergroup differences were determined using a t-Student test for independent groups (with parametric test assumptions met) or the Mann-Whitney U test. To compare the level of variables between the first and second tests, a t-Student test for dependent samples (with parametric test assumptions met) or the Wilcoxon test were used. The significance level $\alpha = 0.05$ was adopted.

Results

The average body height of men from the group subjected to training was 178.9±8.11 cm, with average body weight values of 78.7± 10.73kg. In the control group, these parameters were at a similar level, which amounted to 180.6±5.99 cm and 78±7.73 kg respectively. Also, the BMI index, which on average was equal 24.5±2.20 kg/m^2 in the training group and 23.9±1.87 kg/m^2, did not make the examined groups different.

The quality of the arching of the feet was determined on the basis of the value of the Arch Index. A higher right foot arch has been noted, indicating a lower longitudinal arch compared to the left foot in both groups. Intensive lower limb training did not significantly change the arching of the feet, while in the second study the control group noted a significant increase in the right foot Arch Index (lowering of the arching) (Table 1).

In both groups there was a tendency of increasing forefoot load in the second examination, but the changes observed in the control group were not significant (Table 2, Table 3). After training, the load on the lateral forefoot of the left foot (zone M5) and the load on the medial forefoot (zone M1) of both feet increased significantly in the case of the examined men. The average load on the head area of the fifth bone of the left metatarsal after strength training increased by 4.83 kPa, the average load on the right forefoot by 2.00 kPa and the left by 3.67 kPa.

Strength training of the lower limbs caused a significant reduction in the load on both the lateral and medial hindfoot in the right foot. In the control group, after a one-hour lecture spent in a sitting position, there was a slight decrease in the medial load on the medial hindfoot in the right foot and a slight increase in the load on the lateral zone of both feet as well as the medial side of the hindfoot in the left foot.

Discussion

Many authors believe that practising specific sports has an impact on the morphological architecture and structure of the feet. The research showed that not only regular physical activity, but even one-time, intensive training of the lower limbs significant-

Table 1.

The value of the Arch Index of the right and left foot in the group subjected to training and in the control group in both examinations

Group	Foot	Examination	Avg.	Mdn	Min	Max	SD	p
Subjected to training	right	first	23.35	24.10	17.17	28.40	3.26	0.75
		second	23.19	23.89	3.270	30.49	5.02	
	left	first	19.16	22.23	0.70	32.63	8.93	0.47
		second	21.39	22.17	2.730	33.70	7.23	
Control	right	first	23.35	24.32	2.99	32.07	5.75	0.03*
		second	23.99	24.45	6.960	32.88	5.18	
	left	first	21.90	23.17	0.68	32.80	8.52	0.08
		second	21.66	22.45	4.320	33.66	7.65	

* statistically significant difference

Table 2.

Average pressure [kPa] of selected right foot zones in the training group, before and after training, and in the control group, before and after the lecture

Examination	Training					Zone	Control					p
	Avg.	Mdn	Min	Max	SD		Avg.	Mdn	Min	Max	SD	
first	13.43	12.50	7.00	26.00	4.56	M1	14.83	14.00	6.00	27.00	5.67	0.29
second	16.43	16.50	6.00	33.00	6.25		15.13	13.50	4.00	33.00	6.53	0.43
	p=0.006*						p=074					
first	22.70	22.50	9.00	38.00	8.41	M5	24.33	23.00	10.00	42.00	7.91	0.44
second	24.10	23.00	12.00	42.00	7.14		25.63	24.50	7.00	39.00	7.46	0.41
	p=0.16						p=0.26					
first	31.57	31.50	23.00	39.00	4.74	LH	31.07	30.00	22.00	43.00	5.40	0.62
second	27.70	28.50	14.00	38.00	5.88		32.73	32.00	23.00	53.00	5.80	0.004*
	p=0.001*						p=0.22					
first	31.77	31.50	25.00	37.00	2.81	MH	31.23	31.00	21.00	40.00	5.27	0.54
second	28.47	29.00	13.00	36.00	5.59		23.03	32.50	18.00	47.00	6.25	0.002*
	p=0.001*						p=0.12					

* statistically significant difference, M1 head of the first metatarsal bone, M5 head of the fifth metatarsal bone, LH lateral side of the hindfoot, MH medial side of the hindfoot

Table 3.

Average pressure [kPa] of selected left foot zones in the training group, before and after training, and in the control group, before and after the lecture

Examination	Training					Zone	Control					p
	Avg.	Mdn	Min	Max	SD		Avg.	Mdn	Min	Max	SD	
first	11.27	10.50	3.00	24.00	5.30	M1	11.67	10.00	3.00	27.00	6.35	0.16
second	14.93	12.00	6.00	31.00	7.00		12.90	12.00	3.00	34.00	6.40	0.25
	p=0.007*						p=0.61					
first	13.40	11.50	0.00	29.00	6.31	M5	15.40	12.50	6.00	35.00	8.40	0.75
second	18.23	16.50	4.00	41.00	9.42		16.43	15.00	6.00	39.00	8.41	0.44
	p=0.009*						p=0.12					
first	27.93	27.50	19.00	40.00	5.22	LH	28.37	29.50	13.50	38.00	5.88	0.87
second	28.00	29.50	13.00	42.00	6.93		30.27	30.00	20.00	47.00	5.69	0.12
	p=0.95						p=0.06					
first	29.20	28.50	24.00	39.00	4.05	MH	29.40	31.00	16.00	39.00	5.32	0.76
second	28.13	27.50	15.00	42.00	6.92		30.67	30.00	21.00	44.00	5.45	0.17
	p=0.38						p=0.21					

* statistically significant difference, M1 head of the first metatarsal bone, M5 head of the fifth metatarsal bone, LH lateral side of the hindfoot, MH medial side of the hindfoot

ly changes the pattern of foot load. Rohan et al. noticed that in the case of runners who ran a half marathon, the weight load asymmetry of the body is compensated[7]. The group they studied initially put more weight on the left foot, but after the exercise was over, the difference between the load on the left and right limb was reduced. A change in the load on individual foot zones as a result of physical activity is also observed. Studies carried out by Kanatli et al. among young women and men prove that during walking, the heads of the second and third metatarsal bones, compared to the other metatarsal bones, are under the greatest pressure [8,9]. In over 60% of people surveyed by this research team, the central part of the foot was subjected to the highest loads. Similar studies have been conducted by Maslon et al. among regularly running women [10]. In this group, higher pressure was usually concentrated on the heads of the first and second metatarsals in the left foot, and on the heads of the third, fourth and fifth metatarsals in the right foot. In own research, after the training, weight transfer from the hindfoot to the forefoot was observed, moreover, most people observed increased pressure on the medial side of the forefoot. Changes in the load on the soles were also noted after completing the long run, although they were significant only in the left foot, in which the load on both the forefoot and hindfoot increased significantly [7]. Contrasting with own results, Piątek et al. obtained results by examining the disco dance team [11]. Girls had a significant deformation of the fifth toe, which suggests that dance training focused on endurance and speed may affect the lateral side of the forefoot.

Our study did not show statistically significant changes in longitudinal arching of the feet as a result of one-time intensive strength training. Also, analyses of the impact of training on the foot structure of children practising volleyball [12] as well as athletics, football and handball [13] showed that the average values of the parameters of the longitudinal arch and the front support zone are within normal limits. According to Demczuk-Włodarczyk, martial arts also do not have a negative impact on the quality of the arching of the feet [14], although Andrzejewska et al. [15] question this. However, the tendency to lower the Arch Index (and thus increase the longitudinal arch) under the influence of sport was observed by Aydog et al. in the group of elite gymnasts [16]. The same author in his next work showed differences in the morphological structure of the feet of players practising different sports. The quality of the arching of the feet in individual groups (football, wrestling, weightlifting, handball and gymnastics) varied significantly, differences were also seen in comparison to non-training people. Moreover, in sport disciplines in which one of the lower limbs is clearly dominant, significant disproportions between the formation of the right and left foot were observed [17].

It is widely believed that undertaking various forms of physical activity has a positive effect on body posture, and also improves the arching of the feet [12–14,18,19]. However, it should be remembered that both incorrectly selected loads and incorrect methodology for performing individual exercises can be detrimental to both the structure of the foot and its proper functioning.

Conclusions

Strength training of the lower limbs carried out within 60 minutes does not change the size of the arch of the longitudinal arch of the foot. However, statistically significant changes in the load pattern of individual foot zones are observed, consisting in the transfer of body weight from hindfoot to forefoot, especially its medial part. The position of the feet when performing strength exercises should be constantly monitored by a trainer and a person exercising.

References

[1] Puszczałowska-Lizis, E. (2011). Częstość występowania płaskostopia poprzecznego u młodzieży akademickiej w świetle dwóch technik opracowania plantogramu. Kwart. Ortop. 3, 267–272.

[2] Pauk, J., Ezerskiy, V., Raso, J. V., & Rogalski, M. (2012). Epidemiologic factors affecting plantar arch development in children with flat feet. Journal of the American Podiatric Medical Association, 102(2), 114–121.

[3] Brügger A. (2000). Lehrbuch der funktionellen Störungen des Bewegungs systems. Zollikon, Brügger-Verlag.

[4] Adamczyk, J. G., Kowalski, P., Boguszewski, D., Ochal, A., & Siewierski, M. (2012). Postawy prozdrowotne u mężczyzn regularnie ćwiczących na siłowni. Pedagog. psihol. med.-biol. probl. fiz. vihov. sportu, 2, 138–145.

[5] Ambroży, T. (2004). Trening holistyczny–metodą kompleksowej uprawy ciała. EAS, Kraków.

[6] Ambroży, T., Mucha D., Nowak M., Ambroży D., & Mucha T. (2015). Fizjologia treningu siłowego jako forma profilaktyki zdrowotnej i przeciwdziałania zagrożeniom cywilizacyjnym. Kultura Bezpieczeństwa Nauka – Praktyka – Refleksje, 17, 212–231.

[7] Rohan A., Nyc M., Rogóż A., &Furgiel J. (2017). Changes in plantar pressure distribution after long-distance running. New Medicine, 21(2), 58–68.

[8] Kanatli, U., Yetkin, H., Simsek, A., Ozturk, A. M., Esen, E., &Besli, K. (2008). Pressure distribution patterns under the metatarsal heads in healthy individuals. Acta Orthop Traumatol Turc, 42(1), 26–30.

[9] Kanatli, U., Yetkin, H., &Bolukbasi, S. (2003). Evaluation of the transverse metatarsal arch of the foot with gait analysis. Archives of orthopaedic and trauma surgery, 123(4), 148–150.

[10] Maslon, A., Golec, J., Szczygiel, E., Czechowska, D., & Golec, B. (2017). Assessment of the influence of jogging on the shape of female foot arches. Annals of Agricultural and Environmental Medicine, 24(4), 596–601.

[11] Piątek, E., Barczyk-Pawelec, K., Demczuk-Włodarczyk, E., & Hawrylak, A. (2015). Ocena budowy morfologicznej stóp młodych tancerek disco dance. Physiotherapy/Fizjoterapia, 23(4), 24–32.

[12] Lizis, P., Puszczałowska-Lizis, E., & Ridan, T. (2011). Budowa morfologiczna stóp dziewcząt i chłopców uprawiających siatkówkę. Young Sport Science of Ukraine, 3, 149–153.

[13] Stawowiak, S. (1999). Charakterystyka budowy podeszwowej powierzchni stóp w wybranych dyscyplinach sportu u chłopców w wieku 12 lat. Praca magisterska. AWF, Kraków.

[14] Demczuk-Włodarczyk, E., &Bieć, E. (2002). Budowa morfologiczna stóp zawodników trenujących sporty walki. Fizjoterapia, 10, 3–4.

[15] Andrzejewska, J., Burdukiewicz, A., Chromik, K., Pietraszewska, J., & Stachoń, A. (2010). Budowa morfologiczna oraz charakterystyka stóp zawodników dżudo. Acta Bio-Optica et InformaticaMedica, 16(1), 21–24.

[16] Aydog, S. T., Özçakar, L., Tetik, O., Demirel, H. A., Hascelik, Z., & Doral, M. N. (2005). Relation between foot arch index and ankle strength in elite gymnasts: a preliminary study. British Journal of Sports Medicine, 39(3), e13-e13.

[17] Aydog, S. T., Tetik, O., Demirel, H. A., & Doral, M. N. (2005). Differences in sole arch indices in various sports. British journal of sportsmedicine, 39(2), e5-e5.

[18] Lichota, M., Plandowska, M., & Mil, P. (2013). Wysklepienie stóp zawodników wybranych dyscyplin sportowych. Pol. J. Sport Tourism, 20, 135–146.

[19] Trocińska, A. (2009). Charakterystyka wybranych parametrów budowy stóp kobiet i mężczyzn uprawiających karate. Sport i turystyka we współczesnym stylu życia, AWF, Poznań, 89–95.

Streszczenie

Wstęp: Stopa ludzka jest ważną częścią dynamiczno-statyczną narządu ruchu, stąd też zagadnienia dotyczące jej struktury i funkcjonowania są często poruszane w literaturze. Wielu autorów uważa, że budowa morfologiczna stopy w pewnym stopniu dostosowuje się do regularnie podejmowanych aktywności. Wciąż prowadzone są badania nad wpływem uprawiania określonych dyscyplin sportu na wzorzec wysklepienia i obciążenia stopy. Nie jest dostatecznie udokumentowane, czy krótkotrwały, intensywny wysiłek nasila istniejące nieprawidłowości ustawienia stóp.

Cel pracy: Celem badań była ocena wpływu 60-minutowego intensywnego treningu siłowego na wysklepienie stóp oraz obciążenie bocznej i przyśrodkowej strony przodo- i tyłostopia dorosłych młodych mężczyzn.

Materiał i metody: Badaniami objęto 60 studentów w przedziale wiekowym 19–26 lat podzielonych na dwie grupy. Głównym narzędziem pomiarowym służącym do oceny wysklepienia oraz obciążenia poszczególnych stref stopy była platforma barorezystywna BTS P-WALK. Pomiar trwał 30 sekund, obejmował analizę w warunkach statyki i został powtórzony po upływie 60 minut. Grupa I w tym czasie wykonywała trening na siłowni obejmujący ćwiczenia kończyn dolnych, grupa II ten sam okres czasu spędzała biernie, w pozycji siedzącej.

Wyniki: W grupie poddanej treningowi siłowemu w obu pomiarach boczna i przyśrodkowa strona tyłostopia były symetrycznie obciążone, natomiast w sposób istotny zwiększyło się obciążenie przodostopia, zwłaszcza części przyśrodkowej. Godzinny wysiłek nieznacznie wpłynął również na wysokość wysklepienia obu stóp, aczkolwiek u części badanych doszło do zwiększenia, a u innych do obniżenia łuku przyśrodkowego podłużnego. Zmian takich nie zaobserwowano w grupie kontrolnej.

Wnioski: Jednorazowy, intensywny trening siłowy zmienia zarówno wzorzec obciążenia stopy jak i wysokość wysklepienia podłużnego stóp.

Słowa kluczowe: stopa, stan wysklepienia, nacisk na podłoże, trening siłowy