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Biomechanical analysis of changes of selected dynamic foot parameters during and after application of load

Analiza biomechaniczna zmian wybranych parametrów dynamicznych stóp w czasie i po obciążeniu

The foot's support, stabilizing, shock absorption, and sensory functions will be fulfilled when the passive-active system fulfils well its role, when it works rhythmically, when it undergoes alternate contraction and extension and when there is time for regeneration. The system of muscles keeping the foot in full efficiency works in its own special lever system [4]. During movement, some muscles contract concentrically, performing a joint bend, and others antagonistically stretch eccentrically, concentrating the bend. To keep the movement fluent, cooperation is necessary with a third group of muscles which perform static work and control the two first muscular groups, e.g. the movement of bending in the ankle joint. The movement of bending is performed by the calf's tricep, which contracts concentrically, and the antagonist are extensors, which stretch eccentrically. The innervation which makes such work possible is reciprocal innervation. When a person is standing, muscles are under the influence of a constant isometric load, hence the rapid growth of tiredness processes. The foot is mechanically better adapted to static-dynamic work than to static work. The foot's arch protects nerves against pressure, and supplying its sole side ensures free blood circulation and increases the foot's resilience [1].

The aim of the study is to present the changes in selected dynamic parameters during and after the application of load, imitating a school rucksack.

MATERIAL AND METHOD

The studies were conducted in spring 2004 in a randomly chosen school in the province of Lubuskie and covered 45 girls aged 12.

The methodology of the examination included the measurement of selected feet parameters for 13 minutes with the load placed on shoulders, then for 12 minutes without the load at 1-minute intervals: measurement 1 - in the habitual posture, 2 – in unloading, measurement 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 – with the load, measurement 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27 – without the load in the habitual posture. The examined girl walked about between measurements. A computer stand for evaluation of body posture - Posturometer M was used for the analysis of values of selected parameters, describing the foot unit. The technique of examination conforms with adopted principles [2]. The obtained results in the form of a three-dimensional graphic picture allowed the quantitative description of the examined parameters. Diagnostic analysis was applied to the following parameters: Ky l – Sztriter-Godunow's index for the left foot, Cl l (degrees) – Clarke's angle in the left foot. Respectively for the right foot. Dł Ł 1, 2, 3, 4 and 5 – length of five consecutive longitudinal arches in the left foot, Wys. Ł l 1, 2, 3, 4 and 5 – height of five consecutive longitudinal arches in the left foot, Sz Ł l 1, 2, 3, 4 and 5 – width of five consecutive longitudinal arches in the left foot. Respectively for the right foot.

DISCUSSION OF RESULTS

The obtained results presented in table 1 were developed statistically defining: mean value, standard deviation, coefficient of variation, maximal and minimal value. Because of the very large volume of calculation results only significant differences in study results have been placed in tab. 2a, 2b.

Table 1 Statistical description of all examined dynamic foot parameters N = 45

Feature	Mean value	Stand. dev.	Coeff. of var.	Min.	Max.
KY r	0.76	4.19	551.31	0.0	39.6
KY l	0.54	2.99	552.08	0.0	38.4
Cl r	37.02	6.53	17.66	23.6	58.0
Cl l	39.63	6.37	16.09	23.0	60.0
DŁ r 1	93.43	20.1	21.58	54.0	128.0
2	86.61	24.34	28.11	37.0	127.0
3	73.13	34.62	47.34	0.0	126.0
4	45.79	47.17	103.02	0.0	121.0
5	32.38	39.71	122.61	0.0	110.0
DŁ l 1	65.35	40.02	61.24	0.0	129.0
2	57.54	36.76	63.89	0.0	121.0
3	51.72	76.13	147.2	0.0	655.0
4	20.95	28.44	135.72	0.0	111.0
5	5.51	17.8	323.07	0.0	107.0
Wys.Ł r 1	6.52	3.52	54.16	1.0	20.0
2	6.18	3.12	50.69	1.0	17.0
3	4.51	3.17	70.31	0.0	13.0
4	2.5	3.06	122.46	0.0	10.0
5	1.57	2.4	152.98	0.0	9.0
Wys.Ł l 1	5.29	4.1	77.63	0.0	15.0
2	4.38	3.59	81.98	0.0	14.0
3	2.85	2.79	97.79	0.0	10.0
4	1.35	2.22	164.07	0.0	10.0
5	0.44	1.55	349.29	0.0	9.0
Sz Ł r 1	15.36	3.42	22.26	7.0	25.0
2	10.82	3.9	36.11	2.0	20.0
3	5.96	4.27	71.62	0.0	16.0
4	2.61	3.37	128.96	0.0	12.0
5	0.88	1.84	207.55	0.0	10.0
Sz Ł l 1	15.74	3.71	23.61	8.0	27.0
2	10.88	4.1	37.72	3.0	23.0
3	5.91	4.62	78.27	0.0	19.0
4	2.54	3.7	145.62	0.0	16.0
5	0.98	2.3	234.79	0.0	12.0

Source: own research

Table 2a Significance of differences in mean values of foot parameters during and after the application of load. N = 45

Consecutive measurement	Wys. Ł l	Wys. Ł right foot		
	4	1	2	3
1 - 23				*
1 - 24				*
1 - 27			*	
3 - 22		*		
5 - 27			*	
6 - 11			*	
6 - 23				*
6 - 24				*
6 - 26			*	
6 - 27			*	

Consecutive measurement	Wys. Ł 1	Wys. Ł right foot		
	4	1	2	3
9 - 21		*		
9 - 22		**		
9 - 23		*		
9 – 26		*		
11 - 13			*	
11 - 17			*	
11 - 21		*		
11 - 22		*	*	
11 - 23		*		
11 - 26		*		
12 – 23				*
12 – 24				*
12 - 27	*			
13 - 26			*	
13 - 23				*
13 - 24				*
13 - 27			**	
17 - 24			*	
17 - 26			**	
17 - 27			***	
18 - 24			*	
18 - 26			*	
18 - 27			***	
21 - 27		**		
22 - 23				*
22 - 24				*
22 - 26			*	
22 - 27		**	**	
23 - 27		*		
24 - 27			*	
25 - 27			*	
26 - 27		*		

Source: own research

Table 2b Significance of differences in mean values of foot parameters during and after the application of load. N = 45

Consecutive measurements	Foot parameters									
	Length of the arch of the left foot				Dł Łr	Sz Ł left f.		Wys. Ł left foot		
	1	2	3	4	3	2	3	1	2	3
1 – 25					*					
3 – 27							*			
5 – 25					*					
5 – 27							*			
6 – 27							*			
8 – 11		*	*							
8 – 14	*	*								
8 – 15		*	*							
8 – 16										*
8 – 24	*	*	*							**
8 – 25										*
8 – 27										
10 – 27						*	*			
11 – 22									**	
11 – 27							*			
12 – 13				*						
12 – 14				*						

Consecutive measurements	Foot parameters									
	Length of the arch of the left foot				Dł Łr	Sz Ł left f.		Wys. Ł left foot		
	1	2	3	4	3	2	3	1	2	3
12 – 27				*			*			
14 – 22								*	**	
14 – 27							*			
15 – 22								*	**	
16 – 22									*	*
16 – 25					*					
17 – 22									*	
17 – 27							*			
19 – 22									*	
19 – 25					*					
20 – 22								*	**	
20 – 25					*					
22 – 24								*	*	*
22 – 25								*	*	*

Source: own research

Legend: * = difference significant to a small degree, ** = difference of medium significance
*** = very significant difference

It appears from the obtained measurements that significant differences occurred only in the case of: the length of the 1st, 2nd, 3rd and 4th arch of the left foot and the 3rd arch of the right foot, the width of the 2nd and 3rd arch of the left foot, the height of the 1st, 2nd, 3rd and 4th arch of the left foot and the 1st, 2nd and 3rd of the right foot. A very significant difference occurs in the height of the 2nd arch of the right foot between the 4th and 12th as well as the 5th and 12th minute after the load's removal. A difference of medium significance occurs in: the height of the arch of the left foot between the 9th minute of the load and the 9th minute after the load is removed, between the13th minute of the load and the 9th minute after it is removed and between the 5th and the 9th minute after the load is removed, in the case of the 3rd arch of the same foot, between the 8th minute of the load and the 11th after it is removed, in the height of the 1st arch of the right foot between the 9th minute of the load and the 9th after it is removed, the height of the 2 arch of the same foot between the 13th minute of the load and the 12th minute after it is removed as well as the 9th and 12th minute after the load is removed. Other differences are significant to a small degree. The differences concern mainly significant changes in dynamic parameters of the left foot: the height of the 1st, 2nd, 3rd and 4th arch, the length of the 1st, 2nd, 3rd and 4th arch and the width of the 2nd and 3rd arch. The differences between the mean values of the 1st and 2nd examination weren't significant, which indicates small deformations of the measured parameters. The other mean values of obtained study results did not show significant differences.

CONCLUSIONS

1. In 12-year-old girls significant changes in dynamic parameters of the left foot can condition their smaller efficiency in comparison with the right foot.
2. The most unfavourable changes in foot dynamics take place between the 6th and 10th minute of the load
3. No significant differences occur in mean values of the measured foot parameters between examination in the habitual posture and loading the shank, which constitutes a minimal diagnostic value of feet efficiency.
4. A very significant and remaining drop in the height of the right foot's 2nd arch in 12-year-old girls occurs from the 3rd to the 5th minute of the load, in the 12th minute after removal the arch is restituted.

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STRESZCZENIE

Celem pracy jest przedstawienie zmian wybranych parametrów dynamicznych w czasie i po 6 kg obciążeniu, imitującym szkolny plecak. Badania przeprowadzono Posturometrem M na 45 dziewczynach w wieku 12 lat, w postawie habitualnej i z obciążeniem kręgosłupa ciężarem 6 kg, w czasie 13 minut. Wnioski: 1. U 12 letnich dziewcząt znaczące zmiany w parametrach dynamicznych lewej stopy, mogą warunkować ich mniejszą wydolność w stosunku do stopy prawej. 2. Najbardziej niekorzystne zmiany w dynamice stopy zachodzą między 6 a 10 minutą obciążenia 3. Nie występują istotne różnice średnich wartości mierzonych parametrów stóp między badaniem w postawie habitualnej i obciążeniu ciężarem podudzia, co stanowi znikomą wartość diagnostyczną wydolności stóp. 4. Bardzo istotny i utrzymujący się spadek wysokości 2 łuku prawej stopy u 12 letnich dziewcząt występuje od 3 do 5 minuty obciążenia, w 12 minucie po zdjęciu, łuk powraca do wartości wyjściowej. Słowa kluczowe: wysklepienie podłużne stopy

ABSTRACT

The aim of the study is to present changes in selected dynamic parameters during and after the application of 6 kg load, imitating a school rucksack. The studies were conducted using a Posturometer M on 45 girls aged 12, in the habitual posture and loading the backbone with 6 kg of weight, for 13 minutes. Conclusions: 1. In 12-year-old girls significant changes in the left foot's dynamic parameters can condition their smaller efficiency in comparison with the right foot. 2. The most unfavourable changes in foot dynamics take place between the 6th and 10th minute of the load. 3. No significant differences occur in mean values of the measured feet parameters between examination in the habitual posture and loading the shank, which constitutes a minimal diagnostic value of the foot's efficiency. 4. A very significant and remaining drop in the height of the right foot's 2nd arch in 12-year-old girls occurs from the 3rd to the 5th minute of the load, in the 12th minute after removal, the arch is restituted. Key words: foot longitudinal arch.