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Assessment of spatio-temporal gait parameters in the group of 9 years old healthy children

Ocena parametrów czasowo-przestrzennych chodu w grupie zdrowych dzieci w wieku 9 lat

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ABSTRACT

Introduction: Gait analysis can be defined as a measurement, description and assessment of human locomotion. The development of quantitative gait analysis methods and their increasing application to pathological gait assessment in children has created an urgent need for establishing normative data. The spatio-temporal gait parameters must be compared with valid reference data for the appropriate interpretation.

Objective: The aim of this study was the assessment of the spatio-temporal gait parameters of 9 years old healthy children, considering the subject's gender and the potential difference between right and left lower limb. Additional purpose of our study was to develop own reference data for the gait analysis in this age group.

Material and methods: 42 healthy, nine years old children (19 girls, 23 boys), participated in this study. 3D gait analysis was performed using the computerized optoelectronic

STRESZCZENIE

Wprowadzenie: Analizę chodu można zdefiniować jako pomiar, opis i ocenę lokomocji człowieka. Rozwój ilościowych metod analizy chodu oraz ich rosnące zastosowanie w ocenie patologii chodu u dzieci spowodował pilną potrzebę stworzenia danych normatywnych. Najczęściej stosowane parametry czasowo-przestrzenne chodu muszą być porównywane z wartościowymi danymi referencyjnymi w celu prawidłowej interpretacji.

Cel: Celem badań była ocena parametrów czasowo-przestrzennych chodu w grupie zdrowych dzieci w wieku 9 lat, z uwzględnieniem płci badanych oraz ewentualnych różnic pomiędzy prawą i lewą kończyną dolną. Dodatkowym celem naszych badań było opracowanie własnych danych normatywnych dotyczących analizy chodu w grupie zdrowych dzieci w wieku 9 lat.

Materiał i metoda: W badaniach udział wzięło 42 zdrowych dzieci (19 dziewczyn, 23 chłopców) w wieku 9 lat, spełnia-

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system (BTS Smart, Italy). Basic spatio-temporal gait parameters (percentage share of the stance and swing phase, right and left lower limb step lenght, as well as step frequency and average gait speed, were anylysed.

Results: Our research showed no statistically significant influence of gender, and no differences between the right and left lower limbs on most of the gait parameters in the study group.

Key words: gait, child, reference values

jących przyjęte kryteria włączenia. Trójwymiarowa analiza chodu została wykonana przy użyciu komputerowego systemu optoelektonicznego BTS Smart (BTS Bioengineering, Włochy). Analizie poddano podstawowe parametry czasowo--przestrzenne chodu, takie jak udział procentowy fazy podporu i wymachu oraz długość kroku dla prawej i lewej kończyny dolnej, częstość kroków i średnią prędkość chodu.

Wyniki: Nasze badania wykazały brak istotnie statystycznego wpływu płci oraz brak różnic pomiędzy prawą i lewą kończyną dolną w odniesieniu do większości rozważanych parametrów chodu w badanej grupie.

Słowa kluczowe: chód, dzieci, wartości referencyjne

Introduction

Gait analysis, based on measurement and assessment of the values that characterize human locomotion is widely use in clinical practice.Advanced optoelectronic, computer motion analysis systems enable the measurement of temporal-spatial parameters of gait (gait velocity and step frequency, step length, the percentage share of single and double support and the swing phase in gait cycle), kinematic parameters (the relative changes of the angles between the body segments in joints), kinetic parameters (ground reaction forces, moments of force, power), and bioelectrical signals recorded using non-invasive, dynamic electromyography method (surface electromyography - SEMG).Analysis of the obtained information allows for better understanding of the biomechanics of patients gait pattern and evaluating the size and source of gait disorders in case of pathology, as well as planning and monitoring the effects of the applied therapeutic intervention [1,2,3,4,5].

In case of gait pathology the quantitative identification of the size and character of pathological changes in patients gait pattern and accurate interpretation of these findings require a comparison of the obtained data with the healthy reference group. Each gait laboratory should strive to develop their own reference gait data for healthy children and adult groups, which has no pathological changes in medical history and observational gait assessment [7,8,9].

The purpose of this study was the assessment of the spatio-temporal gait parameters of 9 years old healthy children, considering the gender of the subjects and the difference between right and left lower limb. For the purpose of our study we hypothesized that there should be no difference in basic spatio-temporal gait parameters between right and left lower limb, knowing that gait symmetry is very important indicator of normal gait, though we may expect some difference due to the subjects gender. Additional purpose of our study was to develop own, valid reference data for the gait analysis in this specific age group.

Material and method

The study group

42 healthy children (19 girls, 23 boys), at the age of nine years, meeting inclusion criteria, were qualified for this study (Tab. 1). The inclusion criteria in the study group were the correct development of the children, lack of past injuries, neurological disorders and diseases affecting their functional status and gait and parents' written consent. Shapiro-Wilk test, used for statistical analysis of the anthropometric parameters, showed normal data distribution in the study group. Besides, there are no difference in the basic anthropometric parameters (height, weight and lower limb length) between boys and girls in this group.

The equipment

The research was conducted in the Gait Laboratory (Institute of Physiotherapy, University of Rzeszow, Poland).

Table 1. Basic anthropometric parameters of the study group

Gender	Height (m)				Weight (kg)			
	$\bar{x}$	s	Min	Max	$\bar{x}$	s	Min	Max
TOGETHER	1,34	0,08	1,17	1,51	29,8	5,4	21,0	41,5
Girls	1,34	0,07	1,20	1,51	30,9	7,0	21,0	41,5
boys	1,34	0,07	1,17	1,51	28,9	3,6	22,0	37,0
Gender	Right leg length [m]				Left leg length [m]			
	$\bar{x}$	s	Min	Max	$\bar{x}$	s	Min	Max
TOGETHER	0,69	0,05	0,57	0,80	0,69	0,05	0,58	0,80
girls	0,69	0,05	0,57	0,77	0,69	0,05	0,58	0,77
boys	0,69	0,04	0,60	0,80	0,69	0,04	0,60	0,80

Table 2. Stance phase (% of gait cycle)

Gender	Stance phase (R) %				Stance phase (L) %			
	$\bar{x}$	s	Min	Max	$\bar{x}$	s	Min	Max
TOGETHER	**59,0**	**1,7**	**55,1**	**63,8**	**58,8**	**1,8**	**55,2**	**63,8**
girls	59,3	1,9	55,1	63,8	59,0	2,0	56,6	63,8
boys	58,8	1,4	56,2	61,7	58,7	1,7	55,2	61,5
p	0,3681				0,6573			

Table 3. Swing phase (% of gait cycle)

Gender	Swing phase (R) [%]				Swing phase (L) [%]			
	$\bar{x}$	s	Min	Max	$\bar{x}$	s	Min	Max
TOGETHER	41,0	1,7	36,2	44,9	41,2	1,8	36,2	44,8
girls	40,7	1,9	36,2	44,9	41,0	2,0	36,2	43,4
boys	41,2	1,4	38,3	43,8	41,3	1,7	38,4	44,8
p	0,3755				0,6575			

Table 4. Step frequency

Gender	Step frequency [steps/minute]			
	$\bar{x}$	s	Min	Max
TOGETHER	128,6	11,7	109,2	160,8
girls	132,0	11,0	111,6	160,8
boys	125,8	11,7	109,2	148,8
p	0,0865			

Gait parameters were assessed using BTS Smart opto-electronic motion analysis system (BTS Bioengenering, Italy). The system includes 6 analog cameras with sampling frequency of 120 Hz, tracking the movement of retro-reflecting markers placed on the patient's body according to a particular protocol. Other options of the system, i.e. the registration of signals from two force platforms and surface electromyography, were not used in this study .

The gait analysis consist of the system calibration, preparation of the patient, collection and processing of data, and generation of a report. Preparation of the patient consist of anthropometric measurements and markers placement on the patient's body according to Davies Protocol. Anthropometric data consist of : height, weight, length of lower limbs, pelvis width and depth, knee width and ankle width. Anthropometric measurements and markers placement were performed by the same person. Collection of the data included one static trial (standing) and few (10 – 15) dynamic trials – walking with normal, self-selected speed through the 8 meters walking path of the gait laboratory contained in the view of the BTS motion analysis system cameras. Data processing included the assignment of each marker to a specific point of the kinematic model (Davies model) and defining gait cycle - heel strike and toe off for the right and left lower limb in all dynamic trials. One static trial and the mean values from six gait cycles for the right and left lower limb, for each subject were considered for further statistical analysis.

The statistical methods

To compare differences between groups (subject's gender) appropriate statistical test was used – *t* test for independent variables . To compare differences within the same parameters between the subjects right and left lower limb, *t* test for dependent variables was used. To verify the hypothesis of normal distribution of the obtained data Shapiro–Wilk test was used. Statistical significance level was assumed at $p<0,05$ level.

Results

Stance phase

Table 2 shows the distribution of stance phase results for both limbs (% of gait cycle) with the respect to gender. The differences are minimal and not statistically significant. An average value of stance phase is 59 % of gait cycle for the right lower limb (59,3 % for girls and 58,8 for boys) and 58,8 % of gait cycle for the left lower limb (59 % for girls and 58,7% for boys). Stance phase analysis for right and left lower limb in the group (regardless of the gender of the subjects) using *t* test for dependent variables also showed no significant differences between the results($p = 0,3540$).

Swing phase

An average value of swing phase is 41 % of gait cycle for the right lower limb (40,7 % for girls and 41,2 % for boys) and 41,2% of gait cycle for the left lower limb (41 % in the group of girls and 41,3% for boys). Sta-

Table 5. Step length for right and left lower limb

Gender	Step length (R) [m]				Step length (L) [m]			
	$\bar{x}$	s	Min	Max	$\bar{x}$	s	Min	Max
TOGETHER	0,48	0,06	0,30	0,60	0,48	0,06	0,32	0,60
girls	0,49	0,07	0,33	0,56	0,49	0,06	0,35	0,59
boys	0,47	0,07	0,30	0,60	0,47	0,07	0,32	0,60
p	0,5900				0,3117			

Table 6. Mean gait speed

Gender	Mean gait speed [m/s]			
	$\bar{x}$	s	Min	Max
TOGETHER	1,14	0,15	0,88	1,48
Girls	1,19	0,14	0,91	1,48
boys	1,10	0,14	0,88	1,38
p	0,0453*			

Table 7. Summary of all measured variables

Variable (parameter)	Mean ± SD	Min-Max	95% CI	*p*
Stance Phase R [%]	59,0 ± 1,7	55,1-63,8	58,5-59,5	0,2762
Stance Phase L [%]	58,8 ± 1,8	55,2-63,8	58,3-59,4	0,7643
Swing Phase R [%]	41,0 ± 1,7	36,2-44,9	40,5-41,5	0,2705
Swing Phase L [%]	41,2 ± 1,8	36,2-44,8	40,6-41,7	0,7517
Step frequency [step / minute]	128,6 ± 11,7	109,2-160,8	125,0-132,2	0,1665
Step Lenght R [m]	0,48 ± 0,06	0,30-0,60	0,46-0,50	0,0004***
Step lenght L [m]	0,48 ± 0,06	0,32-0,60	0,46-0,50	0,0878
Stance Phase Speed R [m/s]	1,19 ± 0,16	0,95-1,55	1,15-1,24	0,1198
Stance Phase Speed L [m/s]	1,19 ± 0,15	0,93-1,54	1,15-1,24	0,3649
Swing Phase Speed R [m/s]	2,59 ± 0,32	2,08-3,29	2,49-2,68	0,3850
Swing Phase Speed L [m/s]	2,57 ± 0,32	1,85-3,23	2,47-2,67	0,8225
Stride Lenght R [m]	1,11 ± 0,08	0,97-1,32	1,09-1,14	0,2910
Stride Lenght L [m]	1,11 ± 0,08	0,96-1,35	1,09-1,14	0,2564
Step Widht [m]	0,14 ± 0,02	0,09-0,17	0,13-0,14	0,0092**
Average Gait Speed	1,14 ± 0,15	0,88-1,48	1,09-1,19	0,4119

***p* – result of Shapiro–Wilk test**

tistical analysis of swing phase showed no significant differences between the results obtained in the groups of boys and girls and between the right and left lower limb (Tab. 3).

Step frequency

Average step frequency in the study group was 128.6 steps per minute (132 steps for girls and 125,8 steps in the group of boys). Statistical analysis of the step frequency showed no significant influence of gender on this parameter of gait (Tab. 4). However, p - value less than 0.1 indicated the need to consider further, similar study on larger group, to verify this result.

Step length

Average step length in the study was 48 centimeters (49 cm in the group of girls and 47 cm for boys). The results of step length for girls and boys did not show statistically significant differences. Results of *t* test for dependent variables (p = 0.6075) showed no statistically significant differences of the results between right and left lower limb in the whole group (Tab. 5).

Gait speed

Mean gait speed was 1.14 m / s and it is slightly lower in the group of boys - 1.1 m / s compared with a group of girls - 1.19 m / s and the difference is statistically significant (p – value of the *t* – test for independent variables is 0.0453) (Tab. 6).

Summary of all measured variables

Table 7 contains mean value, standard deviation, minimum and maximum, as well as 95 % confidence interval for all variables. Additionally results of Shapiro–Wilk test for all considered parameters is included in the table. For most variables (excluding step length for the right lower limb and the step width) p-value was statistically non significant, which indicates normal distribution of analysed gait parameters in this study group (Tab. 7).

Discussion

Laboratory gait analysis is a complex, 3 dimensional, objective and quantitative method of clinical assessment of gait pathologies. Gait analysis provides an effective tool for evaluating and quantifying the effects of a surgical intervention or other treatment [1,5,6]. Clinicians can evaluate whether a patient's gait has become more "normal" following intervention and quantify the specific features of the gait that have changed [10].

Many scientific publications concern different gait pathology, but such a data have to be compared with valid normative data for interpretation. However, publications concerning reference data for gait analysis are generally limited to specific groups. These results are often based on relatively small numbers of subjects, spread over many age groups [7,8,9,11,12,13].

Stansfield et al. pointed on a fact that in many publications gait parameters (kinematic, kinetic) were not normalised to subjects anthropometric data. This is the reason for the differences existing in some gait parameters of the subjects (i.e. step length) regard to their anthropometric parameters (i.e. height, lower leg length) [14]. It all makes the comparison of the results between different gait laboratories very difficult, although normalisation of the gait parameters is possible [15].

Besides, different equipment of gait laboratories and methods used in gait analysis results interpretation and evaluation, makes the comparison even more difficult [8]. In Pediatric Rehabilitation Department of Childrens Hospital in Sawannah (GA, USA) a questionnaire consist of 15 multiple choice question was elaborated. Question concerned methods, procedures and standards used in pediatric, laboratory gait analysis (i.e. tests used for motor development assessment, functional tests, reference data for gait analysis, methods for therapy effects evaluation). The questionnaire was sent to 13 labs specializing in pediatric gait analysis. Results of this study highlighted lack of similar criteria in gait analysis in different gait labs and need for its standardization [8].

The results of all measurements, including gait analysis, are also dependent on the test condition. As a result reference data are only valid for a similar test situation and condition. Gait analysis data should always be interpreted with regard to a defined test situation. Oberg et al. have observed that gait speed increases regard to walkway length (tends to be higher on a long walkways) [8]. Similar assessment was done by Waters et al. on 60,5 m long walkways in 260 healthy subjects, 6 to 80 years of age. Gait speed in their study ranged from 1,18 to 1,34 m/s [16]. Differences in the spatio-temporal gait parameters occurs also in relation to subjects gender. Murray et al. showed that women's gait speed and step length were smaller, but steps cadence was higher, comparing to men [17,18].

Conclusion

— Independently of the gender of the subjects in this study (for all subjects – boys and girls), no statistically significant differences between right and left lower limb were observed,

— No statistically significant influence of subjects gender on most of considered spatio- temporal gait parameters were found in this specific age group. In our study only gait speed was significantly lower in male group,

— Results obtained in this study and normal data distribution may indicate that this data can be considered valid in gait analysis for this specific age group in an indoor laboratory situation.

The major limitation of this work is a relatively small group of subjects, and it seems to be necessary to continue this study on bigger group of children, also in different, uniform age group, to obtain valid reference data for gait analysis. Considering different aspects and dynamics of children development in this and similar age groups, it will be also necessary to consider normalizing such a data to the subjects anthropometric parameters. Valid reference data for gait analysis should be based on large, uniform and age-specific groups, with the special consideration for potential gender - and anthropometric parameters related differences.

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