ORIGINAL ARTICLE

Repeatability of spatiotemporal gait parameters: comparison between normal children and children with hemiplegic spastic cerebral palsy

Repetibilidade dos parâmetros espaço-temporais da marcha: comparação entre crianças normais e com paralisia cerebral do tipo hemiplegia espástica

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Abstract

Objective: To evaluate the repeatability of spatiotemporal gait parameters by means of a comparative study between normal children and children with cerebral palsy (CP). **Methods:** The sample consisted of 17 children divided into two groups: a group of nine children with spastic hemiplegia CP and a group of eight normal children. The children were evaluated by the same researcher in two different sessions, with a one-week interval between the sessions. The children walked at self-selected velocities, and six attempts were performed at each session to represent the average. To record the spatiotemporal parameters, the Peak Motus system was used with two SVHS video cameras with an acquisition rate of 60 Hz. The intra-class correlation coefficient (ICC) and Bland-Altman concordance limits were chosen for data analysis. **Results:** The results demonstrated that the children with CP presented lower velocity and shorter cycles than the normal children in sessions 1 and 2. For all the spatiotemporal parameters, the two groups presented moderate to excellent ICC values, i.e. greater than 0.70. **Conclusion:** It can be concluded that the two groups presented good levels of repeatability for all the parameters analyzed when six attempts were used to represent the average.

Key words: gait; children; cerebral palsy; repeatability.

Resumo

Objetivo: Avaliar a repetibilidade das medidas dos parâmetros espaço-temporais da marcha por meio de um estudo comparativo entre crianças normais e crianças com paralisia cerebral (PC). **Métodos:** A amostra foi composta por 17 crianças divididas em dois grupos: um grupo de nove crianças com PC do tipo hemiplegia espástica e um grupo com oito crianças normais que foram avaliadas pelo mesmo pesquisador em duas sessões diferentes, com intervalo de uma semana entre as sessões. As crianças caminharam em velocidade autosselecionada e foram utilizadas seis tentativas nas sessões 1 e 2 para representar a média. Para registro dos parâmetros espaço-temporais, foi utilizado o sistema Peak Motus, com duas câmeras de vídeo SVHS com taxa de aquisição de 60 Hz. Coeficiente de correlação intraclasse (ICC) e limites de concordância de Bland-Altman foram escolhidos para análise dos dados. **Resultados:** Os resultados demonstraram que as crianças com PC apresentaram menor velocidade e comprimento do ciclo do que as crianças normais para as sessões 1 e 2. Para todos os parâmetros espaço-temporais, os dois grupos apresentaram valores de ICC de excelentes a moderados, ou seja, maior do que 0,70. **Conclusão:** Pode-se concluir que os dois grupos apresentaram níveis bons de repetibilidade para todos os parâmetros analisados quando seis tentativas foram utilizadas para representar a média.

Palavras-chave: marcha; crianças; paralisia cerebral; repetibilidade.

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Introduction ⦂⦂⦂.

Cerebral palsy (CP) is a chronic disorder that affects movement and posture and results from damage to an immature brain due to various pre-, peri- and post-natal factors. This kind of injury to the neurological system usually leads to abnormal motor control. Children with CP have a series of disturbances, such as muscle weakness, sensory loss and spasticity. These neuromusculoskeletal disorders affect upright stance, balance, and the ability to walk. As a consequence, gait performance in these children is poor when compared to that of normal children, leading to difficulties in carrying out daily and even leisure activities[1-4].

The current techniques of three-dimensional gait analysis allow a quantitative description of lower limb movements during gait. Thus, there is a better understanding of the biomechanics of normal human gait, which makes it possible to better identify the disorders and therefore assess them objectively. This analysis has played a significant role in the treatment of CP because it helps in decision-making with regard to clinical practice and also in the evaluation of the results of therapeutic interventions given that improving these children's gait pattern is one of the goals of the treatment[5-7]. Spatiotemporal parameters are often used to evaluate gait development in children and to identify potential disorders. The analysis of these parameters, in addition to evaluating aspects of pathological gait, also quantifies post-surgical improvement or conservative treatment[8,9]. Nevertheless, in order to make evidence-based decisions concerning the treatment of patients with gait disorders, it is necessary to evaluate the repeatability of these parameters[10-13].

Repeatability can be defined as the agreement between results within a short period of time, by the same examiner and using the same instrumentation[14]. Generally, gait evaluation data are based on the collection of attempts recorded during a single visit of the patients to the laboratory and compared to the data of the control-subjects, that is, without compromising the gait pattern. It is extremely important to ensure that these values represent the child's locomotion pattern. Kadaba et al.[15] found good levels of repeatability for the spatiotemporal parameters in normal adults, by using the mean of three attempts to the gait cycle. Stolze et al.[9] found excellent repeatability for normal adults for all spatiotemporal gait parameters using a mean of 15 attempts to the gait cycle, whereas normal children showed a greater variation. The authors claim that there is a lower repeatability of these parameters for children when compared to adults. Therefore, the aim of the present work is to verify, by means of a comparative study, the repeatability of the spatiotemporal gait parameters in normal children and in children with CP.

Methods ⦂⦂⦂.

The type of study design chosen was the controlled cross-sectional type.

Subjects

The sample consisted of two groups of children aged six to 13, selected in a non-probabilistic manner according to accessibility. One group was composed of nine children (six male and three female) with a previous clinical diagnosis of spastic hemiplegia CP and treated at the Child Rehabilitation Center of Universidade Católica de Brasília. The second group was composed of eight normal children (two boys and six girls) recruited by relatives and friends of the study's supervising researcher. The children's guardians were informed by the researcher concerning the purpose and importance of the study and signed a consent form. Ten children with CP and ten normal children were initially selected to take part in the study. One child with CP withdrew from the study and was not able to complete it. Two children from the control group did not take part in the study because they did not receive parental permission. Therefore, at the end of the study, the sample totaled 17 subjects.

To be included in the study, the children had to be six to 13 years old with preserved cognition so that they could understand the instructions. The children with CP also had to be able to execute an independent gait, without being aided in the locomotion or making use of orthoses, and have a previous clinical diagnosis of spastic hemiplegia CP with grade 1 spasticity in the Ashworth scale. The criterion for exclusion for the normal children were a clinical history of neurologic or musculoskeletal problems. For the children with CP, it was orthopedic surgery up to one year before taking part in the present study. The study was approved by the Research Ethics Committee of the Faculty of Health Sciences of Universidade de Brasília, on July 28, 2006, under the protocol number 033/2006.

Procedures for collection

The data collection itself consisted in filming each child on two different days, called session 1 and session 2, with a 1-week interval between sessions to obtain the spatiotemporal gait parameters. The data collection for each child was carried out at the same time of the day on both sessions. For the gait analysis, the Peak Motus system, version 7.2.6 (Peak Performance Inc.), was used with two high-frequency SVHS video cameras, with a 60 Hz acquisition rate. The cameras were placed 5 meters from the subject's sagittal plane, with a minimal convergence angle between them, following the procedures established for three-

dimensional movement reconstruction and in accordance with the Direct Linear Transformation (DLT) method.

Upon arrival at the laboratory, the children and their guardians were allowed to familiarize themselves with the environment where the collection was to take place. Afterwards, each child was instructed to put on a swimsuit. The children were evaluated barefoot to eliminate any influence caused by the shoes. Then, each child had their height measurement taken, and external reflexive markers were placed onto the upper and posterior part of the calcaneus, on the axis of the foot, bilaterally, for subsequent calculation of the spatiotemporal parameters. The height measurements were used for the normalization of the variables of the study[16,17].

As the collection was being carried out, the children were instructed to walk along a 10m path, at a self-determined speed. The first attempt was discarded and the six following valid attempts were selected for data processing. The choice of the first six attempts was carried out to avoid the effects of fatigue, especially in children with CP. For the analysis procedures, the mean of the six attempts from the first session and from the second session was calculated. All of the subjects were evaluated by the same examiner in both sessions. The data from the video images were processed by the Peak Motus software. The right and left points of the calcaneus were selected for conversion into digital form. Based on these two points, it is possible to calculate the spatiotemporal variables of the gait cycle, both for the right and left sides (or plegic and nonplegic sides). In order to avoid conversion errors, the coordinates were filtered through a 4th order Butterworth digital filter (in the temporal domain) on the rough coordinates of interest to the subject, with a cutoff frequency set at 6 Hz because good results have been found with this kind of filter for kinematic gait data[18].

The variables analyzed in the present study were stride and gait cycle length, cadence, total gait cycle, total stance phase, swing phase, and velocity. The values for gait cycle length, stride length, total gait cycle, total stance phase, swing phase and velocity were described based on absolute and normalized values. The parameters obtained for gait cycle length, stride length and velocity were normalized according to each child's height, i.e. we obtained the ratio of absolute values to subject height. The parameters for time were normalized according to the gait cycle.

Statistical analysis

The software Statistical Package for the Social Science (SPSS) version 13.0 was used to carry out the statistical treatment. The Shapiro-Wilk test was used for the distribution analysis of the values for each sample to determine whether the values had a normal distribution. Levene's test was applied to test the homogeneity of the variances. When the analysis obtained through these two tests resulted in p>0.05, parametric tests were carried out to compare the groups; however, if the analysis resulted in a *p* value lower than 0.05, either for the normality test or for the variance homogeneity test, nonparametric tests were carried out for the comparisons.

To characterize the sample selected for the study, procedures from descriptive statistics were used (mean ± standard deviation), and afterwards, the due inferences were made. To compare the measurements of the intragroup spatiotemporal parameters, either the parametric paired *t* test or the non-parametric Wilcoxon test was used. For the intergroup comparison of the same variables, we used the *t* test for independent samples or the non-parametric Mann-Whitney test. The level of significance adopted was p<0.05.

The information about the repeatability of the data obtained from each group of patients was analyzed by means of two procedures associated with the concordance index between measurement replicas:

a) Intraclass Correlation Coefficient (ICC): for this calculation, the two-way mixed model was chosen, with a confidence interval of 95%. To interpret the ICC values, we used the value scale suggested by Menz et al.[19]. Values greater than 0.75 show excellent repeatability; values between 0.40-0.75, moderate/fair repeatability, and values lower than 0.40 indicate poor repeatability.

b) Bland-Altman method: this method was used to define the magnitude of agreement between the measurement values of days 1 and 2 of the test. A limit agreement of 95% was chosen. When limits of agreement are calculated, "D" represents the mean difference between the subjects for the variables measured on days 1 and 2; "SD difference" represents the standard deviation of the differences of the variables measured on days 1 and 2. The limits of agreement set at 95% are calculated as D ± (SD difference multiplied by 2). The coefficients of repeatability recommended by Bland-Altman assume that the mean difference between the attempts is equal to zero. Nevertheless, the limits of agreement which indicate a good repeatability are also part of the researcher's judgment[20-22].

Results

The results obtained in the present study will be presented according to the following evaluated parameters: gait cycle length, stride length, velocity, cadence, gait cycle, stance phase, and swing phase. Intra- and intergroup comparisons were made by using the mean of six attempts of the gait cycle.

Inter- and intragroup comparison

Table 1 shows the data for the sample's age and stature, grouped by the presence or absence of CP.

Table 2 shows the spatiotemporal gait parameters: velocity, cadence, gait cycle, stance phase, swing phase, and gait cycle length (absolute data) for both normal and CP children when the means of six attempts in sessions 1 and 2 are compared.

Table 3 displays the normalized values for velocity, stance phase, swing phase and gait cycle length for normal and CP children when the means of six attempts in sessions 1 and 2 are compared.

Table 4 shows the values for the comparison between the stride on the plegic side of the children with CP and the right stride of normal children (absolute and normalized data). It also shows the values for the comparison of the plegic and nonplegic stride length of children with CP (absolute and normalized data) when the means of six attempts on days 1 and 2 are compared.

Repeatability

Tables 5 and 6 show values for the repeatability of the spatiotemporal gait parameters: velocity, cadence, gait cycle phase, stance phase, swing phase, and gait cycle length (absolute data) for the normal and CP children when the mean of six attempts made on days 1 and 2 are compared.

Table 7 shows the repeatability values for stride length on the plegic side of children with CP and stride length on the right side of normal children (absolute data) when the mean of six attempts made on days 1 and 2 are compared.

Discussion ⦂⦂⦂⦂

The aim of the present study was to evaluate the spatiotemporal gait parameters from two days of tests, comparing normal children with CP children and using the mean of six attempts of the gait cycle. The findings show that for all spatiotemporal parameters, both groups had excellent to moderate ICC values, i.e., greater than 0.70. Because the measurement of these parameters constitutes an important tool for decision-making in clinical practice with CP patients, it is very important to ensure that these data reproduce the locomotion pattern of these children, thus generating accurate data for gait evaluation.

No statistically significant differences were found (p>0.05) when comparing the means of the age and height variables between the normal and the CP groups. This is evidence that the sample was homogeneous. For intergroup comparisons, significant differences (p<0.05) were found for velocity, both in the normalized and in the absolute values, in sessions 1 and 2, between normal children and those with CP. The normal children walked at a higher velocity.

These results corroborate the study on gait maturation by Sutherland et al.[23]. The authors claim that the maturation of the Central Nervous System (CNS) contributes to the evolution of gait, and that the increase in velocity is proportional to the level of maturation. Because children with CP have a lesion in

Table 1. Mean (SD) and p-value for age and stature of normal and CP subjects.

	Normal (N=8)	CP (N=9)	p
Age (years)	9.13 (3.04)	8.89 (3.14)	0.89
Height (m)	1.32 (0.16)	1.30 (0.15)	0.86

p value is a result of the t test. Significant difference between normal and CP at p<0.05.

Table 2. Mean (SD) of spatiotemporal parameters (absolute values) measured in two sessions with the mean of six gait attempts for normal and CP children.

Spatiotemporal Parameters	Session	Normal	CP
Velocity (m/s)	1	1.03 (0.14) Aa	0.81 (0.15) Ba
	2	1.01 (0.14) Aa	0.81 (0.13) Ba
Cadence (strides/min)	1	124.89 (14.89) Aa	112.43 (15.98) Aa
	2	119.18 (8.06) Aa	114.36 (14.07) Aa
Gait cycle time (s)	1	0.97 (0.11) Aa	1.09 (0.14) Aa
	2	1.01 (0.07) Aa	1.06 (0.13) Aa
Stance phase (s)	1	0.61 (0.08) Aa	0.66 (0.09) Aa
	2	0.64 (0.04) Aa	0.65 (0.09) Aa
Swing phase (s)	1	0.37 (0.04) Aa	0.43 (0.06) Ba
	2	0.37 (0.04) Aa	0.42 (0.06) Aa
Stride length (m)	1	1.00 (0.18) Aa	0.87 (0.15) Aa
	2	1.02 (0.18) Aa	0.85 (0.15) Aa

Means with different capital letters on the same line (inter-group comparison) or different small letters in the same column (intra-group comparison), for each gait parameter, differ statistically (p<0.05).

Table 3. Mean (SD) of spatiotemporal parameters (normalized values), measured in two sessions, with the mean of six gait attempts for normal and CP children.

Spatiotemporal parameters	Sessions	Normal	CP
Velocity (m/s/height)	1	0.78 (0.07) Aa	0.62 (0.11) Ba
	2	0.76 (0.05) Aa	0.62 (0.11) Ba
Stance phase (% of cycle)	1	62.34 (2.36) Aa	60.91 (2.09) Aa
	2	63.56 (1.86) Ab	60.68 (3.14) Ba
Swing phase (% of cycle)	1	37.66 (2.36) Aa	39.08 (2.07) Aa
	2	36.44 (1.86) Ab	39.34 (3.15) Ba
Gait cycle length (% of height)	1	75.95 (6.79) Aa	66.88 (5.83) Ba
	2	77.20 (6.66) Aa	65.23 (6.67) Ba

Means with different capital letters on the same line (inter-group comparison) or different small letters in the same column (intra-group comparison) for each gait parameter differ statistically (p<0.05).

the CNS and changes in motor development, they are expected to have lower gait velocities.

Steinwender et al.[24] also found a lower velocity in children with CP when compared with normal children. The values found were 1.33 m/s and 1.24 m/s for normal children and children with CP, respectively. The authors justify that the limitation of movement in children with CP due to spasticity may be a contributing factor for the reduced velocity. Spasticity is the

Table 4. Mean (SD) of stride length (absolute and normalized values) measured in two sessions, with the mean of six gait attempts for normal and CP children.

	Session	Normal	CP	
		Right stride (m)	Plegic stride (m)	Nonplegic stride (m)
Absolute values (m)	1	0.52 (0.09) Aa	0.44 (0.08) Aa	0.44 (0.08) Aa
	2	0.53 (0.09) Aa	0.43 (0.08) BCa	0.43 (0.08) Ca
Normalized values (% of height)	1	38.87 (3.41) Aa	33.50 (2.88) BCa	33.70 (3.70) Ca
	2	39.78 (3.99) Aa	32.50 (3.49) BCa	32.73 (3.39) Ca

Means with different capital letters on the same line (inter-group comparison) or different small letters in the same column (intra-group comparison) for each parameter differ statistically (p<0.05).

Table 5. Difference between means (D), SD of differences (SD diff.), Bland-Altman limits of agreement (LOA), intra-class correlation coefficient (ICC) and 95% confidence interval (CI) for repeatability of absolute values of normal children for spatiotemporal parameters when the mean of six gait attempts on days 1 and 2 are compared.

Spatiotemporal parameters	D	SD diff.	Limits of agreement	Bland and Altman 95% (LOA)	LOA range	ICC [95% CI] Correlation
Velocity (m/s)	0.03	0.09	0.18	[-0.15; 0.20]	0.35	0.8 [0.29; 0.96]
Cadence (strides/min)	5.5	8.47	16.94	[-11.10; 22.10]	33.20	0.74 [0.14; 0.94]
Gait cycle time (s)	-0.03	0.06	0.12	[-0.16; 0.08]	0.24	0.76 [0.19; 0.95]
Stance phase (s)	-0.04	0.05	0.10	[-0.12; 0.05]	0.65	0.72 [0.11; 0.94]
Swing phase (s)	-0.01	0.02	0.04	[-0.05; 0.04]	0.09	0.85 [0.42; 0.97]
Gait cycle length (m)	-0.02	0.05	0.10	[-0.11; 0.08]	0.19	0.96 [0.83; 0.99]

D = the mean difference in each parameter between days 1 and 2 for all subjects. SD diff. = the standard deviation for the differences in each parameter between days 1 and 2 for all subjects.

Table 6. Difference between means (D), SD of differences (SD diff.), Bland-Altman limits of agreement (LOA), intra-class correlation coefficient (ICC) and 95% confidence interval (CI) for repeatability of absolute values of CP children for spatiotemporal parameters when the mean of six gait attempts on days 1 and 2 are compared.

Spatiotemporal parameters	D	SD diff.	Limits of agreement	Bland-Altman 95% (LOA)	LOA range	ICC [95% CI] Correlation
Velocity (m/s)	0.01	0.06	0.12	[-0.11; 0.13]	0.24	0.91 [0.64; 0.98]
Cadence (strides/min)	-2.11	6.21	12.42	[-4.29; 10.07]	24.36	0.92 [0.68; 0.98]
Gait cycle time (s)	0.02	0.05	0.10	[-0.08; 0.13]	0.21	0.92 [0.70; 0.98]
Stance phase (s)	0.02	0.03	0.06	[-0.05; 0.08]	0.13	0.93 [0.73; 0.98]
Swing phase (s)	0.01	0.03	0.06	[-0.04; 0.06]	0.10	0.89 [0.59; 0.97]
Gait cycle length (m)	0.02	0.06	0.12	[-0.10; 0.14]	0.24	0.92 [0.69; 0.98]

D = the mean difference in each parameter between days 1 and 2 for all subjects. SD diff. = the standard deviation for the differences in each parameter between days 1 and 2 for all subjects.

Table 7. Difference between means (D), SD of differences (SD diff.), Bland-Altman limits of agreement (LOA), intra-class correlation coefficient (ICC) and 95% confidence interval (CI) for repeatability of absolute values of normal and CP children for the parameter of right stride length (normal children) and plegic stride length (CP children) when the mean of six gait attempts on days 1 and 2 are compared.

Spatiotemporal parameters	D	SD diff.	Limits of agreement	Bland-Altman 95% (LOA)	LOA range	ICC [95% CI] Correlation
Right stride (m)	-0.01	0.03	0.06	[-0.07; 0.04]	0.11	0.96 [0.80; 0.99]
Plegic stride (m)	0.01	0.04	0.08	[-0.06; 0.09]	0.15	0.89 [-0.09; 0.88]

D = the mean difference in each parameter between days 1 and 2 for all subjects. SD diff. = the standard deviation for the differences in each parameter between days 1 and 2 for all subjects.

result of a pathological increase in muscle tonus, hyperreflexia and loss of inhibitory control of antagonist muscles. It is generally accompanied by other motor dysfunctions such as lack of coordination, weakness, muscle atrophy, loss of control of selective movements, dexterity, and co-contraction[25]. This is also in agreement with the results found in the present study. Abel and Damiano[26] found higher velocity values in normal children compared to children with spastic diplegia CP. This reinforces the hypothesis that associates the impairment of CP children and the execution of activities such as walking. Pirpiris et al.[27] state that gait velocity is reduced in proportion to the subject's degree of motor impairment and that one of the features of patients with neuromuscular disorders is lower velocity. Raimundo et al.[28], in their study on gait velocity in normal children aged four to six, found values of 1.03 m/s (absolute) and 0.90 m/s/height (normalized).

With regard to gait cycle length, only the normalized values showed significant differences between the groups on both days of tests, with shorter gait cycle lengths for the children with CP. The differences in gait cycle length between normal and CP children may be related to a lack of stability of the supporting limb which is found in the CP children, due to changes in motor development, as well as limitations in range of motion in joints such as the hip, knee, and ankle. The children in the present study had been diagnosed with hemiplegia, which is characterized by motor deficit and unilateral spasticity that affects the upper and lower limbs contralateral to the affected brain hemisphere. The hemiplegic child moves preferably by favoring their normal hemibody and has a deficit in body alignment, which makes it difficult to transfer the weight onto the affected side and justifies the present findings[2,29]. Steinwender et al.[30] also found higher values for velocity and gait cycle length in normal children when compared with those with CP. Abel and Damiano[26] used three attempts of the gait cycle to calculate the mean and found that, for normalized values, the children with CP had a shorter gait cycle length than the normal children.

The total stance phase comprises the sum of the simple and double stance phases. The duration of the limb's stance phase is an indicator of stability. A reduction of this period during the gait cycle may result from muscular fatigue or a lack of motor control[23]. Differences were found between the groups for the normalized stance phase in session 2 with a shorter duration for children with CP. This may be explained by a reduction in the simple stance phase of the plegic limb because these children often have muscle weakness and favor the nonplegic limb, as described previously. Although the statistical difference only occurred on the second day of testing, which may be a sign of variability, it was noted that on the first day the children with CP also scored lower means for the duration of the stance phase.

In their study on children with CP, Sorsdahl, Moe-Nilssen and Strand[8] state that the simple stance phase of the plegic limb is shorter than the duration of the simple stance phase of the nonplegic limb. Abel and Damiano[26] found greater values for the duration of the stance phase and lower values for the swing phase in normal children.

For the stride length with normalized values, there was a significant difference between the stride length of normal children and the length of the plegic stride of children with CP on both days. However, for the absolute values, only the second day of tests showed a significant difference for this parameter. This result once again reinforces the presence of changes in the motor development presented by CP children in relation to normal children, and shows some degree of gait impairment.

With regard to the intragroup comparison, only the normalized values for the stance phase and for the swing phase had significant differences between the two days of testing for the group of normal children, which did not occur for the CP children. This difference may be justified by the subject's natural variability because normal children, having better motor control, also have a more extensive motor repertoire and a greater capacity to change the locomotor pattern. Stolze et al.[9] found significant differences between the two days of testing for normal children, but only in the duration of the stance phase. The authors explain that this slight reduction in the stance phase may have been caused by a marginal increase in the velocity on the second day of testing due to the subject's familiarization with the protocol. In the present study, there was a slight increase in the duration of the stance phase, which can also be explained by the small reduction in velocity on the second day of testing. Mackey et al.[3] evaluated the spatiotemporal parameters of children with hemiplegic CP and with approximately the same age as those of the present study. The authors claim they did not find any significant differences between parameters of stride length, gait cycle length, cadence and velocity, which is in agreement with the results of the present study.

According to the results, the ICC showed excellent levels of repeatability for all parameters analyzed when comparing the mean of six attempts on the two days of testing, except for the stance phase and cadence of the normal children who had moderate repeatability. Nevertheless, the Bland-Altman method exhibited acceptable variations in the limits of agreement for all the parameters analyzed, which indicates a good repeatability of the data. While analyzing the repeatability of the spatiotemporal gait parameters of normal children, Thorpe, Dusing and Moore[22] found levels of repeatability for children aged four to eight, i.e. ICC values ranging from moderate to excellent: velocity (0.74), cadence (0.84), stride length (0.82) and gait cycle length (0.81). For children aged eight to 11, they found

a level of repeatability ranging from poor to excellent: velocity (0.73), cadence (0.93), stride length (0.40) and gait cycle length (0.41). The authors explained that the poor level of repeatability in stride and gait cycle length for this age group may be due to the fact that these children felt more at ease on the second day of tests, which caused them to walk faster.

Although the ICC values had excellent levels of repeatability for most of the parameters, the normal children had a tendency to score lower ICC values than the children with CP. The justification may be based on the fact that children with CP have less freedom of movement, hence a smaller natural variability in their locomotion pattern, which increases their capacity to reproduce the same movement at each new session. In the gait analysis of children with CP aged two to 15, Sorsdahl, Moe-Nilssen and Strand[8], although they used a different protocol, they found excellent repeatability, i.e. great levels of ICC for the following variables: cadence (0.94), length of the plegic stride (0.95), gait cycle length (0.94), and simple stance phase (0.89). Maynard et al.[31] suggest that a minimum of three

gait cycles may be used as a mean when one wants to evaluate the repeatability. Nevertheless, Steinwender et al.[24] compared the repeatability of gait in normal children, as well as in children with CP using the mean of ten attempts, and both groups showed high variability.

Conclusions ⁖⁖⁖.

The results showed that the children with CP had lower velocity and gait cycle length values when compared to the normal children in sessions 1 and 2. Both the normal children and those with CP had an excellent to moderate repeatability for all the parameters analyzed. Considering the results obtained in this study, it can be concluded that the gait parameters recorded in the laboratory with a one-week interval have sufficient repeatability and serve as a comparative reference for normal children as well as children with spastic hemiplegia CP, when six attempts are used.

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