MedicalExpress

ORIGINAL RESEARCH

The use of the Gait Deviation Index for the evaluation Post-stroke Hemiparetic Subjects

Carolina C. Alcantara[I,II], Angelica Castilho Alonso[III], Danielli S. Speciali[I,IV]

[I] Hospital Israelita Albert Einstein, São Paulo, SP, Brasil.
[II] Universidade de São Carlos, Departamento de Fisioterapia, Laboratório de Fisioterapia Neurológica (LaFIN), São Carlos, São Paulo, Brasil.
[III] Universidade São Judas Tadeu (USJT), Departamento de Pós-Graduação Ciências do Envelhecimento, São Paulo, SP, Brasil.
[IV] Faculdades Metropolitanas Unidas (FMU), Centro Universitário das São Paulo, SP, Brasil.

BACKGROUND: The Gait Deviation Index, initially conceived to evaluate the gait of children with cerebral palsy, has been used as a quantitative parameter of gait pattern changes of individuals with other conditions. However, there are no studies evaluating changes in the gait pattern of chronic hemiparetic post-stroke subjects based on this index.
AIMS: To characterize the changes in gait pattern according to the Gait Deviation Index and gait spatiotemporal parameters of chronic hemiparetic subjects compared to healthy subjects.
METHODS: Retrospective study. Data were obtained from the database of the Gait Laboratory of Hospital Israelita Albert Einstein. Thirty subjects were included in this study, with previous unilateral, ischemic or hemorrhagic chronic stroke (time post-lesion > 6 months) and ability of walking classified as 2, 3, 4 or 5 according to Functional Ambulation Category. Data from 87 healthy subjects were included in control group, obtained from a normality database. Statistical analysis was applied through the Kruskall Wallis test, followed by Mann-Whitney post-hoc test, considering a critical p value <0.05.
RESULTS: The Gait Deviation Index scores were decreased for both paretic (64.69 ± 16.29) and non-paretic limbs (64.88 ± 15.00) compared to control (101.01 ± 10.12; $p < 0.001$). No differences were observed in Gait Deviation Index scores between paretic and non-paretic limbs ($p > 0.99$).
CONCLUSION: The findings of the current study demonstrate that the Gait Deviation Index may be a sensitive parameter to identify changes in the gait pattern of chronic hemiparetic post-stroke subjects.

KEYWORDS: stroke, gait, kinematic, hemiparetic.

Alcantaral CC, Alonso AC, Speciali DS. The use of the Gait Deviation Index for the evaluation Post-stroke Hemiparetic Subjects. MedicalExpress (São Paulo, online). 2017, June;4(3):M170305

Received for Publication on February 6, 2017; **First review** on April 12, 2017; **Accepted for publication** on May 10, 2017; **Online on** June 2, 2017

E-mail: carolinaalcantara@hotmail.com

INTRODUCTION

Stroke is currently the third leading cause of death in developed countries and the first for disability in the adult population, worldwide.[1,2] Although about 60% of surviving individuals regain the ability to walk, deficits in lower limbs functions often remain, affecting gait pattern and functional mobility.[3, 4]

Gait assessment is often performed in clinical practice, as well as in research projects, given that tridimensional analysis is considered the gold-standard for the evaluation of patients with gait disorders.[5-7] Some studies that assessed kinematic gait changes following stroke showed that the spatiotemporal asymmetries are among the main observed disorders.[8] Other changes observed in the gait pattern of this population include angular parameter disorders of joint movements in both stance and swing phase. Although a high variability can be found between subjects, some patterns are commonly observed in this population.[5, 9]

The analysis of specific gait parameters may provide important information to the evaluation of

DOI: 10.5935/MedicalExpress.2017.03.05

changes in gait pattern of post-stroke subjects. However, this analysis requires the interpretation of extensive data with compartmentalized information. In this sense, obtaining a single parameter that expresses the changes in gait pattern would help the gait assessment. It would also aid in designing interventions in this field.[10,11] Research has been performed aiming to identify indexes capable of comprehensively quantifying changes in gait pattern as well as classifying gait pattern as normal or pathologic compared to data obtained from healthy subjects.[12, 13]

One of the main indexes created for this purpose is the Gait Deviation Index (GDI). This index was initially validated in children with cerebral palsy; it quantifies the gait pattern as a single parameter based on a kinematic data set.[13]

The index result expresses the magnitude of changes in gait pattern compared to a control group. This index can be useful to gait change assessment by itself, to quantify the effect of a treatment or even to evaluate the natural improvement in gait pattern over time.[11]

However, no study has aimed to classify the gait pattern of hemiparetic post-stroke subjects through GDI score. Furthermore, most studies do not evaluate the gait changes for the entire motor system. Rather, they have been evaluating gait in a compartmentalized way, i.e., emphasizing only one or a few joints. Thus, the hypothesis tested in the present study is that post-stroke subjects present a decreased GDI score compared to healthy subjects, accompanied by changes in spatiotemporal gait parameters.

The general objectives of this research is to characterize the changes in gait pattern of hemiparetic compared to healthy subjects.

As specific objectives, we aim to characterize, through data extracted from an adequate database, the changes in gait pattern according to Gait Deviation Index (GDI) and the spatiotemporal gait parameters of chronic hemiparetic subjects compared to healthy subjects.

MATERIAL AND METHODS

General

This study was performed according to the guidelines and standards for human research (Resolution 466/2012, of the National Health Council) and it was approved by Ethics Committee of Hospital Israelita Albert Einstein – HIAE (case # 1.464.939).

This was a retrospective study, performed, through the analysis of kinematics data of the database obtained at the Gait Laboratory of Hospital Israelita Albert Einstein.

Subjects were included in the hemiparetic group if they presented a previous unilateral stroke, confirmed with imaging exams and medical reports. Patients diagnosed with chronic stroke (time post-lesion > 6 months), ischemic or hemorrhagic, were included. The participants, of both genders, and more than 21 years old, should have a walking score from 1 to 5 according to Functional Ambulation Category (FAC),[14] indicating that they are able to walk with or without a gait device. Subjects were excluded if they had not completed the kinematic evaluation for any reason, or if they did not fit the inclusion criteria of the study.

Procedures

Data extraction

The patients' medical charts were selected based on the study inclusion/exclusion criteria. Initially, a list with details regarding diagnostic history was consulted and the charts from people with diagnostic history of stroke were selected. Then, charts were analyzed one by one, for a more detailed selection regarding the patients that met the study criteria, allowing us to exclude patients with a previous history of bilateral stroke, subdural hemorrhage, post-traumatic brain injury, etc. After the selection, the charts were analyzed and the following information was extracted:

1. Demographic description and characterization of included sample (gender, age, time post-stroke, type of injury, hemiparesis side);
2. Data regarding step and stride time, cadence, opposite foot off, opposite foot contact, foot off, single and double support time, step and stride length, gait speed and Gait Deviation Index (GDI), resulting from gait kinematic evaluation performed at Laboratório de Estudos do Movimento do Hospital Israelita Albert Einstein (LEME).

Gait kinematics assessment protocol

Data were retrospectively extracted from the LEME database. For spatiotemporal gait parameters and GDI scores, a movement analysis system (Vicon Motion Capture System) consisting of ten cameras was used. Passive reflexive markers were fixed with adhesive tape on the following anatomical references: lateral malleolus, II metatarsus, calcaneus, tibialis crest, base of the patella, thigh, anterior superior iliac spine and sacrum. All kinematic data were collected with a sample frequency of 120 Hz.

The system was initially calibrated covering the data collection volume, according to the description of the equipment manual. Then, a static record was obtained for 5 seconds, during which the subject was advised to keep aligned in the orthostatic position with the arms along with the body and looking forward.

Subsequently, participants were instructed to walk 10 meters barefoot, at their self-selected comfortable walking speed.[15] They started walking 2 meters before the collecting area and finished 2 meters after. This procedure was performed aiming to exclude initial acceleration and final decelerating phases. The adaptation consisted

of three gait trials performed before the beginning of data collection.[7] For data analysis, five gait trials were consecutively collected.

All kinematic data were filtered with a 4th order filter, zero-lag, low pass Butterworth filter at 6 Hz (visual 3D™ Software C Motion, Inc., Rockville, MD, USA). This was followed by a calculation of spatiotemporal parameters through the Matlab Software (The MathWorks, Natick, Massachusetts) The Gait Deviation Index was calculated based on the kinematic data.

Statistical analysis

The information obtained from patients' medical charts was organized into spreadsheets. The condition (paretic, non-paretic or control limbs) was considered as the independent variable. The GDI score and spatiotemporal gait parameters were considered as dependent variables.

The data were tested for normality according to Kolmogorov-Smirnov test, while homogeneity was verified by Levene test. Since all variables presented non-parametric data, the Kruskal Wallis test was applied, followed by Mann-Whitney as a post-hoc test, to analyze differences between limbs. The significance level was set at $p \leq 0.05$, considering the Bonferroni adjustment for multiple comparisons ($\alpha = 0.017$). The SPSS software (Statistical Package for Social Science) version 17.0 for Windows was used for all statistical analysis.

RESULTS

Sample characterization

Table 1 shows the characterization data collected for the hemiparetic and the control group, consisting of 30 and 87 subjects, respectively. The healthy controls had no previous stroke history.

Gait Deviation Index (GDI)

The GDI score was lower for paretic (64.69 ± 16.29) and non-paretic (64.88 ± 15.00) limbs compared to control (101.01 ± 10.12; $p<0.001$). No differences were observed for GDI scores between paretic and non-paretic limbs ($p>0.99$). Figure 1 shows a representative graph for GDI scores for control, paretic and non-paretic limbs.

Table 1 - Sample characterization (hemiparetic group)

Variables	hemiparetic	controls
Age (years)	62 (45 – 81) [a]	55 (40 – 65) [a]
Gender(M/F)	18/12	44/43
Time post-stroke (months)	24 (14 - 84) [a]	Not applicable
Stroke type (isq./hemorr.)	23/7	Not applicable
Hemiparesis side(R/L)	16/14	Not applicable

[a] Data showed as mean (min – max).

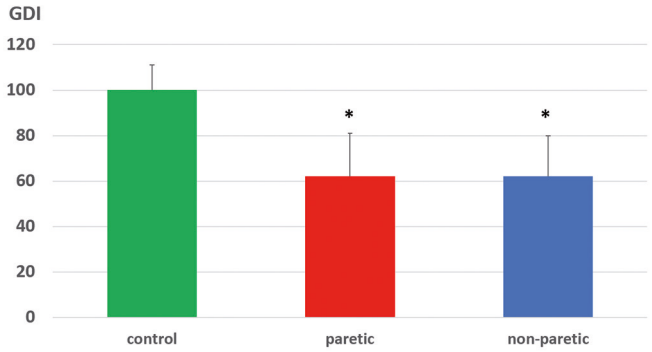

Figure 1. Gait Deviation Indices (GDI) scores for control, paretic and non-paretic limbs: Both paretic and non-paretic limbs have significantly lower values vs. observed in healthy controls, but do not differ between them

Spatiotemporal parameters

For all spatiotemporal variables, except for single support time, changes were observed in paretic and non-paretic limbs compared to control ($p<0.05$). For Opposite Foot Contact no difference were observed between the three groups; for single support post-stroke vs. controls, no difference was oberved for the paretic, but a difference occurred for the non-paretic limb. No differences were observed between paretic and non-paretic limbs ($p>0.05$). Table 2 presents the mean and standard deviation obtained for each variable for paretic, non-paretic and control limbs, as well as the comparisons between them.

DISCUSSION

The assessment of post-stroke gait changes is extremely important to delineate rehabilitation programs. The current study is the first to characterize the GDI concurrently with the description of spatiotemporal gait parameters of chronic post-stroke subjects. In general, the results of the present study demonstrate a decrease in GDI scores for chronic hemiparetic subjects, compared to healthy subjects, as well as changes in spatiotemporal gait parameters.

The GDI was initially proposed to analyze changes in gait pattern of children with cerebral palsy;[13] recently it has been used to evaluate gait in other populations, such as in subjects with Parkinson Disease,[11,16] post-hip arthroplasty[17] or lower limb amputation.[18] Because it allows the quantification of changes in gait pattern as a single parameter, the GDI results observed in the current study describe changes in gait patterns of chronic hemiparetic subjects through a concise parameter that requires less complex interpretation than a set of data presented separately. The decrease in GDI score in the gait analysis of stroke subjects compared to healthy subjects suggests that this index seems to be sensitive enough to detect changes in the gait pattern of these subjects.

Table 2. Spatiotemporal gait parameters

VARIABLE	Control	Paretic	Non-paretic
Stride time (sec)	1.06 ± 0.07	1.71 ± 0.66 *	1.72 ± 0.69 *
Step time (sec)	0.53 ± 0.04	0.87 ± 0.36 *	0.84 ± 0.44 *
Cadence (steps/min)	114.10 ± 70.88	79.21 ± 240.19 *	79.07 ± 240.45 *
OppositeFootOff (%cycle)	12.67 ± 20.26	21.27 ± 100.85 *	21.78 ± 60.80 *
OppositeFootContact (%cycle)	50.17 ± 10.24	48.20 ± 90.50	52.09 ± 90.61
FootOff (%ciclo)	62.55 ± 10.91	69.70 ± 90.84 *	73.20 ± 80.75 *
Single support (sec)	0.40 ± 0.03	0.42 ± 0.13	0.48 ± 0.14 *
Double support (sec)	0.27 ± 0.05	0.81 ± 0.59 *	0.82 ± 0.62 *
Stride length (m)	1.31 ± 0.11	0.73 ± 0.29 *	0.73 ± 0.29 *
Step length (m)	0.65 ± 0.05	0.37 ± 0.16 *	0.36 ± 0.15 *
Gait speed (m/sec)	1.25 ± 0.16	0.53 ± 0.32 *	0.53 ± 0.33 *

Data shown as mean ± SD. * Significant difference compared to control ($p < 0.05$).

Although the GDI does not elucidate by itself the cause of gait changes, it helps in the understanding the extent to which the pattern is altered.[16] Aiming to detail even more the characterization of these changes, some spatiotemporal parameters of gait were also evaluated in these chronic hemiparetic subjects. As expected, a decrease in gait speed, step and stride length during the double support phase was observed in the hemiparetic group compared to the control group. These findings are supported by previously reported studies[19] and highlight the importance of gait assessment and rehabilitation of this population in clinical practice.

Furthermore, an extended duration of the single stance phase was observed in non-paretic limbs compared to controls; in contrast, no such differences were observed between paretic and control limbs. A recent review[8] showed, based on studies that evaluated changes in gait kinematic post-stroke, that temporal asymmetries are among the main disorders observed in this population. On the other hand, spatial asymmetries, such as step and stride length, seem to be less consistent.[20] Although step and stride length are shorter in paretic and non-paretic limbs compared to healthy controls, no differences were observed between paretic and non-paretic limbs for these variables in the current study. A hypothesis that could explain these findings is the high heterogeneity that constitutes the post-stroke population. Some subjects present a longer stride length, while others present a shorter stride length compared to non-paretic side.[20] This variability could explain the absence of differences in step and stride length between paretic and non-paretic limbs demonstrated in the present study. It is noteworthy that the findings of the current study regarding GDI and the spatio-temporal parameters demonstrate changes in gait pattern in both paretic and non-paretic limbs post-stroke. Such changes might be a direct consequence of central nervous system injury, but may also be due to learning and adaptation/compensation processes in response to these consequences.[8] In this sense, these results provide support to the understanding of the characterization of gait changes in chronic post-stroke subjects. Furthermore, they highlight the need of emphasizing the patient as an integral entity, rather than the object of a targeted study of particular limbs during gait rehabilitation. Additionally, the GDI score seems to be a feasible tool to quantify the changes in gait pattern during evaluation of chronic stroke subjects.

The current study presents some limitations. First, the subjects considered for control group were not matched by gender or age with hemiparetic group. However, despite these limitations, the control group has its relevance in the present study since it represents, in a general way, the normality parameters for healthy subjects. Second, the heterogeneity of the post-stroke sample, such as different types of injury and time post-stroke also constitutes a limitation of this study. Future studies might be performed aiming to elucidate changes in gait pattern considering samples with specific characteristics, i.e., bearing more homogenous post-stroke characteristics.

CONCLUSION

The findings of the current study demonstrate that GDI seems to be a sensitive parameter to identify changes in gait pattern of chronic hemiparetic post-stroke subjects. This index may contribute relevant information regarding gait changes in only one parameter, without the necessity of an extensive interpretation of multiple data. Future studies should be conducted to evaluate the gait changes through GDI score in groups with different post-stroke characteristics. Moreover, studies should aim to identify the effectiveness of this index to detect changes in gait pattern following rehabilitation protocol of these post-stroke subjects.

CONFLICT OF INTEREST

Authors report no conflict of interest regarding this project

AUTHOR PARTICIPATION

CCA- Lead author, wrote the manuscript, analyzed the data;

ACA- Corrected the manuscript;

DSS - Corrected the manuscript, analyzed the data, supervisor.

O USO DO ÍNDICE DE DESVIO DE MARCHA PARA A AVALIAÇÃO DE PACIENTES HEMIPARÉTICOS APÓS ACIDENTE VASCULAR CEREBRAL

BASES: O Índice de Desvio da Marcha, inicialmente utilizado para avaliar a marcha de crianças com paralisia cerebral, tem sido utilizado como parâmetro quantitativo de alterações de marcha de indivíduos com outras condições. No entanto, não existem estudos que avaliem alterações no padrão de marcha de indivíduos hemiparéticos crônicos pós-AVC com base nesse índice.

OBJETIVOS: Caracterizar as alterações no padrão de marcha de acordo com o Índice de Desvio da Marcha e parâmetros espácio-temporais da marcha de sujeitos hemiparéticos crônicos em relação a indivíduos saudáveis.

MÉTODOS: Estudo retrospetivos. Os dados foram obtidos a partir da base de dados do Laboratório de Marcha do Hospital Israelita Albert Einstein. Trinta indivíduos foram incluídos neste estudo, com AVC unilateral, isquêmico ou hemorrágico, crônico (tempo pós-lesão> 6 meses) e habilidade de caminhada classificada como 2, 3, 4 ou 5 segundo a Categoria de Ambulação Funcional. Os dados de 87 indivíduos saudáveis foram incluídos no grupo controle, obtido a partir da base de dados de normalidade. A análise estatística foi aplicada através do teste de Kruskall Wallis, seguido do teste pós-hoc de Mann-Whitney, considerando um valor p crítico <0,05.

RESULTADOS: Os valores observados para o Índice de Desvio da Marcha foram menores para os membros paréticos (64,69 ± 16,29) e não-paréticos (64,88 ± 15) em relação ao controle (101,01 ± 10,12; p <0,001). Não foram observadas diferenças nos escores do Índice de Desvio da Marcha entre os membros paréticos e não paréticos (p> 0,99).

CONCLUSÃO: Os achados do presente estudo demonstram que o Índice de Desvio da Marcha pode ser um parâmetro sensível para identificar alterações no padrão de marcha de indivíduos hemiparéticos crônicos pós-AVC.

PALAVRAS-CHAVE: AVC, marcha, cinemática, hemiparética

REFERENCES

1. World Healthy Organization (WHO) 2015. [captured on 01 april. 2015]. Available at:http://www.who.int/cardiovascular_diseases/resources/atlas/en/.
2. Preston E, Ada L, Dean CM, Stanton R, Waddington G. What is the probability of patients who are nonambulatory after stroke regaining independent walking? A systematic review. Int J Stroke. 2011;6(6):531-40. DOI: 10.1111/j.1747-4949.2011.00668.x.
3. Gerrits KH, Beltman MJ, Koppe PA, Konijnenbelt H, Elich PD, de Haan A, et al. Isometric muscle function of knee extensors and the relation with functional performance in patients with stroke. Arch Phys Med Rehabil. 2009;90(3):480-7. DOI: 10.1016/j.apmr.2008.09.562.
4. Chisholm AE, Perry SD, McIlroy WE. Correlations between ankle-foot impairments and dropped foot gait deviations among stroke survivors. Clin Biomech. 2013;28(9-10):1049-54. DOI: 10.1016/j.clinbiomech.2013.09.007.
5. Yavuzer G, Oken O, Elhan A, Stam HJ. Repeatability of lower limb three-dimensional kinematics in patients with stroke. Gait Posture. 2008;27(1):31-5. DOI: 10.1016/j.gaitpost.2006.12.016.
6. McGinley JL, Morris ME, Greenwood KM, Goldie PA, Olney SJ. Accuracy of clinical observations of push-off during gait after stroke. Arch Phys Med Rehabil. 2006 Jun;87(6):779-85. DOI: 10.1016/j.apmr.2006.02.002.
7. Boudarham J, Roche N, Pradon D, Bonnyaud C, Bensmail D, Zory R. Variations in kinematics during clinical gait analysis in stroke patients. PloS one. 2013;8(6):e66421. DOI: 10.1371/journal.pone.0066421.
8. Balaban B, Tok F. Gait disturbances in patients with stroke. PM R. 2014;6(7):635-42. DOI: 10.1016/j.pmrj.2013.12.017.
9. Woolley SM. Characteristics of gait in hemiplegia. Top Stroke Rehabil. 2001 Winter;7(4):1-18. DOI: 10.1310/JB16-V04F-JAL5-H1UV.
10. Wren TA, Do KP, Hara R, Dorey FJ, Kay RM, Otsuka NY. Gillette Gait Index as a gait analysis summary measure: comparison with qualitative visual assessments of overall gait. J Pediatr Orthop. 2007;27(7):765-8. DOI: 10.1097/BPO.0b013e3181558ade.
11. Galli M, Cimolin V, De Pandis MF, Schwartz MH, Albertini G. Use of the Gait Deviation index for the evaluation of patients with Parkinson's disease. J Mot Behav. 2012;44(3):161-7. DOI: 10.1080/00222895.2012.664180.
12. Schutte LM, Narayanan U, Stout JL, Selber P, Gage JR, Schwartz MH. An index for quantifying deviations from normal gait. Gait Posture. 2000;11(1):25-31. DOI: 10.1016/S0966-6362(99)00047-8.
13. Schwartz MH, Rozumalski A. The Gait Deviation Index: a new comprehensive index of gait pathology. Gait Posture. 2008;28(3):351-7. DOI: 10.1016/j.gaitpost.2008.05.001.
14. Wade D. Measurement in Neurological Rehabilitation. Curr Opin Neurol Neurosurg. 1992;5(5):682-6.
15. Kinsella S, Moran K. Gait pattern categorization of stroke participants with equinus deformity of the foot. Gait Posture. 2008;27(1):144-51. DOI: 10.1016/j.gaitpost.2007.03.008
16. Speciali DS, de Oliveira EM, dos Santos NM, Pereira FV, Fracini AC, Fukuda TY, et al. Use of the Gait Deviation Index and spatiotemporal variables for the assessment of dual task interference paradigm. J Bodyw Mov Ther. 2013;17(1):19-27. DOI: 10.1016/j.jbmt.2012.03.001.
17. Jensen C, Rosenlund S, Nielsen DB, Overgaard S, Holsgaard-Larsen A. The use of the Gait Deviation Index for the evaluation of participants following total hip arthroplasty: An explorative randomized trial. Gait Posture. 2015;42(1):36-41. DOI: 10.1016/j.gaitpost.2015.02.009.
18. Kark L, Vickers D, McIntosh A, Simmons A. Use of gait summary measures with lower limb amputees. Gait Posture. 2012;35(2):238-43. DOI: 10.1016/j.gaitpost.2011.09.013.
19. Stokic DS, Horn TS, Ramshur JM, Chow JW. Agreement between temporospatial gait parameters of an electronic walkway and a motion capture system in healthy and chronic stroke populations. Am J Phys Med Rehabil. 2009;88(6):437-44. DOI: 10.1097/PHM.0b013e3181a5b1ec.
20. Balasubramanian CK, Bowden MG, Neptune RR, Kautz SA. Relationship between step length asymmetry and walking performance in subjects with chronic hemiparesis. Arch Phys Med Rehabil. 2007 Jan;88(1):43-9. DOI: 10.1016/j.apmr.2006.10.004