**UNIVERSIDADE FEDERAL DE CIÊNCIAS DA SAÚDE DE PORTO ALEGRE**

**CURSO DE FISIOTERAPIA**

**GUILHERME FAÉS VARGAS**

# Gait parameters in chronic post-stroke walking: a comparison between outdoor and laboratory environment

Porto Alegre

2022

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# Gait parameters in chronic post-stroke walking: a comparison between outdoor and laboratory environment

Trabalho de Conclusão de Curso de Fisioterapia, da Universidade Federal de Ciências da Saúde de Porto Alegre, como requisito parcial para obtenção do título de Bacharel em Fisioterapia

Orientador: Aline de Souza Pagnussat
Coorientador: Maira Jaqueline da Cunha

Porto Alegre
2022

Catalogação na Publicação

Vargas, Guilherme Faés
Gait parameters in chronic post-stroke walking: a comparison between outdoor and laboratory environment / Guilherme Faés Vargas. -- 2022.
25 p. : tab. ; 30 cm.

Monografia (trabalho de conclusão de curso) -- Universidade Federal de Ciências da Saúde de Porto Alegre, Curso de Fisioterapia, 2022.

Orientador(a): Aline de Souza Pagnussat ; coorientador(a): Maíra Jaqueline da Cunha.

1. Gait analysis. 2. Stroke. 3. Spatiotemporal parameters. 4. Movement Analysis. 5. Accelerometers. I. Título.

Sistema de Geração de Ficha Catalográfica da UFCSPA com os dados fornecidos pelo(a) autor(a).

**Gait parameters in chronic post- stroke walking: a comparison between outdoor and laboratory environment**

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Porto Alegre
2022

**À minha família e amigos, especialmente a Virgínia Faés, "in memorian".**

## AGRADECIMENTOS


A minha família, Faés, Vargas e Nunes, por todo esforço e abdicação que tiveram para que eu possa viver esse momento.

Aos meus sobrinhos e afilhado, Marcelo, Virgínia e Murillo que me fazem ver a vida de uma forma completamente diferente cada dia.

Aos meus amigos, que sempre estiveram ao meu lado, nos melhores e piores momentos.

A turma da Fisioterapia 22, pelo acolhimento e por ter tornado o último ano de graduação muito mais leve e alegre.

Aos demais colegas da Fisioterapia e UFSCPA, pelas trocas de experiências e conhecimento.

Aos preceptores dos estágios, pela recepção, acolhida e todo conhecimento compartilhado. Aos pacientes em que encontrei durante esses anos.

Aos professores e funcionários da UFCSPA, por todas as aulas, conselhos, paciência, ensinamentos e trabalhos que marcaram minha trajetória na universidade e fora dela.

A minha orientadora, Aline Pagnussat, a quem admiro e me espelho, como professora e ainda mais como pessoa. Agradeço a confiança e a oportunidade de realizar esse trabalho.

A minha co-orientadora, Maíra Jaqueline, uma pessoa com uma paciência e serenidade admiráveis, me cobrando quando deveria, ajudando quando preciso, sempre atenta e sensível aos momentos que passei durante os últimos anos. Creio que nunca irei agradecer o suficiente.

Por fim aos companheiros de jornada que estiveram comigo desde o início e permanecem até hoje: Augusto Tamujo, Bruna Maurmann, Celso Casaril, Eduardo Baumgardt, Felipe Corrêa, Fernanda Winterscheidt, Gabriela Pedretti, Jonathan Pereira, Mattheus Cancelli, Micheli Carlesso, Paulo Henrique Lemos e Vitor Dalpizol.

## RESUMO

**Objetivo:** Avaliar os parâmetros espaço-temporais da marcha em indivíduos pós-AVC caminhando em ambiente externo e compará-los com os obtidos em laboratório.

**Design:** Os parâmetros espaço-temporais da marcha velocidade (m/s), cadência (passos por minuto) e comprimento da passada (m) foram adquiridos durante o teste de caminhada em ambiente externo com uma unidade de medida inercial (IMU) e o teste de caminhada em laboratório com um sistema optoeletrônico (OES).

**Resultados:** Trinta e dois indivíduos pós-AVC crônicos foram incluídos. Dois participantes foram excluídos da análise por falha no processamento dos dados. O teste t de amostra pareada apresentou maior velocidade ($t(29)=3,19$; $p=0,003$), comprimento da passada ($t(29)=5,58$; $p<0,001$) e cadência ($t(29)=5,59$; $p<0,001$ ) quando os indivíduos foram avaliados no ambiente externo comparado ao laboratório.

**Conclusão:** Os parâmetros espaço-temporais da marcha foram afetados pelos diferentes fatores externos típicos do ambiente clínico e laboratorial.



Palavras-chave: Análise da marcha, Acidente Vascular cerebral, Parâmetros espaço-temporais, Análise do movimento, Acelerômetro.

**ABSTRACT**

**Objective:** To evaluate the temporospatial gait parameters in post-stroke subjects walking in an external environment and compared them with those obtained in the laboratory.

**Design:** The spatiotemporal gait parameters gait speed (m/s), cadence (steps per min), and stride length (m) were acquired during the walking test in the outdoor environment using an inertial measurement unit (IMU) and walking test in the laboratory using an optoelectronic system (OES).

**Results:** Thirty-two chronic post-stroke individuals were included. Two participants were excluded from the analysis due to data processing fault. The paired-sample t-test exhibited higher speed ($t(29)=3.19$; $p=0.003$), stride length ($t(29)=5.58$; $p<0.001$) and cadence ($t(29)=5.59$; $p<0.001$) when subjects were assessed in outdoor environment compared to the laboratory.

**Conclusion:** The spatiotemporal gait parameters were affected by the different external factors typical of the clinical and laboratory settings.

**Key words:** Gait analysis, Stroke, Spatiotemporal parameters, Movement Analysis, Accelerometers

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## LISTA DE ABREVIATURAS E SIGLAS

**10MWT -** 10-meter walk test

**CAAE -** Presentation Certificate for Ethical Appreciation

**FMA-LL -** Fugl-Meyer Assessment Lower Limb

**IMU -** Inertial Measurement Unit

**LL -** Lower Limb

**MAS -** Modified Ashworth Scale

**MMSE -** Mini-Mental State Examination

**OES -** Optoelectronic System

**STROBE -** Strengthening the Reporting of Observational Studies in Epidemiology

**TUG -** Time Up and Go test

**UFCSPA -** Federal University of Health Sciences of Porto Alegre

## SUMÁRIO

**Gait parameters in chronic post- stroke walking: a comparison between outdoor and laboratory environment**

(American Journal of Physical Medicine and Rehabilitation)

(Fator de Impacto: 2.159)

(Qualis A1)

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## 1. Introduction

Hemiparetic gait is characterized by asymmetry, reduced voluntary motor control, muscle weakness [1-3], and delayed and reduced weight bearing on the paretic limb [4], which causes a higher duration in double stance and paretic swing phases, and reduced paretic single stance phase duration and stride length [5]. Besides a marked asymmetry, they often have slower gait velocity and cadence [6, 7]. In this context, gait impairments cause difficulties in performing activities of daily living and reduce independence [8].

Accurate gait assessment is a helpful tool in neurorehabilitation and is an essential precondition to treat patients and measure motor recovery [9-11]. In a clinical setting, gait assessment is often measured with10-meter walk test (10MWT). Usually, 10MWT assessments are based on the total time to complete the task, being a method to measure the gait speed; however, it does not allow a detailed and precise knowledge of all the temporospatial gait cycle [12, 13]. More detailed analysis cannot be performed without the instrumental support of devices specifically designed for human movement analysis.

The optoelectronic system (OES) is the current gold standard for gait analysis; it is possible to obtain better information about the gait cycle [14]. Although instrumented evaluation systems are less subjective and more sensitive, they are expensive and require a well-trained and specific laboratory for installation that is not easily portable [15-17].

Accelerometers are inertial measurement units (IMU) that have been regularly used to evaluate, among other aspects, gait alterations [18], and they have equally effective and reliable systems compared with those obtained in the laboratory using the OES [19-24]. Even though they are still not fully part of the routine clinical assessment, their portability allows the investigation of gait biomechanics outside the laboratory environment [18, 25, 26], providing a more ecological gait assessment [27]. Thereby, providing a more valid and realistic assessment of the distinct stroke gait impairment.

Walking in outdoor environments can be challenging for individuals with motor impairment, especially those with severe compromise [16, 17]. Different surfaces can present significant challenges as they require changes in stride length, foot placement on the ground, and balance adjustments during gait [28].

The environment can influence the test results, and the study found that subjects with Parkinson's disease presented the highest speed and longest strides when assessed in the most ecological situation [15].

Since these considerations, the objective of this study was to evaluate the temporospatial gait parameters in post-stroke subjects while walking in an outdoor environment using an accelerometer and compare them with those obtained in the laboratory using an OES. We aimed to verify if the parameters may be affected by the different environmental conditions (clinical and laboratory settings).

## 2. Materials and Methods

### 2.1. Study Design

This cross-sectional study was approved by the Ethics and Research Committee of the Santa Casa de Misericórdia Hospital of Porto Alegre (CAAE 64819617.0.0000.5335) and was conducted according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist [29]. According to the Mini-Mental State Examination (MMSE) score (Table 1), all participants were presumed competent for decision-making and, for this reason, signed the informed consent.

### 2.2 Participants

Volunteers were recruited through a database of the Santa Casa de Misericórdia Neurology service in Porto Alegre and social networks and then selected according to eligibility criteria. We included individuals with ischemic or hemorrhagic chronic stroke more than six months previously confirmed by imaging (tomography or magnetic resonance imaging); aged between 18 and 80 years; with mild (29-34/34), moderate (20-28/34) or severe (0-19/34) motor impairment according to the Fugl Meyer assessment lower limb (FMA-LL) score [30, 31]; walk at least 10 meters with or without assistance; minimum score of 20/30 points (illiterate) or > 24/30 points (literate) from the MMSE [32]. Furthermore, we also excluded individuals with lower limb musculoskeletal disorders that could interfere in gait and significant visual impairment.

## 2.3. Procedures

This study was conducted at the Movement Analysis and Rehabilitation Laboratory at UFCSPA. Each participant underwent a clinical and documented evaluation session. Indirect assessment of spasticity done of *Modified Ashworth Scale (MAS)* [33] that consists of 6 ordinal values ranging from 0 (no tonus increase) to 4 (stiffness) [34]. Participants were evaluated lying in a supine position and were instructed to remain relaxed during the test. Spasticity of plantar flexors, knee extensors, and hip adductors was tested. FMA [30] was used to assess motor impairment of the lower limb (LL). This scale measures voluntary movement, velocity, coordination, and reflex activity. Each item has three possible scores, 0 (cannot be performed), 1 (partially performed) and 2 (performed entirely).

## 2.4. Outcomes measures

### *2.4.1 Inertial Sensor Gait analysis*

Participants were asked to walk at self-selected speed on a 10-meters flat stone pathway of the university outdoors. This pathway was sheltered from the rain, but participants constantly crossed with other people and received several sensory stimuli during the task. Data were acquired at least twice for each participant. During the evaluation, participants wore an IMU (BTS G-Walk BTS Bioengineering Corporation, Italy). The IMU was attached to the subjects' waists with a semi-elastic belt, covering the L5 S1 segments [35]. Data were transmitted via Bluetooth to a PC, from the acceleration signals, the spatiotemporal gait parameters (gait speed, cadence, and stride length) are automatically obtained using the dedicated BTS G-STUDIO version 2.6.12.0 software [35-37].

### *2.4.2. 3D Gait analysis system*

Gait was assessed using a 3D motion analysis system (BTS Bioengineering, Italy) composed of 6-infrared cameras. Twenty-two retro-reflective spherical markers were placed on anatomic landmarks, as described by the Davis protocol [38]. Participants were asked to walk at a self-selected speed, barefoot, along an eight-meters flat wood pathway, with the assistive walking devices (e.g. cane) if used on a regular basis. They were allowed to take a rest break after each trial. It recorded at least two trials and calculated the mean of them. Raw data were processed using the SMART analyzer software (Version 1.10.458.0 - BTS Bioengineering, Italy). Spatiotemporal gait parameters: gait speed (m/s), cadence (steps per min), and stride length (m).

2.5 Statistical Analysis

Sample size was determined using the G-Power 3.0 software based on previous studies [39-41], considering 90% power and alpha value of 0.05 to detect a minimum clinical difference of 20% in gait speed. Thirty-two participants were estimated as necessary for this study.

Data were expressed as mean and 95% confidence intervals. Shapiro-Wilk tests were used to evaluate the normally of the continuous variables. The spatiotemporal gait measurements obtained by the IMU and those obtained by OES were compared using paired-sample t-tests. Effect sizes were calculated (G-Power) and classified according to Cohen as small (0.2), moderate (0.5), and large (0.8). An effect size > 0.4 is considered clinically relevant [42]. We used the SPSS statistical software version 21.0 for all analyses. The significance levels were set at $p < 0.05$.

## 3. Results

Forty-two individuals with chronic post-stroke were screened for eligibility between September 2019 and March 2020. Out of these forty-four subjects, only thirty-two matched the inclusion criteria and were enrolled in the study and performed outdoor environment and the laboratory walk evaluations. After data collection, two participants were excluded due to data processing fault. The flowchart is presented in Figure 1. The demographic characteristics are presented in Table 1. Most of our sample have an ischemic stroke (73.3%), in the right hemisphere (60%), and present a severe motor impairment according to the LL-FMA.

Statistical analysis revealed a significant effect related to the type of test for all gait parameters. The experimental condition appears to affect gait speed, cadence, and stride length. In particular, with regard to speed and cadence, the paired-sample t-test exhibited higher speed ($t(29)=3.19$; $p=0.003$) and cadence ($t(29)=5.59$; $p<0.001$) for patients when they were assessed with the in outdoor environment compared to the laboratory. The stride length ($t(29)=5.58$; $p<0.001$) was higher in patients when they were assessed with the in outdoor environment than with the to the laboratory.

## 4. Discussion

This study aimed to compare spatiotemporal gait parameters in post-stroke subjects in different conditions: outdoor environment and environment. Our results confirm the preliminary expectations – the gait parameters are influenced by the situations in which patients are assessed. The data revealed the highest speed, cadence, and stride length when post-stroke individuals were assessed in the ecological situation compared to the laboratory condition.

The results of the present study have substantial implications in the clinical assessment of post-stroke, particularly regarding the different situations in which they are assessed. Previous studies demonstrated that the experimental setting affects gait speed [15, 43] and stride length [15] in Parkinson's subjects. Zampieri et al., [44], evaluated six Parkinson's subjects and eight healthy controls; both groups exhibited a lower latency to complete the Time Up and Go test (TUG) when they performed it at home than performed in the laboratory. From this point of view, our findings are consistent with previous studies. The quantitative gait analysis difference may be due to the different conditions in which tests are performed (e.g. presence of footwear and external environment) both in neurologic pathologies and healthy conditions.

The OES is the gold standard for gait analysis [14];However, the laboratory environment does not reproduce the functional activity walking challenges of post-stroke individuals. The IMU is a valid and reliable alternative to analyzing the "real contexts"[15, 45-47]. Several previous studies demonstrate that the IMU are a technique with accuracy very similar to that obtained in tests carried out in the OES [15, 19-21, 23, 24, 45]. Accelerometers are a valuable alternative to evaluate post-stroke individuals in an ecological context and reduce the laboratory settings limitations, such as the highly controlled environment and reduced experimental area [23, 48]

This study has some limitations that need to be highlighted. Firstly, there was a difference in the overall length of the path that participants were requested to walk. The pathway on which the OES is installed has 8 meters, while the outdoor walk distance available was a 10-meter pathway. Other factors may also be responsible for the result, there was no standardization regarding the clothing used in the outdoor environment. They wore footwear of their own choice, so there was no material standardization at the laboratory, the tests were performed barefoot and undressed. Also, there was no standardization regarding the walking surface, which could influence the results. The environment and conditions in which the tests were performed may affect the spatiotemporal gait parameter. Further studies could assess the effect of the presence/absence of footwear on gait parameters in post-stroke using an IMU inside the laboratory condition. Finally, two samples were excluded from the analysis due to a data processing fault, and for this reason, we did not achieve the required sample size.

In conclusion, this study demonstrated that the spatiotemporal gait parameters were affected by the different external factors typical of the clinical and laboratory settings. The results of the present study have implications for the clinical assessment of post-stroke subjects as regards the homogeneity of situations in which they are assessed.

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**Figure 1 -** Flow diagram of the study

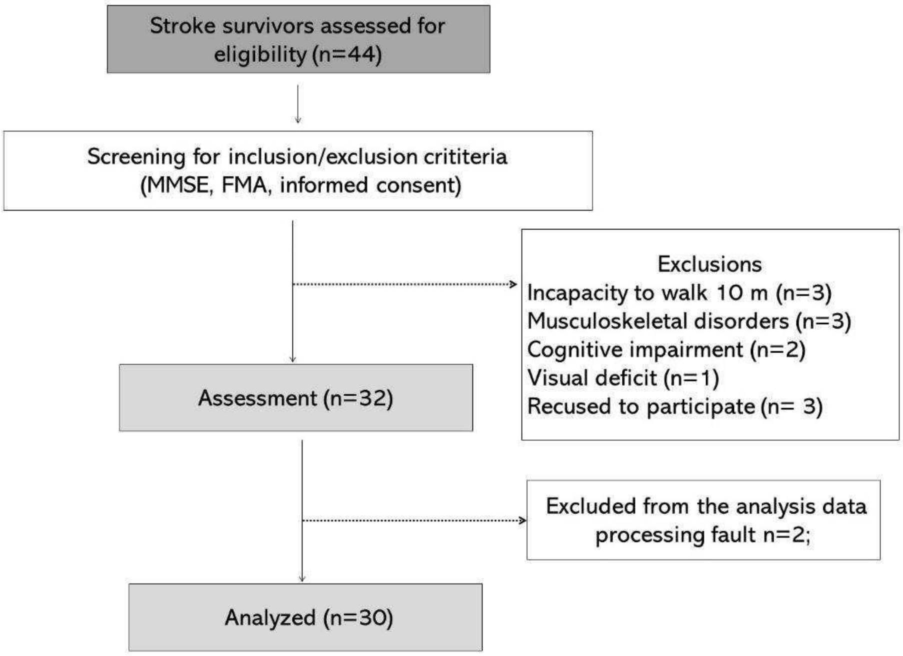

**Table 1. Demographic characteristics**

| | **Subjects** (n=30) |
|---|---|
| **Gender, n (%)** | |
| Male | 20 (66.6) |
| **Age, years, mean ±SD** | 56.1 (±8.84) |
| **MMSE score, median (min-max)** | 29 (21 - 30) |
| **Stroke type, n (%)** | |
| Ischemic | 22 (73.3) |
| Hemorrhagic | 8 (26.6) |
| **Time since stroke, month, median (min-max)** | 37 (6-96) |
| **Affected hemisphere, n (%)** | |
| Left | 12 (40) |
| Right | 18 (60) |
| **Motor impairment, median (min-max)** | |
| FMA-LL (0-34) | 19 (11 -32) |
| **Spasticity, MAS, frequency (0/1/1+/2/3/4)** | |
| Plantar Flexors | (0/3/2/3/11/11) |
| Knee Extensors | (5/6/6/4/7/2) |
| Hip Adductors | (5/4/4/10/7/0) |

Note: n = number of participants; SD, standard deviation; max, maximum; min, minimum; MMSE = Mini-Mental State Examination; FMA-LL = Fugl Meyer Assessment - Lower Limb; MAS = Modified Ashworth Scale

**Table 2. Spatiotemporal Gait Parameters**

| | IMU (n=30) | OES (n=30) | Paired Sample Test | | |
|---|---|---|---|---|---|
| | | | t | *p-value* | Effect Size |
| Gait Speed (m/s) | 0.62 (0.53-0.71) | 0.55 (0.46-0.65) | 3.19 | **0.003** | 0.24 |
| Cadence (step/min) | 91.53 (84.03-99.02) | 81.18 (73.44-88.92) | 5.59 | **< 0.001** | 0.46 |
| Stride length (m) | 1.17 (1.02-1.32) | 0.79 (0.69-0.87) | 5.58 | **< 0.001** | 1.09 |

Note: Data are mean and 95% confidence intervals (CI); n=number of participants; IMU – Inertial Measurement unit; OES - Optoelectronic System.