Original Article

Gait Spatiotemporal Characteristics of Hospitalized Adult Patients with Chronic Heart Failure

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Abstract

Background: **Patients with chronic heart failure (CHF) have a decreased ability to walk, which has been related to the occurrence of hospitalizations and mortality and appears to be associated with the severity of the disease.**

Objective: **To describe spatiotemporal gait characteristics of adult patients hospitalized with CHF.**

Method: **Cross-sectional observational study. Participants diagnosed with CHF, between 18 and 60 years old, functional classification II and III, who were medically authorized to walk as prescribed in their medical records, were included. The walking cycle was based on a distance of 10 meters in a flat, marked corridor.**

Results: **30 individuals participated in the study. The sample was mostly composed of females (n=17; 56.7%) with an average age of 44.5 years. The main etiology was valvular heart disease (n=15;50%), with an average ejection fraction of 44.6%. A strong correlation was observed between gait speed and cadence (r=0.74; p<0.01)) and a moderate correlation between gait speed and stride length (r=0.56; p<0.01). Regarding gait speed, 36.6% of those assessed had values less than or equal to 0.8 meters/second, while 16.6% obtained results above 1m/s.**

Conclusion: **A strong correlation was observed between walking speed and cadence, and a moderate correlation between walking speed and stride length. The other gait parameters were not correlated with each other. According to what was observed in the literature, speed, cadence, stride length, and swing phase were reduced, while there was a slight increase in the stance phase when compared to healthy individuals.**

Keywords: **Spatio-Temporal Analysis; Heart Diseases; Heart Failure; Walking Speed.**

Introduction

Chronic heart failure (CHF) is a syndrome characterized by an abnormality in the structure and/or function of the heart that leads to a decrease in the blood supply needed to meet the body's metabolic demands.[1] It has affected approximately 23 million people worldwide,[1] and it is estimated that, by the year 2030, the number of adult patients with CHF will increase by 46%.[2]

With varied and progressive intensity,[3] these patients have common symptoms, such as dyspnea on exertion, that are associated with impaired functional capacity and independence, poor life quality, exercise intolerance, limitations in performing daily living activities, and consequent social impact.[4]

Reduced exercise capacity is a common finding in this profile of patients,[4] in which peripheral adaptations are also observed, such as muscle mass and strength loss,[5,6] and it disables them to sustain the action needed to perform an efficient gait.[5] The ability to move around supports many basic and instrumental activities necessary for independence, and difficulties in carrying it out establish a crucial point in the individual's functional trajectory.[7]

Patients with CHF have decreased walking ability, which has been related to the occurrence of hospitalizations and mortality, and there seems to be an association with the disease's severity.[8] Instrumented gait analysis has been used to obtain quantitative data regarding its function.[9] In particular, spatiotemporal parameters are widely used in the clinic because they objectively describe the main events of the walking cycle and reflect the patient's ability to meet his/her general needs.[9]

Among the studied gait variables, speed has stood out, as it influences the other spatiotemporal parameters,[10] in addition to its clinical relevance as a predictor of functional disability.[11] Knowing the gait particularities in this patient profile can help to understand how possible changes can affect the walking pattern and to determine rehabilitation methods aimed at improving functional capacity, preventing risks and outcomes.[12]

No studies were found that characterized the spatial-temporal gait in adult patients with CHF, or that observed

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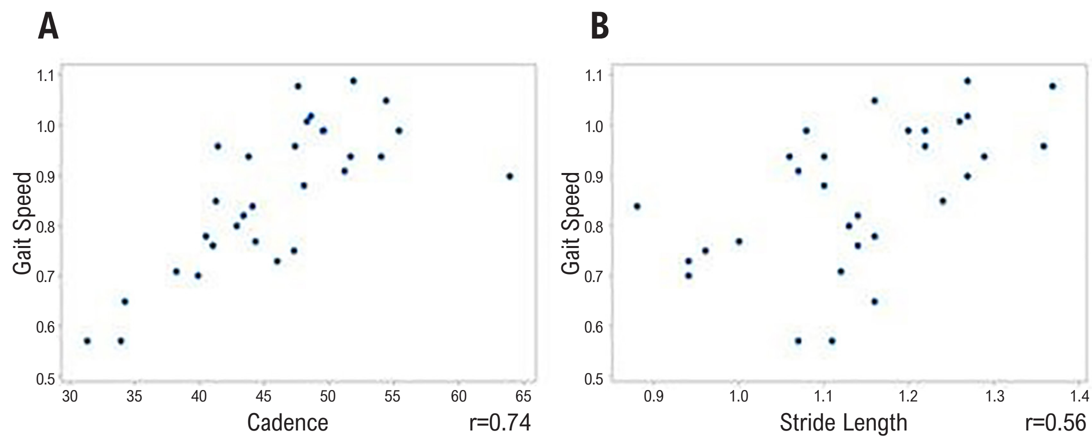
Central Illustration: Gait Spatiotemporal Characteristics of Hospitalized Adult Patients with Chronic Heart Failure



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Correlation between gait speed and cadence (A) and between gait speed and stride length (B) of the sample of patients with heart failure (n=30).

possible correlations between these data. Most studies that assess gait in this population portray elderly individuals, justifying our choice to assess how walking behaves in younger patients. Thus, this study aimed to describe the gait spatiotemporal characteristics of hospitalized adult patients with CHF.

Materials and Methods

This was a cross-sectional observational study conducted with patients admitted to the cardiology ward of Professor Edgar Santos University Hospital in Salvador, Bahia, Brazil. All participants signed the Informed Consent Form. This research was approved by the Research Ethics Committee of the Professor Edgar Santos University Hospital in Salvador, Bahia, Brazil, under opinion number 2.230.651, according to the Declaration of Helsinki.

Patients diagnosed with CHF participated in the study, aged between 18 and 60 years, functional classification II and III characterized through the New York Heart Association (NYHA) scale, and those that had medical clearance for walking prescribed in the medical chart. Those with rheumatic, neuromuscular, orthopedic, and/or traumatological diseases that could bring previous changes in the walking evaluation, in addition to clinical and hemodynamic conditions that would put them at risk, such as complaint of chest pain, dyspnea, basal heart rate (HR) > 100 beats per minute (bpm), peripheral oxygen saturation (SpO2) < 92%, systolic blood pressure (SBP) < than 90 mmHg or > 140 mmHg, and diastolic blood pressure (DBP) < than 60 mmHg or > 90 mmHg, were not included.

Participants who, while walking, needed to interrupt the evaluation due to changes in the clinical and hemodynamic criteria described above were excluded from the study. The variables chosen for monitoring were HR, SBP, DBP, and SpO2. Blood pressure (BP) was measured according to the 7th Brazilian Guideline on Hypertension,[13] following this sequence: BP was measured in the supine position, at the first minute after sedestation, and at the first and third minutes after assuming orthostasis. The HR and the SpO2 were monitored continuously.

Two different researchers performed data collection. The first was responsible for analyzing the patient selection criteria in the medical records. A second evaluator was responsible for collecting the clinical and hemodynamic variables and performing the gait evaluation without prior knowledge of the functional classification of each patient. The information on epidemiological and clinical data was collected from the medical records and recorded on a form prepared by the researchers. When necessary, each patient was approached in their bed in the ward for a maximum of three attempts, with an explanation of the test's dynamics and vital signs measurement.

For the gait parameters analysis, a device called BTS G-Walk (BTS Bioengineering - Free4act - ACC0774N, Italy) was used, a wireless portable system that uses an inertial sensor connected to a computer via Bluetooth, allowing us to determine spatial-temporal parameters based on the weight and height of each evaluated patient.[14] The sensor was located around the participant's waist and remained protected by an ergonomic strap, allowing the body's flowing movement with freedom to walk anywhere. At the end of the test, a report was automatically generated, showing the test parameters calculation.[14]

The space for the gait cycle execution was based on a distance of 10 meters in a flat and demarcated corridor, in which the participants were guided in a standardized manner to perform the walk. To eliminate the acceleration and deceleration component, the volunteers were asked to start the walk 1.5 meters before the beginning of the route and to finish it 1.5 meters after the 10-meter distance. The gait evaluation was performed only once.

The following parameters chosen for evaluation were: Gait variables: walking speed (meters/second - m/s), stride length (meters-m), cadence (strides/minute), stance phase, and swing phase (%). Epidemiological variables were gender and age. Variables related to CHF: functional classification, etiology, left ventricular ejection fraction (LVEF), and length of stay (at the time of collection).

Gait speed ≤ 0.8 m/s will be considered as low performance for moving forward, while data above 1 m/s will be considered as a normal value.[11] The LVEF measurement was carried out through an ultrasound examination carried out during the period of hospitalization by a doctor specialized in the area.

The sample was selected by convenience in a non-probabilistic manner. A descriptive analysis was performed to identify the general and specific characteristics of the studied sample. The Shapiro-Wilk test was used to verify the normality of the data distribution, the graphic analysis, the symmetry, and the flattening of the distribution. To verify the relationship between the quantitative gait variables, Pearson's correlation was calculated for the parametric measures and Spearman's correlation for the non-parametric ones. The data were analyzed using the software R version 3.6.1.

With the aim of identifying the biomechanical factors related to the walking performance of this patient's profile, correlations were performed between the evaluated spatiotemporal parameters. Were taken as a reference to determine the correlation size:[15]

0,90 to 1 (-0,90 to -1) = very strong positive correlation (negative)

0,70 to 0,90 (-0,70 to -0,90) = strong positive correlation (negative)

0,50 to 0,70 (-0,50 to -0,70) = moderate positive correlation (negative)

0,30 to 0,50 (- 0,30 to - 0,50) = low positive correlation (negative)

0,00 to 0,30 (0,00 to -0,30) = insignificant correlation

Results

Thirty patients hospitalized with CHF were included in the study, in which no assessment had to be interrupted due to clinical and/or hemodynamic changes. The epidemiological and clinical variables are described in Table 1. The sample consisted mostly of females (56.7%), with a mean age of 44.5 years. Regarding the functional classification, there were 50% for class II, as well as 50% for class III. The main etiology was valvular heart disease (50%), with a mean ejection fraction of 44.6% and a predominant hospital stay of more than 11.2 days during the moment of the evaluation.

The main drug classes used were beta-blockers (73.3%), diuretics (76.6%), digitalis (36.6%), aldosterone antagonists (43.3%), and angiotensin-converting enzyme inhibitors – ACEis (43.3%).

The description of the spatio-temporal parameters is shown in Table 2. The gait speed of the participants ranged from 0.57m/s to 1.09m/s, in which approximately 11 (36.6%) of the evaluated subjects had lower values or equal to 0.8m/s, and 5 (16.6%) obtained results above 1m/s. The other participants, 14 (46.6%), ranged from 0.81 to 0.99 m/s.

Gait cadence ranged from 31.3 to 55.4 steps/minute, while stride length ranged from 0.88 to 1.37 meters. Regarding the stance phase, in the data from the third quartile (those with values above 65.6%), none of them (7; 23.3%) presented gait speed above 1m/s, and among these (4; 13 .3%) presented walking speed below 0.8m/s.

The correlations between the spatiotemporal gait parameters are shown in Table 3. A strong correlation was observed between gait speed and cadence (r=0,74; p<0,01) and a moderate correlation between gait speed and stride length (r=0,56; p<0,01). The other parameters presented insignificant correlation. Subsequently, in Figure 1, the variables that presented high and moderate correlation are represented.

Discussion

In the present study, a strong correlation was observed between gait speed and cadence and a moderate correlation between gait speed and stride length, while the other parameters did not present positive correlations between them. The obtained values for speed, cadence, stride length and swing phase were reduced, while there was a slight increase for the stance phase when compared to healthy individuals.[16]

Most of the data described in the literature bring comparisons based on healthy and asymptomatic populations with rates considered conventional that can overlay the impact of gait on a given disease.[10] No studies were found that described reference values for walking in individuals diagnosed with CHF so that they could be compared to the data collected from our sample.

Regarding gait speed, estimated data for values above 1 m/s are considered normal for adults without disabilities,[17] while a speed equal to or less than 0.8 m/s is considered poor walking performance, in addition to being an important predictor of clinical outcome.[11]

Although minimal variations are observed with regard to gait speed, this decrease has been associated with mortality,[8] in which a decrease of 0.1 m/s in this variable will present a 10% increased risk of death in five years.[18] That is, a large part of the present sample may be exposed to this clinical outcome, in which rehabilitation measures aimed at improving walking performance could be beneficial in reducing these effects.

To facilitate the increase in muscle work and generate body displacement during gait, measures will be adopted to compensate for the muscles' mechanical capacities that will be modified in individuals with CHF.[8] A low cardiovascular fitness associated with peripheral muscle changes, resulting from the disease's pathophysiology, may justify the reduction in walking speed[19] and consequent compensations of the other gait spatiotemporal parameters in this profile of patients.

Regarding the other studied parameters, in our research, cadence, and stride length were also reduced when compared to healthy middle-aged Brazilians[16] and in another profile of asymptomatic adults.[20] Cadence and stride length are

Table 1 – Distribution of epidemiological and clinical characteristics of the sample of patients with heart failure (n = 30)

Variables	n (%)	Média (DP)
Sex		
Female	17 (56.7)	
BMI		24.9 ±5.3
Age		44.5 (10.4)
Between 18 and 30 years old	3 (10)	
Between 31 and 40 years old	6 (20)	
Between 41 and 50 years old	13 (43.3)	
Between 51 and 60 years old	8 (26.7)	
Functional Class		
Class II	15 (50)	
Class III	15 (50)	
Etiology		
Chagasic	3 (10)	
Ischemic	2 (6.7)	
Hypertensive	3 (10)	
Cardiomyopathy	2 (6.7)	
Valvar	15 (50)	
Others	5 (16.7)	
Ejection Fraction		44.6 (20.1)
< than 40%	13 (43.3)	
41 and 49%	3 (10)	
≥ than 50%	14 (46.7)	
Medications		
Betablocker	22(73.3)	
ACEis	13 (43.3)	
Diuretics	23 (76.6)	
Digital	11 (36.6)	
Aldosterone antagonist	13(43.3)	
Length of hospitalization		11.2 (9.6)
2 and 5 days	9 (30)	
6 and 8 days	7 (23.3)	
8 and 12 days	5 (16.7)	
> than 12 days	9 (30)	

SD: standard deviation; BMI: body mass index; ACEis: angiotensin-converting enzyme inhibitors.

Table 2 – Gait characterization of the sample of patients with heart failure (n = 30)

Variables	Mean (SD)	Median (q1 – q3)
Speed (m/s)	0,86 (0,14)	
Cadence (strides/minute)	45,8 (6,9)	
Stride length (m)	1,14 (0,12)	
Support phase (%)		62,2 (60,4 – 65,6)
Swing phase (%)		36,6 (34,7 – 38,3)

SD: standard deviation; q1 – q3: 1º e 3º quartiles.

considered to be the main determinants of walking speed,[7,20,21] whose changes in these parameters may contribute to increased energy expenditure during walking.[20]

To perform a preferred or self-selected speed, individuals can regulate gait by adjusting cadence, stride length, or a combination of both variables, in which each strategy will provide demands on different kinematics.[20] When evaluating our data on these probable correlations, it seems that the patients adapted the walk, more frequently increasing the cadence than the stride length, in order to generate an adequate speed.

Although there are different gait compensation mechanisms in the CHF population, it is known that the compensatory mechanism of slow walking occurs more commonly by increasing cadence (frequency) than by increasing stride length (amplitude)[21] because it seems to confer greater stability when walking[22] and a strategy to generate less energy expenditure during walking, with fewer biomechanical modifications.

When subjects walk at their normal speeds, increasing cadence to walk faster appears to have little effect on external joint patterns, while increasing stride length generates a noticeable increase in lower limb joint moments, appearing to be a strong predictor of reduced muscle performance as opposed to cadence.[20]

Therefore, as CHF worsens, patients opt for a slower time to walk, showing that the decrease in speed is due to the decrease in the frequency of steps[5] because skeletal muscle inefficiency may be unable to support the necessary action to achieve a longer stride length.[5] This strategy of reducing energy expenditure while walking can have a considerable impact on these individuals, as it can help reduce possible feelings of dyspnea and assist the patient in adapting their functionality and independence.

Understanding the mechanisms related to reduced gait performance in CHF is of functional and clinical importance. This analysis allows us to effectively identify possible changes in the gait mechanics of these patients. These results may help us to reveal the basis for functional limitations in CHF and develop rehabilitation approaches to restore walking ability.[8]

This study had, as limitations, a possible reduction in the sample size because, when visiting the patients in their respective beds to collect gait data, some were undergoing clinical procedures, such as exams, and it was not possible to evaluate them afterward, generating sample losses.

Another observed limitation concerns the lack of evaluation of the muscular strength of the individuals in the sample and clinical stratification regarding left ventricular ejection fraction, not being possible to demonstrate if there is a correlation with the studied spatiotemporal parameters. In addition to the presence of a healthy control group in order to compare the gait performance of the populations studied.

Likewise, in the registration of the participants' medication treatment, only the classes of medication used were known,

Table 3 - Correlation between spatiotemporal gait parameters of the sample of patients with heart failure (n = 30)

Space-time variables	Cadence	Stride length	Support phase	Swing phase
Speed (m/s)	0,74	0,56	- 0,03	-0,06
Cadence (strides/minute)		0,16	0,10	-0,15
Stride length (m)			0,008	-0,08
Support phase (%)				-0,94

and it was not possible to describe their respective dosages in order to infer the adequacy of the treatment and how it could influence their walking performance.

Conclusion

In the present study, a strong correlation was observed between walking speed and cadence and a moderate correlation between walking speed and stride length. The other gait parameters were not correlated with each other.

Speed, cadence, stride length, and swing phase were reduced, while there was a slight increase for the stance phase when compared to a study of healthy individuals in the Brazilian population.

Future studies are needed, especially in more severe patients, in order to know the gait characteristics of this patient profile and, thus, to outline rehabilitation strategies that enable the improvement in walking performance and reduce the inability to tolerate efforts, improve quality of life, and social participation.

Likewise, it is suggested to analyze the gait of patients in this patient profile with the stratification of groups encompassing other diagnostic criteria in addition to functional classification and compare with other populations of interest.

Author Contributions

Conception and design of the research, Statistical analysis and Obtaining financing: Souza E; Acquisition of data: Souza E, Santos TJ, Ribeiro TO; Analysis and interpretation of the data: Souza E, Santos MS; Writing of the manuscript: Souza E, Santos MS; Critical revision of the manuscript for important intellectual content: Ribeiro NMS.

Potential conflict of interest

This article is part of the thesis of master submitted by Emmanuelle Melo Sarraf de Souza, from Universidade Federal da Bahia.

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Study association

This study is not associated with any thesis or dissertation work.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Hospital Universitário Professor Edgard Santos under the protocol number 2.230.651. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

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