Chronic low back pain and walking speed: effects on the spatiotemporal parameters and in gait variability

Dor lombar crônica e velocidade de caminhada: efeitos nos parâmetros espaço-temporais e na variabilidade da marcha

ABSTRACT

BACKGROUND AND OBJECTIVES: Walking is described as one of the abilities most affected by chronic low back pain. This study aimed to determine if chronic nonspecific low back pain and walking speed affect the spatiotemporal parameters (stride length, swing time, contact time, stride time, stride frequency and walking ratio) and the coefficients of variation of stride length and contact time.

METHODS: Ten participants with chronic nonspecific low back pain (low back pain - LG) and ten healthy participants in the control group (CG) walked on the treadmill at preferred self-selected speed, slower and faster than the preferred speed. Spatiotemporal parameters and coefficients of variation were determined by kine-matic analysis. Main effects (group and speed) and their interactions were tested using generalized estimating equations method.

RESULTS: Our results showed that there were no significant differences between groups or significant interaction between group and speed factors. There was a speed effect. Stride frequency and length increased while contact and stride time decreased as the speed increased. The walking ratio (stride length/stride frequency) was relatively consistent across speeds (-1.6 m·stride⁻¹·s) without statistical differences. The coefficients of variation were below 5%.

CONCLUSION: The chronic nonspecific low back pain did not affect the gait spatiotemporal profile, at least for those patients classified as chronic nonspecific low back pain according to the signs and symptoms criteria. Although the preferred speed has affected the spatiotemporal parameters, both groups patients were able to adjust their kinematic parameters to each task demand.

Keywords: Gait, Biomechanical phenomena, Locomotion, Spine.

RESUMO

JUSTIFICATIVA E OBJETIVOS: A caminhada é descrita como uma das habilidades mais afetadas pela dor lombar crônica. Este estudo objetivou determinar se a dor lombar crônica não especifica e a velocidade de caminhada afetam os parâmetros espaço-temporais (comprimento da passada, tempo de balanço, tempo de contato, tempo da passada, frequência da passada e razão de caminhada) e os coeficientes de variação do comprimento da passada e do tempo de contato.

MÉTODOS: Dez participantes com dor lombar crônica não específica (grupo dor lombar GL) e 10 participantes saudáveis (grupo controle - GC) caminharam na esteira na velocidade preferida autosselecionada, e em velocidades mais lenta e mais rápida que a velocidade preferida. Parâmetros espaço-temporais e coeficientes de variação foram determinados por cinemometria. Os efeitos principais (grupo e velocidade) e as suas interações foram testadas pelo método de equações de Estimativas Generalizadas.

RESULTADOS: Não houve diferenças entre os grupos ou interação entre os fatores (grupo e velocidade). Houve efeito da velocidade. A frequência e o comprimento de passada aumentaram, enquanto o tempo de contato e de passada diminuíram à medida que a velocidade aumentou. A razão de caminhada (comprimento da passada/frequência da passada) foi relativamente consistente entre as velocidades (-1.6 m·passada⁻¹·s) sem diferenças estatísticas. Os coeficientes de variação ficaram abaixo dos 5%.

CONCLUSÃO: A dor lombar crônica não específica não afetou os parâmetros espaço-temporais da caminhada, pelo menos para os pacientes classificados com dor lombar crônica não específica pelos critérios de sinais e sintomas. Embora a velocidade preferida tenha afetado os parâmetros espaço-temporais, os pacientes de ambos os grupos foram hábeis para ajustar seus parâmetros cinemáticos às demandas da tarefa.

Descritores: Coluna vertebral, Fenômenos biomecânicos, Locomoção, Marcha.
INTRODUCTION

Low back pain (LBP) is a syndrome-based condition with high prevalence in the world population. The global prevalence of LBP was reported as ranging from 5 to 65%\(^1\). In Brazil, the prevalence of chronic low back pain (CLBP) is 3.9 to 25.4%, and the prevalence in individuals aged between 20 and 59 years is around 19.6%\(^2\). Although the specific causes of LBP can be identified, the specific diagnosis is not possible in most cases, and a nonspecific cause is frequently accepted as the diagnosis\(^3\).

The recognition of the LBP etiology remains a challenge since there is still a poor correlation between anatopathological and clinical presentation\(^4\). Nevertheless, CLBP is usually associated with functional and psychosocial impairment\(^5,6\). A study that identified the main activities performed with difficulty in patients with CLBP pointed out more than 60 types of activities. However, the most prevalent, around 56%, was a decrease in walking tolerance\(^7\).

Walking is an activity of both clinical and functional relevance due to its impact on independence and quality of life, and is often an integral part of rehabilitation programs, including those directed to patients with CLBP. However, the repercussion of LBP on the walking parameters still needs further understanding, given the etiological complexity of this syndrome and the wide range of factors that can contribute to the loss of movement\(^8\).

Spatiotemporal parameters of gait, such as speed, stride length, stride frequency, contact, and balance time, are not unvarying. They interact in a coordinated manner to allow the displacement to be adequate to the task demands and environment and to ensure that it is performed effectively. Therefore, individuals tend to determine these spatiotemporal parameters freely, although dynamic and mechanical factors have a remarkable influence on this choice\(^9\).

Some neurological diseases cause disturbance of gait spatiotemporal synchronism\(^10,11\). In the major part of neurological impairments, the relation between the disease and motor disorders, although complex, is more apparent because the anatopathological disease basis involves the recognized damage to the structures responsible for the generation and conduction of nerve stimuli\(^12\). Often, this framework does not apply to CLBP because these patients tend to choose speeds rates slower than healthy people, and as it has recently been demonstrated, at lower speeds the inter-strides variation is critical\(^16,17\). Based on this, it is expected that participants with CLBP have their dynamical stability impaired (assessed by inter-stride variation) at all speeds tested.

METHODS

After the sample calculation, which was determined for the variable “speed” (WinPepi version 11.18; power = 80%; significance level 5%; SD control group = 0.16; SD low back pain group = 0.21; difference to be detected = 0.3; at least n = 8 for each group), volunteers of both genders and aged over 25 years, with and without CLBP were recruited. The CG consisted of participants without systemic or musculoskeletal disorders in the lower limbs and spine, either chronic or acute, reported during the last year.

The chronic low back pain group (LG) consisted of volunteers with CLBP, from a local Rehabilitation Center, and with no musculoskeletal injuries in other joints on lower limbs and/or systemic illnesses which impairs the ability to walk. They were recruited intentionally and not probabilistically. The inclusion criteria for the LG followed the recommendations of original or review articles that focused on the diagnosis and treatment of LBP, according to the signs and symptoms indicated in the anamnesis and physical examination\(^3,18\). Thus, volunteers should report LBP persisting for more than three months, without radiation to the lower limbs but with physical and clinical characteristics compatible with Category 1 pain (nonspecific low back pain) according to the guidelines for evaluation and treatment that are proposed by the American College of Physicians and the American Pain Society\(^19\).

Volunteers, from both groups, were excluded if they did systematically and routinely engage in physical exercise, two or more times per week for at least 30 minutes; did show obvious differences in length of the lower limbs, postural misalignments and body mass indexes greater than 30.0kg.m\(^{-2}\). For data processing, videos with bad technical quality were excluded from the analysis.

Measures

The experimental design of this study involved the following steps: 1) screening; 2) preferred self-selected speed determination; 3) spatiotemporal assessment; 4) data analysis.

After the explanation about the procedures and objectives of the research, the volunteers underwent clinical screening to identify possible exclusion factors and collection of history and anthropometric data.

To determine the preferred self-selected speed (PS), the participant underwent a familiarization period, for five minutes, on the treadmill (Embrex 563-R3, Brusque, Brazil) and then the PS was determined. The PS was determined as follows: a) the volunteer was asked to choose the most comfortable speed, similar to the

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1. American Pain Society
2. American College of Physicians
3. American Pain Society
4. BrJP. São Paulo, 2019 oct-dec;2(4):342-7
5. BrJP. São Paulo, 2019 oct-dec;2(4):342-7
The spatiotemporal parameters analyzed, and their respective measurement units and definitions are presented in Table 1.\textsuperscript{11,22} We also calculated the CoV of contact time and stride length, obtained by the ratio between standard deviation and the average values arising from each step transformed into percentage values.\textsuperscript{16} The CoV is expressed in percentage values (CoV%).

The present study was previously approved by the Research Review Board of the Universidade Estadual do Oeste do Paraná (Report 1433/2011), in accordance with resolution 466/12, and it was classified as observational, ex-post-facto, exploratory-descriptive, transversal study. All volunteers received clarification regarding the study aims and procedures before inclusion, and all provided formal consent to participate.

**Statistical analysis**

Regarding variable stride length, we considered only normalized values by lower limb length for statistical treatment. We tested the data normality by the Shapiro-Wilk test. For all statistical tests, we adopted $\alpha=0.05$. We compared the participants’ characteristics using the Mann-Whitney test (intergroup comparison). We verified if there was any difference in pain scores for LG between the speeds using the Friedman test. The verification of LBP effect (main group effect), walking speed effect (main effect of speed) and their interactions were made using the Generalized Estimating Equation (GEE) method. In post-tests, we applied the Bonferroni test.

**RESULTS**

In total, 20 volunteers were recruited, being five men and five women in each group. Statistical differences in age, PS, anthropometric characteristics were not observed between the groups, but we found differences in pain scores (Table 2). The pain scores were not different between the speeds for LG ($p=0.8302$). The descriptive statistic for the spatiotemporal variables is presented in Figure 1. No main group effect was found as well as interactions between group and speed, but we found the effect of speed. It can be observed that stride frequency and stride length increased as the speed was higher. The contact time and stride time decreased as the speed was higher. We did not find effect of speed on the walking ratio. The CoVs were below 5%.

### Table 1. List of the spatiotemporal parameters analyzed in the present study, their units and definitions

| Parameters                     | Units          | Definitions                                              |
|-------------------------------|----------------|----------------------------------------------------------|
| Speed                         | m.s$^{-1}$     | Distance traveled per unit time                          |
| Stride time                   | s              | Number of frames of each cycle multiplied by the period   |
| Stride length (normalized by L) | m             | Speed multiplied by $(ST / L)$                           |
| Stride frequency              | Stride.s$^{-1}$| Speed /SL                                                 |
| Swing time                    | s              | Number of frames in that the foot is not in contact with the ground during a stride multiplied by the period |
| Contact time                  | s              | Number of frames in that the same foot is in contact with the ground during a stride multiplied by the period |
| Walking ratio                 | m.stride$^{-1}$s | A speed-independent walking standard index. It is the ratio of SL per SF |

Period = reciprocal of the sampling rate ($1.240^{-1}$).
Table 2. Presentation of descriptive statistics (median, 25%, and 75% percentile) and intergroup comparison between the variables of sample characterization

| Variables               | Median | 25% percentile | 75% percentile | p-value |
|-------------------------|--------|----------------|----------------|---------|
| Age (year)              |        |                |                |         |
| CG                      | 37     | 32             | 44             | .1984   |
| LG                      | 44     | 33             | 53             |         |
| Ll (m)                  |        |                |                | .3215   |
| CG                      | 0.88   | 0.86           | 0.93           |         |
| LG                      | 0.87   | 0.76           | 0.91           |         |
| Stature (m)             |        |                |                | .0634   |
| CG                      | 1.76   | 1.63           | 1.79           |         |
| LG                      | 1.69   | 1.56           | 1.75           |         |
| Body mass (kg)          |        |                |                | .6305   |
| CG                      | 70.5   | 65.4           | 86.1           |         |
| LG                      | 70.4   | 56.6           | 85.0           |         |
| PS (m s⁻¹)              |        |                |                | .6305   |
| CG                      | 0.98   | 0.84           | 1.20           |         |
| LG                      | 0.91   | 0.84           | 1.09           |         |
| Pain at slower speed (by VAS) |    |                |                | .0014   |
| CG                      | 0      | 0              | 0              |         |
| LG                      | 1.6    | 0.3            | 1.7            |         |
| Pain at PS (by VAS)     |        |                |                | .0014   |
| CG                      | 0      | 0              | 0              |         |
| LG                      | 0.9    | 0              | 1.9            |         |
| Pain at faster speed (by VAS) | |                |                | .0014   |
| CG                      | 0      | 0              | 0              |         |
| LG                      | 1.5    | 0.6            | 2.1            |         |

LG = (low back pain; CG = control group; Lll = length of lower limb, walking speed 0.5km.h⁻¹ slower than the preferred self-selected speed (slower); PS = preferred self-selected speed; speed 0.5km.h⁻¹ faster than the preferred self-selected speed (faster); VAS = visual analog scale; significance level=0.05.

Figure 1. Descriptive statistics (mean and 95% confidence interval) and inferential comparisons of the spatiotemporal variables by assessing the effect of speed.
DISCUSSION

We aimed to determine if CLBP and WS affect the spatiotemporal parameters. The results of this study indicated that CLBP did not have a significant effect on the spatiotemporal parameters. However, the WS did affect them.

The effect of speed on the spatiotemporal parameters has been reported before, as speed is accompanied by changes in the kinematic parameters. Likewise, it is emphasized that the walking speed is the product of stride length and frequency, but at the same time, these parameters are also determined by the speed, and this is a consequence of the complex interaction between mechanical parameters, task demand, and motor control. It means that changes in the spatiotemporal parameters observed in this study, by the influence of the speed, are supported by the scientific and technical literature.

As the relation choice between stride length and stride frequency tends to be spontaneous at a self-selected speed, and even at different speeds, the walking ratio is considered an index of the walking pattern which is independent of speed. Thus, a constant walking ratio at different speeds reveals a normal walking pattern. As the walking ratio of the present study in both groups showed no statistical differences between the three intensities in speed and no significant group effect, we concluded that all the studied participants were skilled enough to adapt their kinematic parameters to each task demand.

Besides, the low values and the lack of statistical difference in the CoV index reinforce our findings, indicating stable gait characteristics. Variability of both stride time and length are closely related to the control of the rhythmic stepping mechanism associated with safe gait. Variability, represented by CoV, provides additional information about the behavior of the gait concerning average values of the kinematic variables and tends to be low in walks considered stable, being advocated percentage values for normal coefficient variation lower than 3% among young adults. Also, variability tends to be higher at lower speeds and, on the contrary, lower at higher speeds. The smaller the variability the greater the gait dynamic stability.

In the present study, both groups were able to adjust their spatiotemporal parameters, and the LG reported low pain scores at all speeds without difference between them. We believe to be this the cause of the lack of statistical difference for PS between groups.

Our initial hypothesis was that participants with CLBP are less able to adjust the spatiotemporal parameters due to speed variation. This hypothesis was based on the findings of other authors. In the medical literature, some investigators have highlighted the impairment in the walking pattern in people with CLBP as a synchronous movement between trunk and pelvis leading to “en bloc” style of walking, alteration of proprioceptive postural control, tendency to adopt ankle strategy for walking and slower speed gait than people without CLBP. In general, it is accepted that those adaptations might happen as a protective reaction to avoid pain. However, our data indicate the opposite, and they do not support the theory that patients with CLBP avoid moving due to the pain.

Despite some mechanical reasons to believe that the gait in CLBP patients could be changed, it is possible that the spatiotemporal features may not reflect the kinetics impaired. It is possible to speculate that one should consider other relevant features involved in the etiology of LBP syndrome for that spatiotemporal changes to be present.

Henchoz et al. did not observe differences in the spatiotemporal, mechanical, and metabolic variables in people with and without LBP, even with the self-selected speed for the lumbar group being slower than the control group. One of the arguments suggested to explain these outcomes was that peripheral musculoskeletal disorders, unlike central musculoskeletal disorders, may not be sufficiently large to cause a less efficient walking pattern.

One study suggested that CLBP patients seem to be more effective at slow speeds than fast speeds (speed effect), although there was no difference in free-pain participants. The authors speculated that the repercussion of neuropsychological adjustments due to painful stimuli could explain the motor behavior in people with CLBP and consequently the metabolic parameters.

Indeed, the LBP is a syndrome-based condition, and the contribution of psychosocial and neuropsychological factors on the performance of motor tasks is still poorly understood and confusing in the context of CLBP. The contemporary classification system for this syndrome is yet not sensitive enough to include all etiological aspects. Probably, the physical classification systems for LBP do not consider relevant dimensions as pain characteristics, psychophysical, psychological, social, lifestyle, movement or comorbidities in an integrated manner to provide a diagnosis that allows recognizing single features in each case.

Corroborating other papers, the researchers observed that patients with CLBP, although they had a lower level of strength on dorsal and lower limb muscles or in psychosocial variables, they did not show differences in the six-minute walk tests performance in comparison to healthy people. It is important to highlight that the speeds evaluated were self-selected.

We suggest future papers to include other etiological dimensions in the analysis to compose groups functionally more homogeneous. The major limitation of this study is that we did not have a fixed speed aiming to compare both groups under similar mechanical conditions.

In general, one cause of concern about CLBP rehabilitation relates to the improvement of walking ability; mainly because these patients tend to walk slower. According to two systematic reviews, walking is a recommended strategy to be used in the management of CLBP to reduce pain and disability, although there is low-quality evidence to bespeak that walking is a strategy, in comparison with other non-pharmacological, and more effective, approaches.

Our results make us think if the strategies used in rehabilitation, aiming to correct the spatiotemporal parameter of gait for CLBP patients are necessary. The present findings show that the spatiotemporal profile of gait in this syndrome-based condition does not change across slow, middle, and high walking speeds. The gait variability is an indirect marker of dynamical stability and, though previous evidence shows a greater step width in people with LBP, these changes are not enough to impair the global stability parameters assessed here.
CONCLUSION

We conclude that CLBP does not affect the spatiotemporal parameters, at least for those patients classified as CLBP according to the signs and symptoms criteria. Although the WS has affected the spatiotemporal parameters, both LG and CG patients were able to adjust their kinematic parameters to each task demand sustaining a low variability of gait.

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