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# Gait Differences between Adults with and without Low Back Pain: A Cross-Sectional Observational Study

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## ABSTRACT

**Introduction:** Low back pain (LBP) is a musculoskeletal disorder commonly associated with altered gait patterns; however, little information exists on comparative specific spatiotemporal gait parameters in individuals with LBP. This gap is addressed in the present study by comparing the mean values of stride length, step length, and stride time, as well as corresponding measures of hip extension and peak knee flexion angle, using Kinovea software (version 0.9.5).

**Materials and Methods:** This observational study included 200 participants, 100 healthy individuals (group I) and 100 individuals with LBP (group II). The inclusion and exclusion criteria were used to select the study participants. All participants underwent a gait analysis using Kinovea software (version 0.9.5), and gait parameters, including stride length, step time, and hip extension, were also measured. Statistical associations between gait parameters and LBP presence were analyzed.

**Results:** Subjects with LBP showed significant gait alteration with decreased stride length (mean difference [MD] 32.93 cm, P=0.001), decreased step length (18.52 cm, P=0.001), and reduced hip extension (1.88°, P=0.001) with weak to moderate correlation (r=0.214-0.282). These gait impairments were independent of the body composition.

**Conclusion:** This study identifies significant changes in gait patterns between patients with and without LBP, as revealed by Kinovea software (version 0.9.5), characterized by shorter step length, longer temporal duration, and lower hip extension magnitude. These results provide quantifiable differences in gait dynamics due to inter-individual differences observed clinically.

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## Introduction

Low back pain (LBP) is among the most common musculoskeletal symptoms worldwide. It is considered one of the most critical contributors to functional disability and reduced quality of life (QoL). LBP may occur without accompanying leg pain, and it is a general term for pain localized in the lower back, buttocks, and lower rib cage. It is characterized by back pain or lower back stiffness. The word Lumbago is frequently utilized synonymously with LBP and refers generally to pain in the lower back. It is a symptom resulting from various etiologic factors. It is not a specific diagnosis but may result from several causes, including muscle strain, ligament sprain, intervertebral disc degeneration or herniation, spondylosis-related compression of the spinal cord, postural stress, or an underlying systemic process [1].

LBP is classified based on duration and severity. Acute Lumbago is characterized by symptoms lasting less than six weeks, whereas chronic Lumbago refers to pain that persists or recurs for more than 12 weeks. Pain is classified as inflammatory or neuropathic and acute or chronic, depending on its onset and persistence [2]. The symptoms and indicators of LBP were identified based on prior knowledge and refined through a pre-test with four professionals. These include morning ache, discomfort with trunk extension, sporadic or lateral bending pain, muscle soreness, pain during a straight leg raise, tenderness of the spinous process, and persistent pain while sneezing or coughing [3].

The pathophysiology of LBP, particularly when associated with radiculopathy, involves mechanical and biochemical processes. Degenerative changes in the intervertebral discs contribute to pain through biomechanical alterations, neurovascular ingrowth, and chemical sensitization. Degenerated discs often exhibit increased nerve fibre and blood vessel proliferation, which heightens nociceptive signalling and contributes to chronic pain mechanisms [4].

LBP is a significant public health problem worldwide. International epidemiological studies indicate that LBP affects 12–33% of the adult population and has a one-year prevalence of up to 65%. Other studies on adolescents and older adults also demonstrate the wide range of estimates reported in prevalence figures, depending on study design, diagnostic criteria, and methods used to reduce bias. As more studies are conducted, methodological heterogeneity remains a significant limitation in generating reliable data for global comparisons [5].

Signs and symptoms of LBP (as measured by standardized clinical examinations) have been investigated through systematic reviews and searches of the CINAHL, EMBase, and Ovid Medline databases, with no age or sex restrictions applied. An assessment typically involves examining gait and posture, skin and muscle changes, tenderness, spasm, range of motion (segmental or physiological), hypomobility of joint play, and lower limb muscle strength [6]. Gait analysis, in particular, objectively measures how LBP impacts functional mobility, stability, and general biomechanics. The human gait cycle is divided into two primary phases: the stance phase, which accounts for approximately 62% of the cycle, encompassing initial foot contact to toe-off; and the swing phase, which comprises approximately 38% of the cycle and extends from toe-off to the next foot contact. Prominent functional events, such as initial contact, opposite toe-off, heel rise, tibial vertical alignment, and subsequent foot strike, demonstrate dynamic intersegmental coordination among lower limb segments during walking [7].

A proper gait analysis should include measurements of both temporal (time-dependent) and spatial (distance-based) parameters. Temporal parameters include cadence and walking speed (steps per second or meters/second [m/s]), whereas spatial parameters include step and stride lengths. Step length is the distance from heel strike of one foot to heel strike of the other foot, whereas stride length is the distance covered in a complete gait cycle full description). The time of one gait cycle is termed stride time, while one step takes half of the gait cycle, called step time [8]. In terms of kinematics, hip extension is a crucial measure during the stance phase, representing the backward motion of the thigh concerning the pelvis. Limitations in hip extension can restrict movement, contributing to compensatory movements at the pelvis or lumbar spine and potentially affecting gait stability and efficiency [9].

Technological innovations in motion analysis have driven the improvements. Software, such as Kinovea (0.8.25) and cortex (6.0.0.1645), enables accurate 2D tracking with minimal requirements for reflective markers or sophisticated laboratory environments. Open-source software Kinovea enables a video system, movement analysis-based calibration and validation, while commercial cortex provides a unified platform for automated post-processing, tracking, and calibration [10]. These systems enable the precise evaluation of temporal, spatial, and kinematic gait characteristics in both clinical and research environments.

LBP has been extensively studied; however, there is still a limited understanding of its impact on how people walk. Several previous studies have investigated muscle activity or pain intensity, but have limited knowledge of the detailed components of gait using inexpensive, accessible motion analysis [11].

Therefore, there is a void in knowing what gait changes, including differences in stride length, step time, and hip extension, can be measured using robust yet low-cost measures. To overcome these limitations, the primary goal of this study has been to compare gait parameters between individuals with and without LBP using Kinovea software (version 0.9.5). This study aims to provide a pragmatic understanding of how these pain-related alterations affect gait, which can be relevant to physiotherapists in the clinic attempting to manage them, thereby helping to bridge the translation gap between laboratory-based work and its everyday applicability in clinical practice. The purpose of this comparison is to gain a deeper understanding of LBP's influence on gait dynamics and to inform the development of targeted physiotherapeutic interventions to enhance mobility-related QoL.

## Materials and Methods

### Study design

The current investigation was an observational, cross-sectional case-control study conducted at the Department of Physiotherapy, Saveetha Medical College and Hospital. All participants provided written informed consent, and the Institutional Scientific Review Board approved the research protocol.

### Participants

A total of 244 individuals who presented with non-specific LBP were screened. Based on these criteria, 200 participants met the eligibility criteria and were enrolled and further divided into two groups:

• LBP group (n=100): The participants were suspected to have non-specific LBP.

• Without LBP group (n=100): A group of people who had no history of LBP.

### Calculation of sample size:

The a priori approach used the OpenEpi software to calculate the sample size. With a 2-sided 95% confidence interval (CI), 80% statistical power, and an expected difference in means between groups of 10.33, at least 100 participants per group were required. The sample population was selected using convenience sampling at Saveetha Medical College and its associated hospitals.

### Inclusion and exclusion criteria

Inclusion criteria of LBP group:

Age: 19-50 years old.

Clinical diagnosis of non-specific LBP.

Disability score of less than 60% (Oswestry disability index [ODI]), which represents a moderate or less disability.

Healthy body mass index (BMI: 18.5-24.9 kg/m$^2$).

Inclusion criteria of the without LBP group:

Age: 19-50 years old.

No recent history of severe LBP.

Healthy BMI: 18.5-24.9 kg/m$^2$.

Exclusion criteria (used in each group):

Existence of a neurological disorder (e.g. radiculopathy or neuropathy).

Spinal pathology (e.g. infection, osteoporosis, fracture).

Limb-length difference more than 1 cm.

Within the past year, a history of spinal or lower-limb surgery.

BMI of >25 kg/m$^2$ to avoid overweight and obesity.

### Outcome measures

The primary outcomes were spatiotemporal and kinematic gait measures, which were evaluated using video analysis (two-dimensional):

Spatiotemporal parameters stride length (m), step length (m), stride time (s), step time (s).

Kinematic parametric: Angle of hip extension (°) at end stance.

## Instrumentation:

Gait analysis: A Canon EOS 200D HD camera with a resolution of 1920×1080 and a frequency of 60 fps was used to capture the footage.

Software: Album calibration and parameter extraction were performed with the help of Kinovea software (version 0.9.5).

Clinical measurement: ODI was used to measure functional disability among the LBP population, whereas the calculation of BMI was based on the experimental measurement of height and weight.

## Procedure

### Preparation

The participants were assessed for BMI and limb length to verify their eligibility. The members of the LBP group were then administered to the ODI. Reflective markers were placed on the lower right limb at three anatomical locations, including the greater trochanter, the lateral femoral condyle, and the lateral malleolus.

### Gait recording

Participants were asked to walk in straight marked paths of 6 m at a comfortable pace without shoes. Gait in the sagittal plane was recorded using a digital camera on a tripod at 1 m, positioned 2.5 m perpendicular to the midpoint of the walkway, thereby reducing parallax error.

### Video analysis

The recorded video was imported into the Kinovea software (version 0.9.5) for frame-by-frame analysis.

Calibration: The video was calibrated in the recording settings at a known distance.

Spatiotemporal analysis: The step and stride length, time, and time-steps were measured using step and stride times based on the frame timestamps and the Line tool.

Kinematic analysis: The measurements of hip extension at maximal extension in the stance, as defined by the three reflective markers, were done with the help of the Angle tool.

A single rater was used in all the measurements, and complete operational definitions were adhered to ascertain reliability.

## Statistical analyses

SPSS software, version 27.0 was used for data analysis. Normality tests were conducted using the Shapiro-Wilk test. All variables were presented as descriptive statistics (Mean±SD or frequency).

Group comparisons: Independent samples t-tests were used to compare the gait parameters (stride length, step length, stride time, step time, hip extension angle) between the LBP and control group.

Correlation analysis: The Pearson's correlation coefficient (r) was used to measure the topography and strength of linear correlations between ODI scores and gait parameters in the LBP group.

A P value of 0.05 was used, indicating that the test was statistically significant.

## Results

The results of this study indicated that the LBP group exhibited slower walking speed, reduced step and stride lengths, and decreased hip extension in comparison to the control group, with all gait parameters showing statistically significant differences ($P<0.001$). These represent measurable changes in spatiotemporal gait features, with weak-to-moderate but statistically significant correlations between LBP and gait abnormalities. Even though BMI varied among groups, adjusting for it did not change the outcomes, reinforcing that non-specific LBP significantly affects gait performance regardless of body composition.

## Demographic data

Table 1 presents the characteristics of groups of 100 and 200 participants, further broken down by LBP status and a matched control group. The mean age of the LBP group of 100 persons (47 men, 53 women) was 36.8±7.5 years, the mean height was 170.4±7.2 cm, the mean body weight was 73.6±9.8 kg, and the mean BMI was 23.01±2.759 kg/m$^2$. The outcome questionnaire (OQ) scores were 26.15±9.03 in this group (Mean±SD). The control group consisted of 100 participants (64 males

**Table 1.** Anthropometric characteristics of participants (n=200)

| Anthropometric Characteristics | Groups | Mean±SD | P |
|---|---|---|---|
| Age (y) | LBP | 36.8±7.5 | 0.412 |
| | Control | 35.9±6.9 | |
| Height (cm) | LBP | 170.4±7.2 | 0.995 |
| | Control | 170.4±7.2 | |
| Weight (kg) | LBP | 73.6±9.8 | 0.184 |
| | Control | 71.2±10.3 | |
| BMI (kg/m²) | LBP | 23.01±2.759 | 0.14646 |
| | Control | 22.512±2.141 | |
| Gender (M/F) | LBP | 47/53 | — |
| | Control | 64/36 | |
| OQ scale score | LBP | 26.15±9.03 | — |
| | Control | — | |

Abbreviations: LBP: Low back pain; BMI: Body mass index; OQ: Outcome questionnaire.

*Significant at P<0.05.

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and 36 females) with a mean age of 35.9±6.9 years, a mean height of 170.4±7.2 cm, and a mean weight of 71.2±10.3 kg, corresponding to a mean BMI of 22.5±2.1 kg/m².

In Table 2, compared with the control group, individuals with LBP demonstrated substantially shorter stride length (control: 147.37±8.54 cm vs LBP: 114.44±7.91 cm, P<0.001) and reduced step length (71.84±4.85 cm vs 53.32±6.36 cm, P<0.001). They also showed longer stride time (1.59±0.42 s vs 1.98±0.39 s, P<0.001) and longer step time (0.65±0.19 s vs 0.9±0.15 s, P<0.001). In addition, peak hip extension was lower in the LBP group (13.87±2.53°) compared to controls (15.75±2.09°), with a significant difference (P<0.001). The corresponding mean differences ranged from 1.88° for hip extension to 32.93 cm for stride length, with all 95% confidence intervals excluding zero.

**Table 2.** Descriptive statistics and independent samples t-test results comparing gait parameters between groups

| Gait Parameter | Group | No. | Mean±SD | t | df | P | Mean Difference | 95% CI | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | LL | UL |
| Stride length (cm) | Without LBP (control) | 100 | 147.37±8.54 | 28.303 | 198 | <0.001 | 32.93 | 30.64 | 35.22 |
| | With LBP | 100 | 114.44±7.91 | | | | | | |
| Step length (cm) | Without LBP (control) | 100 | 71.84±4.85 | 23.148 | 198 | <0.001 | 18.52 | 16.94 | 20.1 |
| | With LBP | 100 | 53.32±6.36 | | | | | | |
| Stride time (s) | Without LBP (control) | 100 | 1.59±0.42 | -6.683 | 198 | <0.001 | -0.39 | -0.5 | -0.27 |
| | With LBP | 100 | 1.98±0.39 | | | | | | |
| Step time (s) | Without LBP (control) | 100 | 0.65±0.19 | -10.265 | 198 | <0.001 | -0.25 | -0.3 | -0.2 |
| | With LBP | 100 | 0.9±0.15 | | | | | | |
| Hip extension angle (°) | Without LBP (control) | 100 | 15.75±2.09 | 5.718 | 198 | <0.001 | 1.88 | 1.23 | 2.52 |
| | With LBP | 100 | 13.87±2.53 | | | | | | |

Abbreviations: LBP: Low back pain; CI: Confidence Interval; LL; Lower limit; UL: Upper limit.

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**Table 3.** Correlation analyses and Mean±SD of gait parameters: step length and stride length

| Parameters | Population | Mean±SD | r | P |
|---|---|---|---|---|
| Step length | Without LBP | 73±4 | 0.2269 | <0.02 |
| | With LBP | 53±6.35 | | |
| Stride length | Without LBP | 147.3±8.53 | 0.2144 | <0.03 |
| | With LBP | 114.4±7.9 | | |

LBP: Low back pain.

**Table 4.** Correlation analyses and Mean±SD of gait parameters: step time and stride time

| Parameters | Population | Mean±SD | r | P |
|---|---|---|---|---|
| Step time | Without LBP | 0.6±0.2 | 0.2196 | <0.001 |
| | With LBP | 0.9±0.1 | | |
| Stride time | Without LBP | 2±0.35 | 0.282 | <0.004 |
| | With LBP | 2.3±0.34 | | |

LBP: low back pain.

**Table 5.** Correlation analyses and Mean±SD of gait parameters: hip extension angle

| Population | Parameter | Mean±SD | r | P |
|---|---|---|---|---|
| Without LBP | Hip extension angle (°) | 16±2.08 | 0.2662 | <0.007 |
| With LBP | | 14±2.53 | | |

LBP: Low back pain.

As shown in Table 3, participants with LBP had shorter step lengths (0.56±0.08 m) and stride lengths (1.12±0.15 m) compared to those without LBP (0.62±0.07 m and 1.25±0.14 m, respectively). Both parameters showed weak but statistically significant correlations with LBP (step length: r=0.227, P<0.05; stride length: r=0.214, with a significant P=0.032).

In Table 4, step time and stride time were longer in the LBP group (0.58±0.05 s and 1.15±0.1 s) compared to the non-LBP group (0.53±0.04 s and 1.05±0.09 s). Both showed weak but statistically significant correlations with LBP (step time: r=0219, P=0.001; stride time: r=0.282, with a significant P=0.0044).

In Table 5, hip extension angle, the participants with LBP had a mean hip extension angle of 10.8±3.5°, while the participants without LBP had a mean of 12.4±3.2°. The correlation coefficient (r) was 0.266, with a statistically significant P of 0.0074.

## Discussion

A cross-sectional study conducted in 2020 reported that individuals with non-specific LBP showed reduced hip muscle extensibility and altered hip and pelvic motion during walking. These findings are consistent with the present study, which found that participants with LBP exhibited smaller hip joint movements, shorter stride lengths, wider step widths, longer stride times, and fewer steps during gait. Both indicate that restricted hip mobility influences gait stability and efficiency. In contrast, some previous studies reported no significant differences, likely due to their smaller sample size and methodological limitations [11]. In 2019, Carvalho et al. conducted a comparative cross-sectional study. Associations between body weight, resting $O_2$ saturation in the sitting and supine positions, height, and neck circumference were determined [12]. This contradicts our findings because the current study found that people with pain exhibited distinct spatiotemporal changes. These variations may be attributed to the differences in patient popu-

lation, pain duration, and analysis methods. Our findings indicate that LBP is associated with altered spatial and temporal gait patterns, particularly during hip extension. Although our results align with previous findings on abnormal hip mechanics, they underscore the importance of using 3-D motion capture and electromyography (EMG) to provide valuable information about compensatory mechanisms [12, 13].

In a correlational observational study in 2024, Liu et al. investigated the relationships among gait parameters, muscle activation, and locomotion dysfunction grade (LDG) in older adults [13]. They observed that spatiotemporal, kinematic, and dynamic gait parameters progressively worsened with increasing LDG scores [14, 15]. Surface EMG findings of abnormal muscle activation patterns further supported these observations. These findings show how pain and dysfunction interfere with coordinated gait control. These results are consistent with our findings, as LBP participants exhibited slower gait patterns and reduced stride parameters, which are protective adaptations to pain and instability. The results are consistent with previous studies showing gait changes due to LBP [16]. Smith et al. found specific kinematic and kinetic abnormalities in the trunk and pelvis of participants with LBP, which could explain the biomechanical changes associated with increased lateral body tilt observed in our study [17]. Öberg et al. reported normative data for simple gait parameters, noting that differences in stride and step length should be evaluated relative to age- and sex-matched values, consistent with my study [18]. Park et al. also emphasized that mechanical interventions, including custom-model arch-support insoles, can alter spatiotemporal gait kinematics, suggesting the potential reversibility of abnormal gaits associated with pain conditions [19]. Finally, Winkler et al. demonstrated the effect of recording angle on the precision of Kinovea-based motion analysis, supporting the methodical aspect of our 2-D video analysis. Overall, these studies corroborate the current results, which indicate that back pain alters normal gait kinematics and emphasize the importance of using standard, angle-optimized, and potentially 3D motion analysis in future studies [20]. Some of these limitations are addressed in this current study by objectively comparing parameters of walking, including stride length, step length, step time, and hip extension, between asymptomatic individuals and those with LBP using the Kinovea® motion-analysis software. This provides an inexpensive and readily available tool for biomechanical evaluation in both clinical and research settings. However, this study has some limitations. Participants were selected only if their BMI was within the normal range (18.5–24.9 kg/m²) to minimize the confounding effect of body mass on gait. Mean BMI values were compared between groups to ensure their comparability. In the present study, although overweight and obese individuals were excluded, the average BMIs of each group differed slightly, which may have exerted a subtle influence on the results. Future studies should statistically adjust for BMI or recruit participants with similar body compositions to isolate the effect of LBP on gait parameters. The Mean±SD groups in this study exhibited average BMI values (18.5–24.9 kg/m²). The higher BMI in the LBP group (23.01±2.76 kg/m²) compared to controls (22.51±2.14 kg/m²) was negligible and unlikely to have a clinically relevant influence on gait parameters.

This implies that the differences in gait were related to LBP, rather than morphology, which makes our study very clear. Nevertheless, the present findings provide significant evidence that individuals with LBP exhibit subtle yet meaningful changes in gait mechanics, specifically reductions in stride and step lengths, as well as hip extension. The magnitude of these abnormalities underscores the importance of early gait assessment and targeted rehabilitation interventions to correct gait patterns at the onset of duplication, thereby preventing chronic functional deficits. Previous studies have shown that LBP affects walking kinematics and muscle function. However, results for individual spatiotemporal parameters are conflicting; future studies should employ advanced technologies, such as 3D motion capture or wearable sensors, to gain further insight into joint motion and muscle activation in people with LBP while walking. The addition of EMG might help to bring changes in muscle activation to light, and longitudinal designs could demonstrate how gait alters over time and with rehabilitation. To discover new information, such as how specific treatments can restore normal gait and improve mobility, research should also compare interventions, such as physiotherapy or gait retraining and consider variables, such as BMI and fear-avoidant behaviour [21].

Prospective investigations should combine three-dimensional motion capture systems or wearable sensor technologies to overcome the limitations of a two-dimensional video analysis and obtain more precise kinematic data. The implementation of EMG facilitates the identification of muscle activation patterns that correlate with gait deviations in individuals with LBP. Longitudinal and interventional designs are recommended to determine changes in gait patterns through time and in response to physiotherapeutic or gait retraining interventions. In addition, future research should control for potential confounding factors (e.g. BMI, psychological

factors such as fear-avoidant behavior and pain anxiety, and environmental effects) to isolate better the actual impact of LBP on gait mechanics.

## Conclusion

This study revealed significant differences in gait characteristics between individuals with and without LBP. Significant variations were observed in stride length, step length, stride time, step time, and hip extension angles among people with LBP in spatiotemporal and kinematic analyses using Kinovea software. These differences may be adaptations or compensations that help maintain balance. This result underscores the importance of gait analysis in understanding biomechanical changes associated with LBP.

### Study limitations

Video analysis can yield 2D data; however, out-of-plane movement may not be accounted for, potentially limiting the accuracy of motion measurements. Furthermore, the mood swings and behaviour may limit the generalisability of these results. The influence of extrinsic factors (footwear, walking surface, and fatigue) was not fully controlled, which may have impacted the results. Additionally, fear of pain or anxiety, which are psychological factors known to affect gait patterns, were not evaluated, representing another limitation of the study.

## Ethical Considerations

### Compliance with ethical guidelines

This study was approved by the Institutional Scientific Review Board (ISRB) of Saveetha College of Physiotherapy, Chennai, India (Code: 06/032/2024/ISRB/SR/SCPT) and was conducted in accordance with ethical research guidelines.

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### Authors' contributions

Study design, investigation, data analysis, and writing the original draft: Jayashree Duraimurugan and Shenbaga Sundaram Subramanian; Data interpretation, review, and editing: Fadwa Alhalaiqa, Mohamed Sahal, Eunice Keren Singarayar, and Diovin Derose Vianni; Final approval, and supervision: Shenbaga Sundaram Subramanian.

### Conflict of interest

The authors declared no conflict of interest.

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