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Stance Phase Characteristics and Asymmetry in Females with Low Back Pain

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ABSTRACT

Background: This study aimed to investigate stance phase characteristics and asymmetry in females with non-specific low back pain (LBPP) which they adopt different strategies in walking to reduce pain and enhance walking quality. The results of this research can provide new insight into gait characteristics for individuals with LBPP by examining temporal characteristics and asymmetry in their stance phase during walking.
Methods: In this cross-sectional study, 36 females were purposefully recruited and divided into two groups: one consisting of 18 individuals with low back pain (LBPP) and the other without LBPP. Data were collected using the Footscan system and analyzed with the Footscan Gait 7 gait generation software. Independent t-tests were employed to compare the outcomes between the two groups.
Results: The results indicated that the right (P=0.001) and left (P=0.001) foot progression angles in the low back pain group were higher than those in the healthy group. Additionally, the low back pain group exhibited higher asymmetry in the timings of the initial contact phase (P=0.02) and forefoot contact phase (P=0.02), as well as in foot progression angle asymmetry (P=0.009) compared to the healthy group.
Conclusion: Given the higher foot progression angle and observed asymmetries in individuals with low back pain, rehabilitative exercises need to consider these differences when evaluating and planning rehabilitation procedures.

Introduction

Low back pain (LBP) is a prevalent musculoskeletal issue affecting a substantial percentage of the population, ranging from 60% to 80%. This condition can profoundly impact individuals' daily activities [1], encompassing social, therapeutic, and economic aspects. The considerable therapeutic costs and potential side effects associated with LBP necessitate a specific focus on appropriate rehabilitation [2]. LBP significantly impacts various aspects of an individual's daily life, including walking parameters, efficiency, and coordination [1]. Walking is a fundamental daily activity which is affected by factors such as LBP in various ways. It has been demonstrated that individuals with LBP employ alternative strategies to alleviate pain and enhance postural control while walking. Individuals with LBP often adopt various strategies to improve walking efficiency and reduce pain. These strategies can include reducing walking speed and altering pattern of muscle involvement. Asymmetry in gait is a significant aspect of walking and can be directly or indirectly influenced by LBP [3]. One of the primary factors contributing to altered gait asymmetry is the abnormal transfer of forces from the upper limbs to the lower limbs, highlighting the crucial role of the trunk and core region in human movement [4].

In walking analysis, it is essential to investigate the stance phase function due to its role in force transfer between

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the body and the ground [5]. More recently, to provide a more accurate and detailed examination of the stance phase, studying of plantar pressure distributions has been developed to indicate overall walking mechanics [6]. Differences in plantar pressure distribution compared to healthy individuals have been observed among individuals with chronic LBP. Yazdani et al. demonstrated variations in plantar pressure distribution patterns in different foot regions among those with LBPP [7]. Similarly, Simond et al. found differences in foot loading between individuals with chronic LBP and their healthy counterparts [8].

When investigating the stance phase, it is important to consider its key features. One of these features involves the timing of its sub-phases, with changes in the timing associated with alterations in foot loading patterns [9]. Another feature is foot progression angle which signifies the foot position in the direction of movement. Changes in this component can also affect how foot loading is distributed [10]. Asymmetry is another feature observed in gait, characterized by the lack of symmetry between the two lower limbs during walking [11]. Studies have shown that asymmetry creates excessive load on one of the limbs during movement, leading to further issues [4].

While research on the characteristics of the stance phase of walking and the associated asymmetry provides insights into overall body mechanics, however, there is limited studies addressing impact of LBP on these characteristics. This study will address this gap by investigating the stance phase of walking and the asymmetry between lower limbs in individuals with LBP. A deeper understanding of the challenges and issues affecting walking performance of individuals with LBP can significantly contribute to optimizing rehabilitation and treatment processes. Therefore, the primary objective of this study was to examine stance characteristics and asymmetry in females with low back pain.

Methods

In this cross-sectional study, a sample of 36 females via a convenient and purposive sampling method, dividing them into two groups: one group with chronic low back pain and the other group of healthy individuals, with 18 participants in each group were recruited. The sample size was determined using G-POWER software, considering a statistical power of 0.8 at a significance level of 0.05.

Inclusion criteria for the low back pain group were, diagnosis of chronic non-specific low back pain by a physician, the leg dominance, extending pain to the left leg, aged between 30 and 40 years, and a willingness to participate in the study. The inclusion criteria for the control group were the absence of any spinal complaints or pain in the past six months, aged between 30 to 40 years, willingness to participate in the study, and the right leg dominance.

Exclusion criteria for both groups were, a history of spinal and lower limb surgeries, lower limb abnormalities, neuromuscular disorders, neurological diseases, osteoporosis, cardiovascular disorders, knee joint osteoarthritis, or foot pathologies that might affect gait patterns. The study received ethical approval from the Isfahan University's ethics committee, with the reference number of IR.UI.REC.1400.118, and all participants gave informed consent.

Upon entering to the laboratory and obtaining the participants' written consent, the authors provided an overview of the test conditions. To become familiarized with the test condition, participants were asked to walk on a 15-meter walkway several times. Subsequently, they were instructed to walk barefoot on the walkway for at least six times for each leg, at their self-selected walking speed. In order to record plantar pressure data a Footscan device (RsScan International, Belgium) with dimensions of 578mm × 418mm × 12mm, equipped with 4096 sensors and a sampling rate of 253 Hz was used. Footscan was positioned im midway of the 15-meter walkway. Participants were explicitly instructed to have no voluntarily adjustment or regulation on their walking rhythm when walking on the device to prevent interference with their natural walking.

The collected data was analyzed using the Footscan 7 Gait 2nd Generation software. The software allowed us to calculate and analyze the roll-over sub-phases relative timing and the foot progression angle during walking. To determine the progression angle, the software automatically calculated the angle between the direction of movement and the longitudinal axis of the foot, defined as the line extending from the inner to the outer parts of the heel to the head of the second metatarsal (Figure 1). The software also automatically identified and recorded five distinct moments within the roll-over process:

1. First-foot contact: This corresponds to the moment when the foot initially makes contact with the footscan.
2. First metatarsal contact: The moment when one of the metatarsals initiates its contact with the footscan.
3. Forefoot flat: The first moment when all metatarsals come into contact with the footscan.
4. Heel off: This marks the moment when the heel ceases contact with the pressure plate.
5. Last foot contact: The last contact of the foot with the footscan diminishes (Figure 2).

Between these instances, there are four sub-phases of the initial contact phase (ICP, between the FFC and FMC], forefoot contact phase (FFCP, between the FMC and FFF), forefoot flat phase (FFP, between the FFF and HO), and the forefoot push-off phase (FFPOP, between the HO and LFC). For each sub-phase, the software automatically calculated the relative duration as a percentage of the stance phase. Furthermore, an asymmetry index was calculated for each criterion (progression angle and timing of the four sub-phases) by comparing the dominant and non-dominant legs [10].

To measure the asymmetry index, the following formula was used:

Asymmetry Index, (AI)=|Left−Right|/Dominant leg,

For the statistical analysis, the average values of the six walking attempts' variables were calculated for each participant and used for further analysis. The Shapiro-Wilk test was employed to assess the data for normal distribution. The results indicated normal distribution of the data. To compare the variables between the two groups, an independent t-test was utilized.

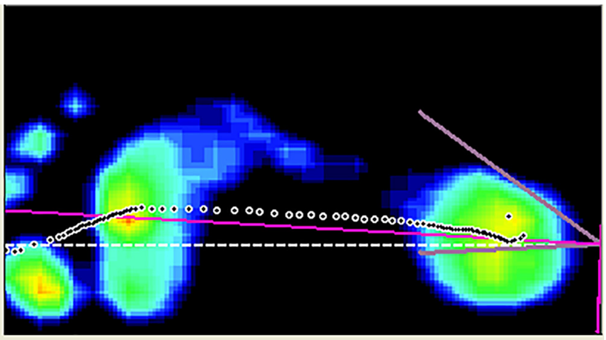

Figure 1: White dashed line: the direction of the walking. Red line: the longitudinal axis of the foot; the angle between the longitudinal axis of the foot and the direction of movement is considered the foot progression angle.

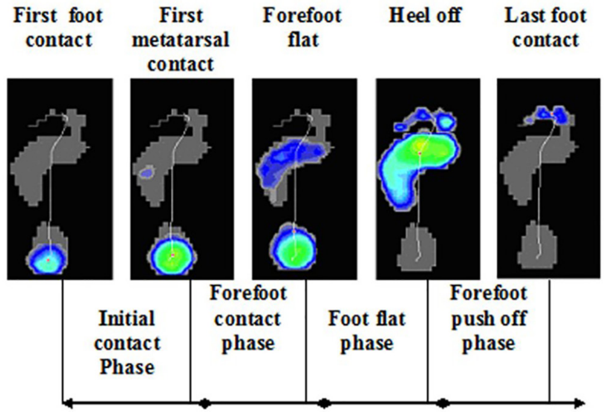

Figure 2: Five distinct temporal characteristics of the roll-over process

All statistical analyses were performed using SPSS version 18 software, with a significance level set at 0.05.

Results

The demographics of participants is presented in Table 1. As shown, the groups did not differ in terms of demographics (P>0.05), indicating homogeneity of the groups.

The findings of timing of the stance sub-phases, and the foot progression angle of both the left and right legs are summarized in Table 2. The results indicate no significant differences between the two groups regarding the relative timing of the stance sub-phases (P<0.05). However, it is noteworthy that the results show a higher foot progression angle in both the right (P=0.001) and left (P=0.001) feet of the LBP group compared to the healthy group.

Regarding asymmetry, the results reveal that the LBP group exhibits greater asymmetry than the healthy group, in the timing of the initial contact (P=0.02) and forefoot contact (P=0.009) sub-phases. Additionally, the asymmetry of the foot progression angle is more pronounced in the LBP group than in the healthy group (P=0.02). These findings are detailed in Table 3.

Discussion

The primary aim of this study was to examine the stance characteristics and asymmetry in females with LBP. The findings of this study demonstrated that women with LBP exhibited a higher foot progression angle in both legs compared to the healthy group. Additionally, the asymmetry index was significantly greater in the LBP group, particularly during the initial contact and forefoot contact sub-phases, as well as in the foot progression

Table1: Demographic information of the participants (Mean±standard deviation)

Group	Age (years)	Weight (kg)	Height(m)
Low back pain	35.5±8.3	71.8±8.4	1.62±0.35
Healthy	34.3±9.8	72.2±7.3	1.63±0.38
t	1.01	0.39	0.46
P value	0.09	0.7	0.64

Table 2: Stance sub-phases outcomes

Variables	Group	Mean±SD	t	P
Right foot initial contact phase (percentage)	LBP	15.1±4.41	-0.13	0.89
	healthy	15.3±5.71		
Right Forefoot contact phase (percentage)	LBP	19.5±9.1	0.36	0.71
	healthy	20.5±10.1		
Right Forefoot flat phase (percentage)	LBP	26.1±12.52	-0.45	0.65
	healthy	24.5±13.1		
Right Forefoot push off phase (percentage)	LBP	39.2±5.9	0.25	0.79
	healthy	39.7±8.4		
Right progression angle (degree)	LBP	17.7±5.5	-5.4	0.001*
	healthy	9.9±4.8		
Left foot initial contact phase (percentage)	LBP	14.7±6.9	0.54	0.61
	healthy	13.8±3.4		
Left Forefoot contact phase (percentage)	LBP	18.1±10.1	0.68	0.49
	healthy	19.7±8.1		
Left Forefoot flat phase (percentage)	LBP	26.6±7.1	-0.59	0.55
	healthy	24.5±7.2		
Left Push off phase (percentage)	LBP	39.7±7.5	0.026	0.98
	healthy	39.8±11.4		
Left progression angle (degree)	LBP	13.5±4.9	-4.6	0.001*
	healthy	7.9±3.6		

Table 3: Information related to the comparison of asymmetry index in two groups

Variables	Group	Mean±SD	t	P
initial contact phase asymmetry	LBP	27.3±8.1	-2.3	0.02
	healthy	15.6±7.3		
Forefoot contact phase asymmetry	LBP	29.1±9.5	-2.6	0.009
	healthy	16.2±6.2		
Forefoot flat phase asymmetry	LBP	26.2±10. 2	-0.46	0.64
	healthy	23.7±18.9		
Forefoot push off phase asymmetry	LBP	11.6±3.1	0.34	0.73
	healthy	12.9±4.8		
progression angle asymmetry	LBP	17.7±5.5	-1.2	0.02
	healthy	27.9±7.7		
	healthy	21.8±7.6		

angle. These results are consistent with the findings of previous results reported by Yazdani et al. [7], Kim et al. [12], and Lee et al. [13], which have reported differences in plantar pressure characteristics in individuals with chronic LBP compared to healthy individuals.

The analysis of the relative timing of the stance sub-phases in both the right and left legs revealed no significant differences between the groups. The timing of the stance sub-phases provides information about the positioning of the foot at various time points during the stance phase, which occurs in the sagittal plane. While some studies, such as the work by Kuai and colleagues [14], have reported differences in the kinematics of LBP patients compared to healthy individuals, there are also findings suggesting that the kinematics of lower limbs in LBP patients can be similar to those of healthy individuals, as observed in the study by Laird and colleagues [15]. Changes in the timing of these sub-phases may be linked to alterations in other sub-phases [9], and research by Esmaeili and Askari has indicated that changes in the timing of stance sub-phases can impact overall walking performance [10].

Based on the results of the present study, there is no significant difference in the timing of the stance sub-phases between the healthy group and the low back pain group. This suggests that chronic low back pain does not have influence on lower limb kinematics, particularly in ankle movements in the sagittal plane. Research has indicated that LBP primarily influences knee joint kinematics, leading to increased extension during initial contact phase. In contrast, hip and ankle joints do not appear to be affected [16, 17]. It’s worth noting that individuals with LBP tend to walk slower than healthy individuals [18]. In the case of healthy individuals, increased walking speed is associated with significant changes in kinematics. As walking speed increases in healthy individuals, greater knee flexion is associated with an improved ability to absorb shock [19].

In individuals with low back pain, knee angle tends to be more extended than in healthy individuals, and this increased extension isn’t correlated with movement speed [16]. It’s possible that individuals with low back pain, experiencing pain in activating lumbar muscles, consciously reduce their movement speed. This speed reduction might be an attempt to mitigate exerted forces on the body by minimizing knee flexion during the contact phase. It’s essentially a compensatory mechanism aimed at reducing loads on the body during foot-ground contact, particularly at the level of the knee joint. Consequently, these observations suggest that lower back pain primarily affects the knee joint in the lower limb through compensatory knee movements. In contrast, other joints in the lower limb remain less affected.

Our findings suggest that in LBP women, foot progression angle in both legs is greater compared to healthy women. This change in the progression angle can lead to alterations in the distribution of foot loading [10]. Specifically, reduction in the foot progression angle can increase the loading on the lateral border of the foot, shifting the loads towards the lateral compartment of the knee [20]. Conversely, an increase in the progression angle can elevate the loading on the medial regions of the foot and redirect the loading towards the medial part of the foot [10, 20]. These observations are in line with Yazdani et al., who found that plantar pressure distribution patterns were higher in the medial part of the midfoot in individuals with low back pain [7].

The observed increase in foot progression angle LBP women may contribute to a medial transfer of foot loading. The Golgi tendon organs, muscle spindles, and other mechanoreceptors in the nervous system may provide altered sensory information during walking in individuals with low back pain [21], leading to subtle changes in muscle activity. One neuromuscular characteristic which is associated with low back pain patients walking patterns is the decreased activity of plantar flexor muscles [22], including the triceps surae muscles. This decreased plantar flexor muscle activity and increased foot progression angle could contribute to the medial load transfer in people with low back pain [7].

The changes in foot progression angle in LBP patients may serve as a compensatory mechanism to reduce trunk movements [23]. This altered walking pattern, characterized by a decreased anterior pelvic tilt, can lead to an increased external rotation of the femur and lesser tibial internal rotation, ultimately reducing the load on the foot.

The results of this study indicate that low back pain is associated with changes in walking mechanics. These changes may be attributed to the weakness of core muscles, which is considered one of the main contributing factors in altering gait patterns. Core muscle weakness can lead to instability in the lumbopelvic region, crucial for maintaining balance, supporting the spine, and facilitating movements of the body segments. Several studies have reported that individuals with LBP exhibit weakened abductor muscles, external rotators, and hip extensors during functional activities [24]. These weaknesses can directly impact pelvic and hip motion, exacerbating issues for LBP patients [25]. Therefore, individuals with LBP usually undergo subtle compensatory mechanisms to enhance stability and reduce further dysfunction. Different studies have demonstrated that body movements are executed through a kinetic chain. It appears that individuals with LBP leverage this characteristic of the body by inducing external rotation in their femur. This action aims to enhance stability in the pelvic girdle by engaging gluteal and external rotator muscles [26].

The results of this study indicated that individuals with LBP exhibited greater asymmetry in the relative time of the initial contact and forefoot contact sub-phases compared to healthy group. These findings are consistent with previous research, such as the study by Fayez et al., which demonstrated increased asymmetry in plantar pressure parameters in individuals with LBP. This increased asymmetry in LBP individuals may be attributed to alterations in the musculoskeletal system's organization [27].

Furthermore, the current study found that the LBP group displayed greater asymmetry in foot progression angle between the right and left legs than the healthy group. In our study, LBP participants reported experiencing pain in their left leg, with dominance on their right leg. This finding is in line with the results of Rahimi et al.'s study, which demonstrated that individuals with LBP exhibit greater external rotation in the lower limb in their dominant leg [28]. This increased external rotation in the dominant leg contributes to increased asymmetry in individuals with LBP [28]. The increased external rotation observed in the dominant leg is associated with greater foot progression angle in the leg [28], substantiating the current study's findings [5]. Furthermore, Zahraei et al. demonstrated that individuals with low back pain exhibit higher kinetic asymmetry levels than healthy individuals [5].

Prior research has predominantly focused on asymmetric neuromuscular movement control to elucidate underlying reasons for asymmetry in kinematic and kinetic parameters [29]. However, this study represents the first investigation of timing asymmetry in the stance sub-phases and progression angle during walking in females with LBP. The findings provide a novel perspective on the existence and origin of asymmetry in the parameters within the existing body of literature.

The current study had some limitations that restricted us. A more comprehensive examination of other variables of interest such as kinematic and kinetic parameters could lead to more useful information. Additionally, electromyography could have furnished valuable insights into the mechanisms by which the nervous system regulates lower limb movements in low back pain. It is important to acknowledge that our study included only female participants, which make it challenging to interpret these findings to the general population.

Conclusion

The findings of the current study indicate that individuals with LBP exhibit a higher foot progression angle in both legs, suggesting a distinct walking pattern. Furthermore, the results reveal greater asymmetry in the relative timing of the initial contact and forefoot contact sub-phases and greater asymmetry for foot progression angle in female LBP patients. This suggests that assessment and addressing asymmetry could be of valuable results in rehabilitating LBP individuals. When evaluating treatment progress for individuals with LBP, assessing the asymmetry between the legs can be an indicative tool.

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Conflict of Interest: None declared.

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