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Effect of Lumbar Extension-Fixed Bracing on Gait Parameters in Individuals with Anterior Pelvic Tilt

Gaeun Song[1], Nayeong Byeon[2], Jaewon Lee[3], Jiheon Hong[4], Jinseop Kim[5], Dongyeop Lee[6], Yeon Gyo Nam[7], Jaeho Yu[8*]

[1,2,3,4,5,6,7,8]Dept. of Physical Therapy, Sunmoon Univ, 70, Sunmoon-ro 221beon-gil Tangjeong-myeon Asan-si Chungcheongnam-do Republic of Korea, 31460
Email: naresa@sunmoon.ac.kr
*Corresponding Author

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ABSTRACT
Background/Objectives:A Lumbar Extension-Fixed Brace's effects on pelvic anterior tilt are not well understood. This study aimed to assess whether the brace improves body alignment and gait parameters.
Methods/Statistical analysis:A total of 12 participants with pelvic anterior tilt were recruited for the study, which involved walking on a treadmill. The participants engaged in a two-minute walking exercise, with data collected for a 30-second interval. A 30-second interval was allotted for rest between each session. The participants were instructed to walk with a natural gait while wearing the LEFB, and the data were subsequently analyzed using Optogait software.
Findings:A comparison of the gait parameters before and after the application of the orthosis revealed an increase in both step length and stride length, while a decrease was observed in both stance phase and cadence.
Improvements/Applications: The lumbar lordosis fixed brace improved body alignment in individuals with pelvic anterior tilt, resulting in positive changes in gait parameters.

Keywords: pelvic anterior tilt, lumbar extension-fixed brace, gait parameters, body alignment

1. INTRODUCTION

The spine plays an important role in cushioning the impact that occurs when we walk or run. The normal sagittal alignment of the spine performs this function by having a curvature consisting of an anterior curve in the neck, a posterior curve in the back and an anterior curve in the lumbar spine[1]. On the other hand, abnormal spinal alignment can cause a shift in the center of gravity, which can lead to compensatory movements and misalignment of other joints in the body. This can lead to cosmetic changes, musculoskeletal pain, nerve sensitivity or degenerative changes, and a variety of functional problems, including decreased balance[2].To illustrate, when the head is positioned in a forward direction, the pelvis tilts forward in order to balance the center of gravity. This results in an increased forward tilt of the pelvis, which inhibits the gluteus maximus and abdominal muscles while simultaneously promoting the hip flexors and lumbar extensors. This can lead to various postural disorders[3,4]. Accordingly, alterations in pelvic alignment have the potential to influence balance, functional performance, and gait[5]. Abnormal lumbar spine and sagittal pelvic alignment represent a significant etiological factor associated with low back pain and a primary cause of lumbar spinal hyperlordosis. Therefore, the prevention and treatment of increased pelvic tilt and lumbar hyperlordosis represent a crucial aspect of postural rehabilitation[6,7].

A common treatment for this abnormal spinal alignment is an orthosis.The most common spinal orthosis in the modern world is the lumbosacral orthosis (LSO)[8]. The goals of LSO include controlling pain, supporting muscle weakness, protecting against further injury, preventing or correcting further deformity, and promoting neutral spinal alignment. It accomplishes these goals primarily by restricting spinal motion[9,10]. The psychological benefits of LSO are associated with the perception of mechanical support provided by the lumbar belt. The biomechanical benefits include improved spinal stability, which is achieved by increasing trunk stiffness and making the entire trunk more resistant to unnecessary motion[11,12]. Furthermore, recent studies have indicated the necessity of preventing low back pain by providing support to the deep muscles that assist in stabilizing the trunk. The use of corsets and pelvic belts has been demonstrated to function in a manner analogous to local muscles, by tightening the pelvic region and thereby reducing strain on the lumbar spine[13].

In a review of recent studies, Munoz reported that patients with low back pain exhibited enhanced balance recovery when wearing a lumbar belt[14]. Kader's results demonstrated that postural stability, limitation of stability, and balance organization exhibited improvement with the orthosis in addition, the gait outcomes indicated that the Spinomed orthosis resulted in notable enhancements in several parameters, including gait rhythm, speed, gait cycle duration, precision gait, and symmetry index of pelvic angle[15]. Furthermore, Hiroshi indicated that in studies examining the effects of continuous use of LSOs, the most common exercise performance measures were peak strength and endurance of trunk flexors and extensors, and fatigue. Additionally, a meta-analysis demonstrated that continuous use of LSOs for a period of 1-6 months did not result in any adverse effects[16]. Wang explains that back braces help limit body movement and prevent poor posture. Walking with poor posture puts more force on the lumbar spine and more pressure on the back, which can lead to abnormal weight bearing in the long run, which can have a negative impact on quality of life. However, researchers have reported that walking with a back brace can significantly reduce forces on the lumbar spine and pressure on the back, which can improve posture[17].

However, according to Johnson, the back belts and corsets commonly used by people provide freedom of movement for the wearer, but their effectiveness is limited to providing a kinesthetic reminder to maintain a neutral posture. These devices have not been demonstrated to reduce the risk of musculoskeletal injuries in the lower back[18]. According to David, lumbar braces are commonly utilized as a safe, readily available, conservative treatment option for managing low back pain. However, he noted that there is a paucity of information on their overall effectiveness or comparisons between different devices[19]. Additionally, Annaswamy indicated that prolonged use of back braces may result in a reduction in pain-related function and quality of life in patients with chronic low back pain[20].

Lumbar orthoses are a common treatment for conditions resulting from abnormal spinal alignment; however, the efficacy of this approach remains uncertain. The objective of this study is to ascertain the impact of a lumbar extension-fixed brace (LEFB, Naresa, South Korea) on temporal and spatial variables of gait in adults with pelvic anterior tilt. Specifically, the study aims to determine the changes in temporal variables (stance phase, cadence) and spatial variables (step length, stride length) when wearing LEFB and to verify its effectiveness.

2. MATERIALS AND METHODS

2.1.Participants

The participants of this study were adults in their 20s enrolled in S University in Asan.The inclusion criteria were as follows: 1) a pelvic anterior tilt of 8 degrees or more, 2) male or female adults aged 18 years or older, and 3) voluntary consent to participate in the study. Individuals who met any of the following criteria were excluded from participation in the study: 1) Those with neurological diseases (e.g., cerebral palsy, stroke), 2) Those without diseases affecting posture (e.g., Duchenne muscular dystrophy, spondylolisthesis), 3) Those with degenerative diseases (e.g., spondylosis, hip osteoarthritis): spondylosis, hip Individuals with recent surgery related to musculoskeletal conditions, psychiatric conditions (e.g., ADHD, insomnia, narcolepsy, depression), skin conditions on the abdomen and lower back, and overweight or underweight individuals who would have difficulty wearing the brace were excluded[21], [Table 1].

Table 1. General characteristics of participants (n=12)

Variables	**Group(n=12)**
Age(years)	23.58±1.37
Height(cm)	171±8.60
Body weight(kg)	71.33±15.28
Leg length(cm)	86.08±5.68
Anterior tilt (˚)	11.87±2.28
Left foot length(cm)	24.25±1.60
Left foot width(cm)	8.83±0.71
Right foot length(cm)	24.25±1.60
Right foot width(cm)	8.83±0.71

2.2. Experiment procedures

The principal investigator was responsible for screening potential participants for eligibility and enrolling them in the study on a voluntary basis. General characteristics, including age, height, and weight, were collected on a single occasion. Participants were scheduled to meet with the researcher for an explanation of the experimental procedure prior to the intervention [Figure 1].

The Optogait system was installed by the researcher on a treadmill with a width of 57 cm and a length of 1 m. The participant was attired in sneakers and comfortable clothing, as previously announced, and the researcher requested that the participant walk at a comfortable gait, adjusting the treadmill speed to resemble their normal walking speed. The participants were instructed to walk for a period of two minutes, after which they were measured for a further 30 seconds. They were then permitted a 30-second rest period until the commencement of the subsequent session, during which the researcher placed the LEFB on the participant. The researcher then requested that the participants walk at their natural gait, at a pace that was consistent with their previous walking speed.

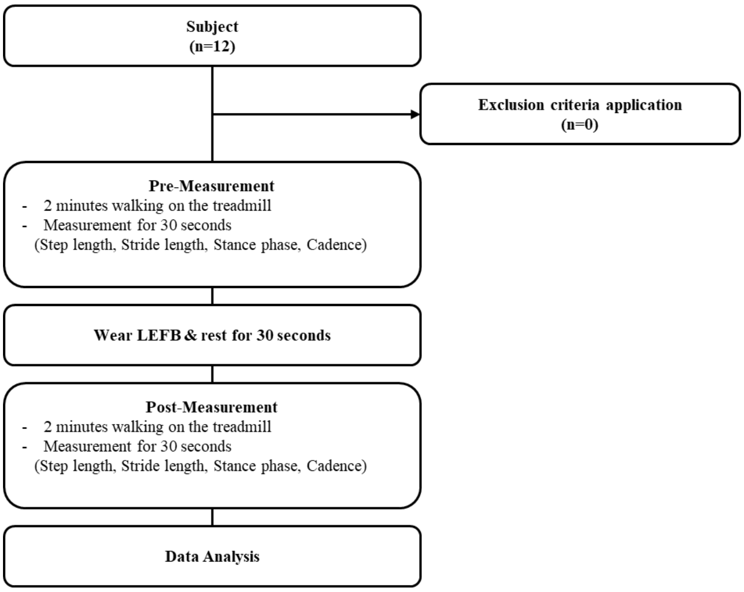

Figure 1. Experiment Procedures

2.3. Measurement Tools and Methods

2.3.1 Measure pelvic angle

Pelvic tilt measurements were obtained in a comfortable standing position. Participants were instructed to maintain gaze at a fixed point in front of them to control for postural sway and to keep their arms crossed over their chest to prevent interference with the measurement[22].The researcher palpated the participant's anterior superior iliac spine and posterior superior iliac spine, marking each protrusion, and calculated the pelvic tilt angle using a trigonometric formula. To do this, the researcher first identified the position of the anterior superior iliac spine and posterior superior iliac spine on the participant's pelvis and then measured the angle between the line connecting these two points and a horizontal plane. This was done according to the formula[23], [Figure 2]. The angle was classified as positive if there was a forward tilt and negative if there was a backward tilt. Additionally, the mean of the two values obtained by a second researcher following a one-minute rest period after the initial measurement by the first researcher was utilized [24].

Figure 2. Measurement of anterior pelvic tilt angle

2.3.2 Lumbar extension-fixed brace

The LEFB (Naresa, South Korea) is designed to provide support to the lumbar spine and is constructed from materials including nylon and polypropylene. The LEFB comprises two straps on either side with a built-in pad in the center, which serves to maintain optimal lumbar alignment. The innermost main strap is utilized to provide primary support to the spine, while the outer Elastic cross strap provides additional compression and facilitate adjustment of the brace to accommodate individual body dimensions [Figure 3, Figure 4]. The brace was donned over clothing to prevent irritation of the skin. Practice walks were conducted to ascertain that the LEFB did not impede the participant's movements, and strap adjustments were made to modify the strength and position of the brace as necessary.

Figure 3. Lumbar extension-fixed brace

A : Front view wearing LEFB, B : Side view wearing LEFB

Figure 4. Wearing a lumbar extension-fixed brace

2.4. Intervention method

2.4.1. Optogait

The OptoGait system comprises a series of rods that transmit and receive light, thereby enabling the measurement of spatiotemporal gait data[25]. Each bar is one meter in length and comprises one hundred light-emitting diodes, arranged in parallel on opposite sides, to transmit a continuous signal between the bars. Consequently, when a subject traverses the space between two bars positioned parallel to the ground, their feet obstruct the transmission and reception of the signal. The system is also capable of measuring distance and duration, and automatically calculates spatiotemporal parameters[26].

The Optogait system was installed on a flat-bottomed treadmill with a width of 57 cm and a length of 1 m. The participant's gait was then analyzed on the aforementioned treadmill with the Optogait system installed. On the day of the study, participants were instructed to walk at a comfortable and safe pace, and the experiment was conducted at the most comfortable pace. All participants were advised to wear sneakers to ensure a safe and accurate gait. Participants walked for two minutes to acclimate to the treadmill, and only the last 30 seconds were evaluated[27], [Figure 5].

The Optogait was connected to a personal computer (PC) via an interface device utilizing the Optogait software program (version 1.6.4.0, Microgate, Bolzano, Italy). The data were extracted at a sampling frequency of 1000 Hz and stored on the PC[28]. In the present study, we measured temporal variables (stance phase, cadence) and spatial variables of gait (stride length, step length) during one experimental session.

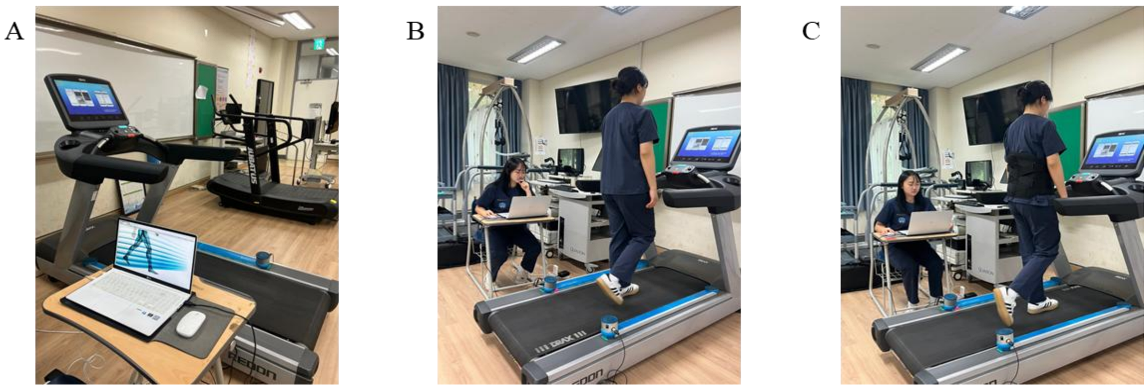

Figure 5. OptogaitA:Treadmill with optogait installed, B: Pre-measurement, C: Post-measurement

2.5. Statistical Analysis

All statistical analyses in this study were conducted using IBM SPSS Statistics Version 29.0.2.0 (20), with the objective of calculating means and standard deviations. Descriptive statistics were employed for the purpose of characterizing the general characteristics of the subjects. Paired t-tests were utilized for the purpose of comparing gait variables before and after LEFB wear. All statistical significance levels were set at $\alpha=0.05$.

3. Results

3.1.Gait Parameters

In this study, we used Optogait to measure the pre- and post-gait parameters when wearing a LEFB in people with pelvic anterior tilt. A paired t-test was performed to compare pre- and post-intervention differences. The results showed that the stance phase of each side was significantly reduced after the intervention ($p<.05$). Cadence was also significantly reduced ($p<.05$). On the other hand, step length increased significantly ($p<.05$), and stride length increased significantly ($p<.05$). When comparing the gait parameters before and after wearing the LEFB, the results showed statistically significant differences in all of the following parameters [Table 2], [Figure 6].

Table 2. Comparison of changes in gait parameters pre and post wearing the lumbar extension-fixed brace

Region		pre	post	t(p)
Step length(cm)	Left	36.97±2.74	38.78±2.56	-3.465**
	Right	37.44±3.34	39.12±3.0	-2.613**
Stride length(cm)		74.41±5.92	77.89±5.45	-3.547**
Stance phase(%)	Left	48.90±6.71	44.23±7.92	5.126***
	Right	49.66±7.37	45.25±8.70	5.050***
Cadence(step/min)		90.05±29.87	85.34±29.23	2.204*

*p<.05, **p<.01, ***p<.001, Mean±SD

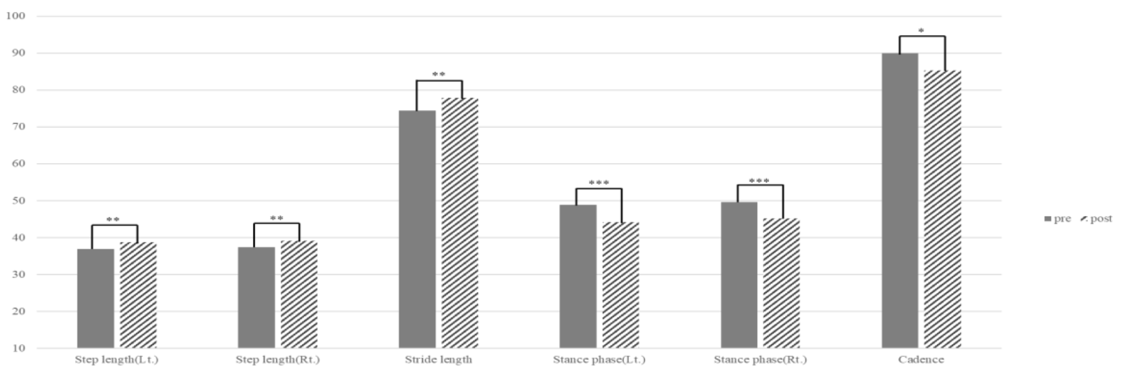

Figure 6. Comparison of changes in gait parameters pre and post wearing the lumbar extension-fixed brace, *p<.05, **p<.01, ***p<.001, Lt: Left, Rt: Right

4. DISCUSSION

The objective of this study was to investigate the impact of an LEFB on the gait parameters of participants with pelvic anterior tilt. It was hypothesized that the LEFB would facilitate changes in gait parameters by adjusting the body alignment of the participants. The results of the study showed that walking with LEFB significantly increased step length and stride length, and shortened stance phase and cadence. This suggests that the LEFB improved the alignment of the hip joint and pelvis, resulting in a more natural gait pattern. In particular, the increase in step length and stride length contributed to an increase in gait efficiency, and together these results suggest that wearing the LEFB may help to improve misalignments common in older adults by aligning the body during walking.

The most common misalignment in older adults is an increase in trunk tilt, which is associated with gait changes, decreased muscle performance, and decreased functional mobility[29]. In particular, it has been observed that older adults with kyphosis, who have a significant increase in the forward tilt of the trunk, exhibit a greater flexion of the hip joint during gait. This increased hip flexion has been reported to impair gait by making it difficult to extend the hip joint. These issues not only impair the mobility of the elderly in their daily lives but can also contribute to an increased risk of falls. Consequently, this review posits that in addition to the trunk tilt angle, the pelvic tilt angle during gait should also be considered as a means of preventing further worsening of anterior trunk tilt and improving walking difficulties in elderly patients[30]. In this respect, it can be observed that the utilisation of LEFBs can assist in alleviating not only the overall tilt of the trunk through lumbar extension, but also the angle of the pelvis. With the enhanced alignment of the lower back when wearing an LEFB, the position of the spine and pelvis remains stable, which is anticipated to contribute to the improved functional movement of the hip joint. A further study demonstrated that the application of an LSO to older adults with spinal misalignment resulted in a reduction in the pelvic anterior tilt angle and a notable increase in walking speed, when compared to the absence of the orthosis[31,32]. In the present study, LEFB was associated with alterations in gait parameters, specifically the extension and realignment of the lower back, which resulted in changes to the aforementioned parameters[30,31]. The human body can be divided into two functional groups during the act of walking: the passenger group and the locomotion group. The passenger group includes the head, neck, torso, and arms and does not directly contribute to the activity of walking. In contrast, the locomotion group, which includes the pelvis and lower limbs, is responsible for the act of walking. The passenger group is situated above the locomotion group[33]. However, people with an anterior pelvic tilt experience direct interference with the musculoskeletal system, which hinders the movement of the lower extremities. Not only does this reduce the efficiency of gait, but in the long run it can put excessive stress on the joints, leading to degenerative changes. In this study, it is believed that body alignment through LEFB reduces this dysfunction and balances the transmission units. In this way, LEFB helps the body maintain stability during gait, which allows muscles to move into position and use force effectively. This process may explain why there were significant results in the stride length, step length, cadence, and stance phases of gait in this study.

One study compared hunched and upright walking on level ground. The results showed that hunched walking resulted in shorter stride lengths and shorter strides than upright walking. This is because hunched walking shifts the center of the hip joint posteriorly, as the hip and knee of the rear leg flex more than in upright walking. This shift has the effect of shortening the stride length by preventing the front leg from moving forward while the trunk is flexed. With the shortening of the stride, stride length is also shortened and the cadence is increased[34]. This can lead to a relatively inefficient gait pattern, resulting in increased energy expenditure. This inefficiency can lead to gait fatigue in the long term and negatively impact gait speed and persistence. Based on these previous studies, we can see that LEFB can help support the body by shifting the center of gravity of the hip joint forward, allowing for a more upright gait. This suggests that wearing LEFB contributes to improved body alignment and increased mobility of the hip joint. These changes suggest a shift in gait parameters, which is expected to have a positive impact on increasing gait efficiency and improving activation patterns of associated muscles.

As previously stated, body misalignment also affects muscle performance. When body misalignment results in an increased pelvic tilt, it inhibits the gluteus maximus and abdominal muscles while promoting the hip flexors and lumbar extensors. These changes can negatively affect the gait pattern, which can ultimately affect balance and stability. Therefore, maintaining proper body alignment is essential for efficient muscle action and improving gait quality. In previous studies, the effects of pelvic belt application on muscle activity were investigated. The findings revealed a decrease in the activity of the transverse abdominis, external oblique, internal oblique, iliacus, erector spinae, and biceps femoris, while the activity of the gluteus maximus increased[35]. This indicates that the belt assists the pelvis in returning to its natural position by extending the lower back and reducing the pelvic anterior tilt angle, which subsequently leads to muscle activation. Furthermore, research has demonstrated that wearing an LSO enhances the function of the muscles, with agonist muscles initiating responses more rapidly than antagonist muscles, which contributes to supporting the efficient functioning of agonist muscles[36]. These alterations in muscle activation may be a significant contributing factor to enhanced stability and efficiency of gait. Based on the findings of previous studies, the results of the present study indicate that wearing the LEFB improved pelvic alignment, which subsequently led to alterations in muscle activation by promoting the correct muscle role, resulting in increased step length and stride length.

The findings of this study indicate that step length and stride length increased following the application of the LEFB. It is generally accepted that individuals with an anterior pelvic tilt tend to exhibit gait characteristics characterised by a relatively short stride length[37]. Previous studies have demonstrated that the use of an LSO has the effect of reducing the range of motion of the trunk and increasing abdominal pressure[12]. The increase in abdominal pressure results in the simultaneous contraction of the abdominal muscles, which contributes to the stability of the body through feed-forward motor control. This is achieved by reducing the angle of rotation of the lumbar spine[38,39]. Furthermore, the augmented abdominal pressure induces a rigid cylindrical deformation of the abdomen, thereby enhancing lumbar spine stability. Collectively, these observations indicate that the augmented abdominal pressure generated by the orthosis confers stability, augments upper extremity stability, and optimizes lower extremity mobility. This implies that the multiple joints of the lower extremity are more efficiently utilized, resulting in a reduction in stance phase and cadence.

This study is limited by several factors. Firstly, as a pilot study, the sample size is relatively small, which limits the generalizability of the results. Secondly, the subjects only wore the orthosis while participating in the experiment, which limits the interpretation of the long-term effects of the orthosis. It would be beneficial for future studies to increase the sample size and extend the duration of the orthosis.

5. CONCLUSION

The purpose of this study was to determine the changes in gait parameters in individuals with pelvic anterior tilt when wearing a LEFB. The results showed that, first, step length and stride length increased with the LEFB. Second, stance phase and cadence decreased with the LEFB. These results suggest that LEFB promotes correct gait by extending the lower back and improving body alignment in people with pelvic anterior tilt. This may explain the underlying reason for the effectiveness of LEFB.

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