

Trunk and pelvic coordination at various walking speeds during an anterior load carriage task in subjects with and without chronic low back pain

TACKHOON KIM, PhD, PT¹⁾, EUNSU CHAI, MS, PT¹⁾*

¹⁾ Department of Physical Therapy, Hanseo University: 360 Daegok-Ri, Haemi-Myun, Seosan-City, Chungnam, Republic of Korea

Abstract. [Purpose] This study compared the coordination patterns of the trunk and pelvis in the transverse plane between healthy subjects and patients with chronic low back pain during an anterior load carriage task at various walking speeds. [Subjects] Ten healthy subjects and 10 patients with chronic low back pain performed an anterior carriage task with a load of 10% body weight at walking speeds of 3.5, 4.5, or 5.5 km/h. [Methods] The trunk and pelvic kinematics were measured by using a motion analysis system. During the anterior carriage task, the continuous relative phase differed significantly between groups with respect to walking speed. [Results] The continuous relative phase was more anti-phase in the chronic low back pain group than the control group. The inter-group continuous relative phase pattern was affected by walking at 5.5 km/h. [Conclusion] Compared to controls, subjects with chronic low back pain are unable to establish an in-phase between the trunk and pelvis from walking at 3.5 to 5.5 km/h during an anterior carriage task.

Key words: Anterior carriage task, Chronic low back pain, Trunk and pelvis coordination

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INTRODUCTION

According to the biomechanical etiologic model of chronic low back pain (CLBP), the suffering of patients with back pain may be due to aberrant patterns of paraspinal muscle activity during movement¹⁻³⁾, these aberrant muscle patterns are caused by dysfunction in the spinal biomechanical system and may compensate for a loss of spinal stability²⁾. They also affect lumbar spine mobility, which may also cause back pain³⁾. Thus, analyzing abnormal trunk and pelvic movement patterns in various environments and during various tasks, would help improve the treatment and rehabilitation of LBP⁴⁾.

Anterior load carriage tasks are mainly used to transfer loads in some industries, such as agriculture and construction^{5, 6)}. They result in increased muscular activity of the anterior deltoid as well as thoracic and lumbar erector spinae muscles. Increased muscle contraction intensity can increase the degree of muscle-generated spinal compression and abnormal movement patterns, which are reported to be factors for the development of LBP⁷⁾.

Transverse trunk and pelvic coordination is important during gait-including anterior load carriage tasks⁵⁾. Stud-

ies of horse gait show that as walking speed increases, the characteristics of quadruped locomotion change with different coordination patterns (e.g., walk, trot, canter, gallop). Therefore, in order to adapt to environmental changes, each segment finds a form of efficient coordination⁸⁾. Healthy subjects use transverse pelvic rotation during unloaded gait in order to increase stride length at an increased walking speed⁹⁾. Anti-phase coordination, in which the trunk and pelvic segments simultaneously move in opposite directions, in transverse plane is increased to decrease total body angular momentum and improve movement efficiency¹⁰⁾. However, while running during unloaded gait, patients with CLBP exhibit more in-phase coordination, in which the trunk and pelvic segments simultaneously move in the same direction than healthy individuals because of their difficulty moving toward anti-phase coordination at an increased walking speed¹¹⁾.

When carrying a backpack weighing (40% of body weight), healthy subjects decrease their transverse pelvic rotation and in-phase coordination of the trunk and pelvis in the transverse plane in order to maintain gait speed as their walking speed increases. In order to compensate for decreased transverse pelvic rotation, healthy subjects increase hip excursion, decrease stride length, and increase stride frequency¹²⁾.

Trunk-pelvis coordination during back-pack and anterior load carriage tasks has been evaluated in healthy subjects. However, no studies have investigated patients with CLBP. As walking speed increases, the segments of the trunk and pelvis can be differentially coordinated in order to achieve overall stability¹³⁾. In other words, individuals with CLBP

*Corresponding author. Eunsu Chai (E-mail: gugudanda@naver.com)

who have reduced stability during an anterior carriage task involving walking are likely to exhibit the opposite changes in the characteristics of trunk-pelvis coordination in the transverse plane compared to healthy individuals¹¹⁾. Therefore, the present study compared trunk-pelvis coordination with respect to walking speed during an anterior load carriage task in subjects with and without CLBP. We hypothesized that patients with CLBP would exhibit more anti-phase coordination during changes of walking speed during the anterior load carriage task than healthy individual.

SUBJECTS AND METHODS

Twenty participants who expressed interest in the study and met the inclusion criteria received information regarding the purpose and methods of this study; all participants signed a copy of the consent form approved by Industry-Academic Cooperation Foundation, Hanseo University in accordance with the ethical standards of the Declaration of Helsinki.

The CLBP group contained subjects who had experienced impairments or abnormalities in low back function for more than two months. LBP was defined as pain under the scapulae and above the cleft of the buttocks. The inclusion criteria were age ≥ 20 years, history of LBP for more than two months without pain referral into the lower extremities.

Subjects were excluded if they had been diagnosed with a psychological illness that might interfere with the study protocol, had neurological signs (i.e., sensory deficits or motor paralysis), or were pregnant. Participants were withdrawn from the study upon request. The control group include age- and sex-matched volunteers to minimize confounding effects during the study period and increase the internal validity of the data¹⁴⁾.

Kinematic data in the transverse plane were collected using the Vicon motion system (Vicon Motion Systems, Oxford Metrics Ltd., Oxford, UK) with six infrared cameras (Vicon MX-F20, Oxford Metrics Ltd.) at a sampling frequency of 150 Hz. The Woltering filter method was used, and the mean squared error was set to 15. Static and dynamic calibrations were performed before capturing axial trunk motion. The centers of rotation of the body were measured in order to obtain height as well as shoulder, elbow, wrist, knee, ankle and leg widths and lengths. Spherical reflective markers (14 mm) from the Plug-In Gait marker set were used for three-dimensional data collection. The positions of the markers were C7, T10, the right-upper back (i.e., mid-scapular spine), between the clavicles, the xiphoid process of the trunk, the bilateral anterior and posterior superior iliac spines, thigh, knee joint, tibia, ankle joint, heel, and toe. The reflective markers collected kinematic data from the trunk and pelvic segments. The trunk segment was defined according to calibration markers placed on C7, T10, the right-upper back, between the clavicles, and the xiphoid process. Meanwhile, the pelvic segment was defined according to calibration markers placed on the bilateral anterior superior and posterior superior iliac spines.

The participants completed a 10-minute warm-up period by waking repeatedly on a 10 m line. They were asked to carry a load anteriorly that was equivalent to 10% of their body weight. They subsequently began walking at 3.5, 4.5,

Table 1. Subject characteristics

	Control group	CLBP group
N (Male/Female)	10 (5/5)	10 (5/5)
Age (years)	21.5 \pm 1.8	21.4 \pm 1.5
Height (cm)	167.4 \pm 6.2	169.9 \pm 5.6
Mass (kg)	65.7 \pm 7.4	66.3 \pm 8.3
Pain scores (VAS)	0	4.5 \pm 0.8
Disability scores (ODI, %)	0	15.5 \pm 2.8

CLBP: chronic low back pain; VAS: visual analog scale; ODI: Oswestry disability index

Table 2. Mean cross-correlation coefficients of the continuous relative phase between groups

	Inter-group coordination		
	3.5 km/h	4.5 km/h	5.5 km/h
Control vs. CLBP	0.97	0.96	-0.72

CLBP: chronic low back pain

or 5.5 km/h selected at random. The tasks were always performed between 10 a.m. and 5 p.m. to account for the diurnal variation in spinal disc fluid content and its effect on the lumbar spine¹⁵⁾.

The continuous relative phase (CRP) during the third right stride (i.e., heel strike to heel strike) of five strides was calculated. The profile was calculated as the ensemble mean of the relative phase (RP) of the control and CLBP groups as follows: $RP(t) = \phi T(t) - \phi P(t)$, where $\phi T(t)$ is the phase angle of the trunk, and $\phi P(t)$ is the phase angle of the pelvis at time t . The RP between the trunk and pelvis was calculated on the basis of the angular displacements^{16, 17)}.

The data were analyzed using SPSS version 20.0 for Windows. Independent t-tests were used to compare the control and CLBP groups. Mean CRP was used to calculate the cross-correlation coefficients of CRP patterns¹⁸⁾. The level of significance was set at $p < 0.05$.

RESULTS

The baseline characteristics of the two groups are shown in Table 1. The CRP is presented in Fig. 1. The CRP differed significantly between groups at all three walking speeds ($p < 0.05$). The mean cross-correlation coefficients of the CRP between groups 3.5, 4.5 and 5.5 km/h were 0.97, 0.96 and -0.72, respectively (Table 2).

DISCUSSION

This study compared the coordination pattern of the pelvis and trunk in healthy people and patients with CLBP carrying an anterior load at various walking speeds. We hypothesized that patients with CLBP would exhibit more anti-phase coordination with walking speed changes during the anterior load carriage task; our findings support this hypothesis.

In humans, increasing walking speed during unloaded walking necessitates achieving proper stability, which also

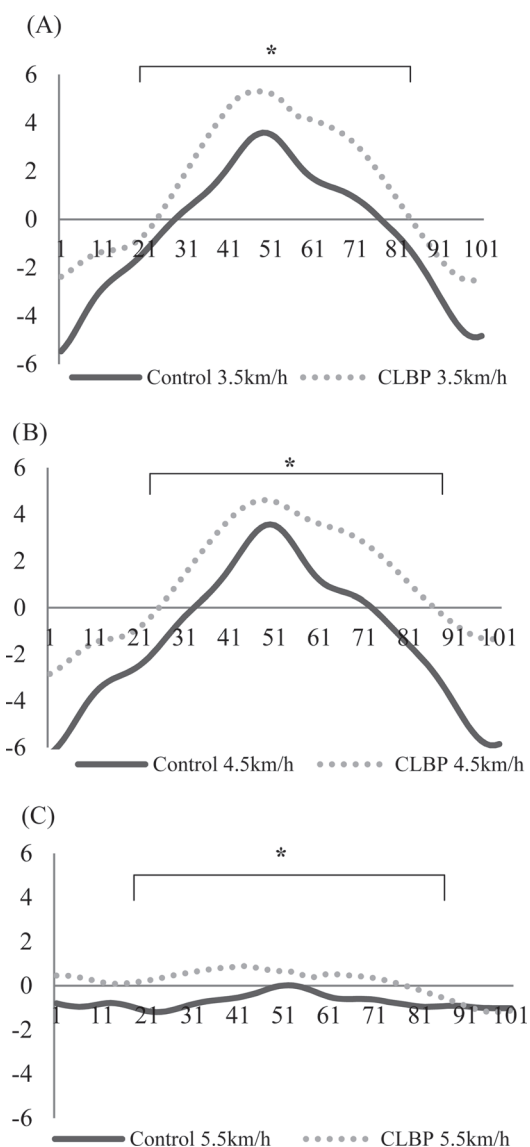


Fig. 1. Continuous relative phase during the anterior load carriage task at 3.3 km/h (A), 4.4 km/h (B), and 5.5 km/h (C) CLBP: chronic low back pain; * $p < 0.05$

changes from more in-phase to more anti-phase trunk and pelvic transverse rotation⁹). LBP status affects pelvis-trunk coordination during walking and running. The transition of runners with LBP from walking to running without a load involves more in-phase trunk and pelvic transverse rotation than healthy controls¹¹).

Studies using back-pack conditions demonstrate another transition from more anti-phase to more in-phase trunk and pelvic transverse rotation¹²).

Gait studies report that patients with LBP have decreased walking speed, step length, swing time, and maximal endurance. Moreover, the transitions of trunk-pelvic transverse rotation are more in-phase as walking speed increases without a load¹⁹).

Ipsilateral arm and leg reciprocal swings in unloaded conditions may assist counterbalancing the angular momentum

of the lower body²⁰). Arm swings help minimize energy consumption and optimize stability in humans^{21–23}). However, unlike backpack conditions, an anterior carriage task does not involve arm swinging but instead only uses the lower body and an upright posture. This suggests the existence of some level of counterbalancing between the upper and lower body during anterior carriage tasks. Accordingly, walking faster than 3.5 km/h during an anterior carriage task may result in a need for counter-rotation between the pelvis and trunk to achieve optimal stability.

The present results indicate the locomotive problems of the CLBP group predominantly involve the coordination of pelvic and trunk transverse rotation. The CLBP group showed a lower CRP throughout the gait cycle at 3.5 and 4.5 km/h, and from 0–90% of the gait cycle at 5.5 km/h. This indicates that patients with CLBP move the trunk and pelvis as one unit and in-phase, suggesting they cannot control the pelvis to maintain a consistent walking speed during an anterior carriage task. These changes are similar to those occurring under back-pack conditions¹²).

The mean cross-correlation coefficients for CRP between groups were close to 1.0 at 3.5 and 4.5 km/h but closer to -1.0 at 5.5 km/h, indicating a different coordination pattern at higher walking speeds; this may be a method for reducing energy consumption at higher walking speeds¹⁸).

The main limitation of this study is the small number of participants, making it difficult to generalize the results. Moreover, CLBP was a certain level, and its effects on muscles and in other planes were not analyzed at different walking speeds. Therefore, further research is required to clarify the three-dimensional motions of the pelvis and trunk, and gait parameters as well as focus on the changes in kinematic parameters and muscle activity patterns associated with the changes in trunk and pelvis coordination.

In conclusion, patients with CLBP use different coordination patterns of trunk and pelvic transverse rotation during an anterior carriage task.

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