ORIGINAL ARTICLE

Comparison of Different Kinematic Values of Lower Extremities during Gait between Individuals with Chronic Non-Specific Low Back Pain and Healthy Persons

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Objective: The primary purpose of the present study was to compare the differences in lower extremity kinematic parameters in individuals who have chronic non-specific low back pain (CNLBP) with healthy control subjects (CTRL) during subphase of the stance phase. The secondary purpose was to compare the average walking speed of individuals who had CNLBP with CTRL during stance phase.

Materials and Methods: The present study was conducted with 26 patients, 13 of 26 were participants with CNLBP and the other 13 were CTRL. To study the subject's walking characteristics, 3D motion analysis was applied. Each subject was attached to 47 retroreflective markers and asked to walk barefoot on a 10-meter walkway at the preferred walking speed. The independent t-test and Mann Whitney U-test were used to compare joint excursions of each subphase of the stance phase and the average walking speed between two groups.

Results: The CNLBP group had significantly lower forefoot motion in the sagittal plane during the initial contact phase than CTRL group, (p=0.017). They exhibited significantly lower hip motion in the sagittal plane (p=0.043), and lower knee motion in the transverse plane (p=0.007) during the forefoot contact phase as well. The CNLBP group exhibited significantly increased rearfoot motion in the frontal plane (p=0.002) during the foot flat phase. Moreover, the CNLBP group had significantly lower hip motion in the sagittal plane during the push-off phase (p=0.033).

Conclusion: Individuals with CNLBP might modify their walking characteristics of the lower extremities and walk slower when compared with healthy persons to accommodate the pain they were dealing with.

Keywords: Lower Extremity; Kinematics; Chronic Non-specific Low Back Pain; Gait; Gait Speed

Received 10 May 2023 | Revised 24 May 2023 | Accepted 31 May 2023

J Med Assoc Thai 2023;106(9):889-96

Website: http://www.jmatonline.com

Non-specific low back pain (NLBP) is a diagnosis of low back pain (LBP) symptoms in which an individual has unidentified pain at the lower back region, located in the region between the spinous process of the thoracic spine level 12 and the inferior gluteal folds, with unknown pathological and anatomical causes, as well as no signs of a serious underlying condition[1,2]. Most LBP sufferers are non-specific, and only approximately 10% have a specific cause of pain[3]. NLBP lasting more than three months is defined as chronic non-specific low back pain (CNLBP)[1]. Patients with CNLBP and high levels of pain and disability often report functional impairment in performing daily activities[4].

The associated factors for LBP are multi-dimensional, including work-related factors, psychosocial, and physical factors. One of the most common factors associated with LBP is physical factors[5]. It includes both individual characteristics and physical structures. According to the literature, the LBP not only have direct physical structure problems in the lumbo-pelvic region such as abnormal lordotic curve, poor strength of core muscles, iliosacral, and sacroiliac joint dysfunction[6-8], but also have factors in the indirect correlation with the lumbo-pelvic region, such as abnormal hip range of motion[9], and characteristic of abnormal foot posture[10], which may lead to abnormal lumbo-pelvic motion and contribute to LBP. In addition, some studies have also reported that some functional activities are associated with LBP, including prolonged standing[11] and walking[12], as well as prolonged sitting and working in a static

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How to cite this article:

Chinpeerasathian C, Chenboonthai W, Pensri P. Comparison of Different Kinematic Values of Lower Extremities during Gait between Individuals with Chronic Non-Specific Low Back Pain and Healthy Persons. J Med Assoc Thai 2023;106:889-96.

DOI: 10.35755/jmedassocthai.2023.09.13863

posture[13].

Previous studies indicated that patients with chronic low back pain (CLBP) had gait shifted from regular pattern. They moved with slower walking speeds than healthy persons[14,15]. Additionally, CLBP patients had a longer stance duration and shorter step length than healthy persons[15,16]. The change in walking pattern of CLBP individuals may come from physical and psychological factors. The slower walking reflects the presence of pain associated with fear-avoidance behavior[14,15]. Patients who believe that walking can aggravate the symptoms of LBP may alter their ability to perform normal gait at different velocities[14]. They may avoid performing other activities that they believe would further damage their spine and aggravate their pain[17]. In addition, patients with CLBP have limitations in motor control and neuromuscular strategies for movement[18,19].

Each lower extremity segment has an interaction chain with the pelvis and spine. Changes to one joint mechanism can have an impact on the rest of the joint chain[20]. Studies have shown changes in lower extremity kinematics in patients with CLBP during walking[15,16,20], which investigated the motion of a system of bodies without considering for forces. The lower extremity kinematic studies showed that CLBP patients altered the walking pattern. The CLBP showed significantly lower hip motion in the transvers plane, and lower knee and ankle motion pattern in the sagittal plane[20]. Moreover, CLBP group had more knee extension at the heel strike than the healthy group during level and uneven walking[15,16]. Previous studies have shown that CLBP patients seem to have lower extremity kinematics differences from healthy individuals. However, the lower extremity kinematic values presented in those studies were inconclusive and incomplete because the kinematics of the foot complex were not reported. Those studies investigated the entire stance phase rather than a subphase of the stance phase[15,16,20].

To understand a clear picture of the walking characteristics of patients with CLBP during walking, it is necessary to consider kinematic data of hip, knee, and ankle joint, as well as complex foot joint movements and the walking speed. Therefore, the primary objective of the present study was to compare the whole lower extremity kinematics between individuals with and without CNLBP, including the multisegmented foot kinematics, in the four subphases of the stance phase of the gait cycle. The second objective was to compare the average walking speed during stance phase between both subject groups.

Materials and Methods

The present study was a cross-sectional study. All subjects had to do self-administered questionnaires and three screening examinations. The sample size was calculated from the G*Power software version 3.1.9.2. According to our pilot study, using the result of Cal-Met; Foot flat, frontal plane to calculated, the mean and standard deviation (SD) in the CNLBP group and the healthy group were 2.66 (0.17) and 1.61 (1.26), respectively[21]. The alpha error probability (α) was set as 0.05 and the power analysis was set as 0.8. Twenty-six patients were included based on the inclusive criteria based on the questionnaires. They were aged between 18 to 40 years old. The subjects were divided into two groups with 13 patients with CNLBP and 13 healthy individuals (CTRL). All patients signed the consent form. Potential subjects were excluded if they had at least one of the following conditions, 1) specific LBP such as spondylolisthesis or herniated nucleus pulposus (HNP), 2) body mass index (BMI) more than 30 kg/m², 3) leg length discrepancy, 4) highly pronated or highly supinated foot posture assessed by foot posture index (FPI), 5) positive sciatica sign, 6) history of lower extremity fracture or surgery, 7) a diagnosis of gout, diabetic neuropathy, rheumatoid arthritis, tumor, cancer, systemic lupus erythematosus (SLE), or infectious disease, and 8) increasing one level of pain over the baseline pain intensity during the data collection phase. Fortunately, all study patients did not have any of the exclusive criteria. The present study was approved by the Internal Review Board of Chulalongkorn University (100.1/2018) since it was a study related to humans and complied with all relevant national regulations and institutional policies.

Screening tools

A self-administered questionnaire on the history of musculoskeletal disorder was used to screen the ineligible subjects out. For the screening examination, three tests were conducted consisting of leg length measurement, straight leg raising (SLR) test, and FPI assessment.

Kinematic assessment

Lower-extremity kinematics were collected from an eight-camera motion analysis system (Motion Analysis Corp., Santa Rosa, CA) with a flash rate of 120 Hz. The cameras were synchronized with three force transducers (Bertec force, Columbus, OH, USA), which were set to have a sampling frequency of 1,200 Hz on a 10-meter walkway. The software from the motion analysis system (Cortex, version 2.5) contained three major functions, calibrating the capture volume, tracking, and identifying marker locations in calibrated 3D space, and processing data for other packages. Marker histories and analogue signals were smooth with 6th-order, low-pass Butterworth filters at 5 Hz and 50 Hz, respectively.

The kinematic assessment was conducted in the Musculoskeletal Biomechanics Laboratory, Faculty of Allied Health Sciences, Chulalongkorn University. At the beginning of a gait trial, subject preparation was performed. The spherical retroreflective markers were placed on the subject's anatomical landmarks following the Helen Hayes marker set(22) and multisegmented foot model(23) by a blind research assistant. The present study used the Usual 10-Meter Gait Speed to test walking speed(24). After the markers were attached, the subjects were asked to practice walking at their usual walking speed as well as walking at a comfortable/natural pace with markers in a 10-meter walkway to get familiar with all markers. They were then instructed to walk barefoot along a 10-meter walkway at their usual preferred walking speed for five successful trials. Each trial meant the complete contact of both feet on the force plate. The walking speed was calculated using the automated software from the motion analysis system (Motion Analysis Corp., Santa Rosa, CA) using the average step length divided by step time during the stance phase on the force plates. The automated timing system began when the first initial contact of the first leg was made and terminated when the first initial contact of the other leg was made. In the present study, the standard error of measurement (SEM) of the 3D motion analysis ranged between 0.03 and 0.26.

Data processing

Walking speed as a gait parameter was collected from each subject throughout the stance period. The stance phase of a gait cycle was defined as the duration between first and last contact of the same foot, which was then normalized with 60% of the gait cycle. Two peaks of vertical ground reaction forces were used to determine four components of the stance phase, which included the initial contact phase (ICP), forefoot contact phase (FFCP), foot flat phase (FFP), and forefoot push off phase (FFPOP). ICP was the duration between the first heel contact and metatarsal contact. FFCP was the duration between first metatarsal contact and forefoot flat. FFP was the duration between the forefoot being flat and heel off. Additionally, FFPOP was the duration between the heel off and last foot contact(25).

The kinematic data of the dominant leg of each subject were computed from custom MATLAB software (R2018b) in all three planes, sagittal, frontal, and transverse. A joint excursion was defined as the difference between the maximum and minimum joint angles within each subphase of the stance phase. Joint angles were calculated using a Cardan XYZ sequence of rotations with six degrees of freedom, and the distal segment was relative to the proximal segment. A total of lower extremity segments from Helen Hayes models was studied, including the pelvis, thigh, and shank. Specific multisegmented foot models were studied, including shank-calcaneus (Sha-Cal) in the rearfoot, calcaneus-midtarsus (Cal-Mid) in the midfoot, and midtarsus-metatarsus (Mid-Met) in the forefoot, as well as calcaneus-metatarsus (Cal-Met)(22,23). The planar angles of the first metatarsophalangeal (MTP) joint and the medial longitudinal arch (MLA) were computed with MATLAB software.

Statistical analysis

IBM SPSS Statistics, version 22.0 (IBM Corp., Armonk, NY, USA) was used for quantitative data analysis. Demographic data of the subjects in both groups were presented as the mean and standard deviation for the numerical data. For the normality test, the Shapiro-Wilk test was performed. The comparisons between groups were performed using either the independent t-test (parametric statistics) or Mann-Whitney U test (non-parametric statistics). A level of p-value less than 0.05 was considered statistically significant.

Results

A summary of the subjects' demographics confirmed that there were no significant differences between the groups for age, height, weight, or BMI, as shown in Table 1. There were 26 participants in the present study, 13 patients with CNLBP and 13 healthy individuals (CTRL), with six women and seven men in each group.

Table 2 demonstrates the average walking speed of both groups. The results showed that the CNLPB group had significantly slower walking speed than the CTRL group (p=0.038).

Table 3 and 4 demonstrate and compare the results of hip, knee, ankle, and multisegmented foot

Table 1. Demographics of the studied groups

Variables	CTRL (n=13) mean (SD)	CNLBP (n=13) mean (SD)	p-value
Age (year)	24.1 (2.7)	24.5 (3.3)	0.754
Weight (kg)	63.8 (9.8)	62.1 (9.7)	0.643
Height (cm)	166.2 (8.7)	166.4 (9.5)	0.959
BMI (kg/m^2)	22.9 (2.4)	22.3 (2.4)	0.456

SD=standard deviation; CTRL=control group; CNLBP=chronic non-specific low back pain group; BMI=body mass index

* Significant level at p<0.05

Table 2. Summary of mean walking speed and standard deviation (in cm/second) for CTRL and CNLBP

	CTRL (n=13) mean (SD)	CNLBP (n=13) mean (SD)	95% CI (p-value)
Walking speed	114.1 (13.8)	103.3 (11.0)	0.65 to 20.85 (0.038*)

SD=standard deviation; CTRL=control group; CNLBP=chronic non-specific low back pain group; CI=confident interval of the difference

* Significant level at p<0.05

joint excursions between the CNLBP and CTRL groups. In the current study, the multisegmented foot was divided into four regions, rearfoot, midfoot, forefoot, and hallux. The rearfoot contained the shank-calcaneus (Sha-Cal) model. The midfoot contained the calcaneus-midtarsus (Cal-Mid) model. The forefoot contained the midtarsal-metatarsus (Mid-Met) and calcaneus-metatarsus (Cal-Met). During ICP, the CNLBP group had significantly lower forefoot motion in the sagittal plane (p=0.017) than the CTRL group. However, there was no significant difference between the groups in hip, knee, and ankle joint excursions in this phase. In the FFCP, the CNLBP group significantly decreased hip motion in the sagittal plane (p=0.043) and knee motion in the transverse plane (p=0.007), while the other regions did not show significant changes. Regarding the FFP, only the rearfoot motion of the CNLBP group, the frontal plane was significantly increased compared with that of the CTRL group (p=0.002). In the FFPOP, the CNLBP group had significantly decreased hip motion in the sagittal plane (p=0.033), while there was no difference in knee, ankle, or foot-segmental joint excursions between the groups.

Discussion

The aim of the present study was to compare lower

Table 3. Summary of mean joint excursion and standard deviation (°) of hip, knee, and ankle during four subphases of stance for CTRL and CNLBP

		Initial contact			Forefoot contact			Foot flat			Forefoot push off		
		CTRL mean (SD)	CNLBP mean (SD)	95% CI (p-value)	CTRL mean (SD)	CNLBP mean (SD)	95% CI (p-value)	CTRL mean (SD)	CNLBP mean (SD)	95% CI (p-value)	CTRL mean (SD)	CNLBP mean (SD)	95% CI (p-value)
Hip													
SAG	E/F	10.2 (3.3)	12.0 (8.4)	−6.99 to 3.37 (0.898)	15.6 (5.8)	11.9 (2.5)	0.05 to 7.24 (0.043*)	13.2 (3.3)	15.3 (3.7)	−4.99 to 0.71 (0.136)	11.0 (1.9)	8.3 (2.0)	0.12 to 5.17 (0.033*)
FL	Add/Abd	8.5 (2.6)	8.7 (3.5)	−7.14 to 3.52 (0.897)	3.9 (1.9)	3.1 (1.8)	−0.66 to 2.32 (0.263)	2.2 (1.5)	2.9 (2.3)	−2.25 to 0.96 (0.590)	12.6 (2.8)	12.2 (2.1)	−1.57 to 2.44 (0.658)
TVS	IR/ER	7.3 (3.1)	7.8 (3.4)	−3.12 to 2.14 (0.706)	3.0 (1.1)	3.3 (1.8)	−1.59 to 0.79 (0.778)	2.8 (1.1)	3.1 (1.2)	−1.26 to 0.65 (0.517)	11.0 (3.5)	13.0 (3.6)	−4.86 to 0.88 (0.165)
Knee													
SAG	E/F	11.2 (9.1)	13.4 (16.6)	−13.05 to 8.64 (0.778)	7.7 (4.6)	−6.2 (3.0)	−1.63 to 4.63 (0.331)	5.1 (2.5)	5.3 (2.3)	−2.13 to 1.74 (0.836)	39.9 (6.3)	36.7 (5.2)	−1.55 to 7.78 (0.317)
FL	Add/Abd	4.7 (1.8)	5.8 (2.9)	−3.02 to 0.88 (0.271)	1.6 (1.4)	2.0 (1.6)	−1.57 to 0.90 (0.397)	1.8 (0.8)	2.4 (2.1)	−1.92 to 0.69 (0.898)	4.6 (1.8)	4.0 (2.0)	−0.98 to 2.15 (0.317)
TVS	IR/ER	3.5 (1.7)	4.6 (4.7)	−3.95 to 1.77 (0.817)	2.0 (1.0)	1.5 (1.2)	0.16 to 1.75 (0.007*)	1.7 (0.8)	1.7 (2.4)	−0.50 to 0.58 (0.731)	5.2 (1.7)	5.0 (2.1)	−1.37 to 1.70 (0.555)
Ankle													
SAG	DF/PF	10.4 (5.3)	10.3 (7.2)	−5.02 to 5.21 (0.701)	7.5 (4.0)	−6.3 (2.4)	−1.49 to 3.87 (0.367)	5.3 (2.5)	6.5 (3.2)	−3.53 to 1.10 (0.289)	31.3 (5.2)	29.4 (5.5)	−2.52 to 6.18 (0.394)
FL	Inv/Eve	8.4 (3.2)	8.6 (3.0)	−2.73 to 2.29 (0.859)	1.8 (1.5)	2.7 (1.7)	−2.20 to 0.38 (0.158)	5.4 (1.9)	6.6 (3.1)	−3.32 to 0.81 (0.173)	8.0 (3.3)	9.6 (4.5)	−4.84 to 1.55 (0.298)
TVS	Add/Abd	7.1 (2.7)	8.3 (4.9)	−4.40 to 1.98 (0.739)	4.6 (1.7)	4.8 (3.0)	−2.20 to 1.79 (0.555)	4.1 (1.4)	5.3 (1.6)	−2.19 to 0.31 (0.133)	6.5 (3.0)	5.6 (3.4)	−1.81 to 3.43 (0.528)

SD=standard deviation; CTRL=control group; CNLBP=chronic non-specific low back pain group; CI=confident interval of the difference; SAG=sagittal plane; FL=frontal plane; TVS=transverse plane; E/F=extension/flexion; Add/Abb=adduction/abduction; IR/ER=internal rotation/external rotation; DF/PF=dorsiflexion/plantarflexion; Inv/Env=inversion/eversion

* Significant level at p<0.05

Table 4. Summary of mean joint excursion and standard deviation (°) of multi-segment foot during four subphases of stance for CTRL and CNLBP

			Initial contact			Forefoot contact			Foot flat			Forefoot push off		
			CTRL mean (SD)	CNLBP mean (SD)	95% CI (p-value)	CTRL mean (SD)	CNLBP mean (SD)	95% CI (p-value)	CTRL mean (SD)	CNLBP mean (SD)	95% CI (p-value)	CTRL mean (SD)	CNLBP mean (SD)	95% CI (p-value)
Rearfoot														
Sha-Cal	SAG	DF/PF	9.7 (4.7)	10.9 (7.0)	−6.05 to 3.58 (0.590)	7.7 (4.4)	5.9 (2.6)	−1.15 to 4.74 (0.209)	6.3 (2.7)	7.3 (2.8)	−3.50 to 0.97 (0.256)	29.1 (5.4)	27.0 (5.0)	−2.05 to 6.31 (0.303)
	FL	Inv/Eve	4.7 (2.4)	5.8 (3.1)	−3.34 to 1.88 (0.397)	1.7 (1.6)	2.5 (2.9)	−1.97 to 0.37 (0.158)	2.8 (1.0)	5.0 (2.0)	−3.43 to −0.94 (0.002*)	5.4 (2.0)	5.9 (3.1)	−2.67 to 1.57 (0.595)
	TVS	Add/Abd	6.7 (2.5)	7.7 (4.3)	−3.86 to 1.86 (0.590)	4.3 (1.6)	4.3 (2.9)	−1.86 to 1.90 (0.555)	3.5 (1.5)	4.3 (2.0)	−2.27 to 0.57 (0.144)	6.4 (3.2)	4.5 (2.4)	−0.39 to 4.20 (0.100)
Midfoot														
Cal-Mid	SAG	DF/PF	6.5 (1.9)	6.1 (3.8)	−2.11 to 2.79 (0.590)	2.7 (1.4)	2.0 (1.3)	−4.99 to 1.73 (0.980)	2.3 (0.5)	3.2 (1.8)	−1.89 to 0.23 (0.270)	9.8 (2.5)	8.8 (1.8)	−1.59 to 3.77 (0.898)
	FL	Inv/Eve	5.1 (1.1)	4.8 (2.9)	−1.50 to 1.70 (0.902)	1.2 (0.6)	1.0 (0.9)	−0.88.3.14 (0.207)	2.1 (1.1)	2.1 (0.8)	−1.30 to 0.63 (0.476)	8.1 (2.7)	10.1 (4.3)	−1.46 to 4.80 (0.626)
	TVS	Add/Abd	6.7 (2.2)	5.7 (2.0)	−7.15 to 9.56 (0.427)	2.1 (0.9)	2.0 (0.8)	−3.92 to 9.82 (0.980)	2.6 (1.4)	2.4 (1.7)	−2.92 to 1.94 (0.681)	5.8 (2.6)	6.0 (4.0)	−0.95 to 9.19 (0.174)
Forefoot														
Mid-Met	SAG	DF/PF	9.7 (5.0)	6.0 (2.8)	0.40 to 6.91 (0.017*)	5.3 (5.0)	3.1 (1.6)	−0.84 to 5.17 (0.369)	4.1 (1.5)	4.6 (2.1)	−1.94 to 0.97 (0.555)	13.8 (8.1)	11.8 (3.9)	−3.17 to 7.14 (0.739)
	FL	Inv/Eve	10.5 (12.0)	7.3 (3.4)	−3.90 to 10.35 (0.980)	3.3 (3.5)	2.5 (1.4)	−1.32 to 2.99 (0.898)	3.9 (3.4)	3.9 (1.7)	−2.16 to 2.18 (0.270)	14.6 (15.7)	9.4 (3.9)	−4.10 to 14.44 (0.191)
	TVS	Add/Abd	8.5 (1.6)	7.0 (1.4)	−5.57 to 8.47 (0.130)	6.2 (13.0)	3.2 (0.9)	−4.43 to 10.40 (0.317)	4.8 (1.8)	5.1 (2.3)	−2.58 to 0.83 (0.298)	8.4 (4.8)	8.0 (5.3)	−3.71 to 4.48 (0.555)
Cal-Met	SAG	DF/PF	6.5 (1.9)	6.1 (3.8)	−2.11 to 2.79 (0.144)	2.7 (1.4)	2.0 (1.3)	−0.50 to 1.73 (0.270)	2.3 (0.5)	3.2 (1.8)	−1.89 to 0.23 (0.489)	9.8 (3.1)	8.8 (3.5)	−1.59 to 3.77 (0.408)
	FL	Inv/Eve	5.1 (1.1)	4.8 (2.9)	−1.51 to 2.00 (0.317)	1.2 (0.6)	1.1 (0.9)	−0.47 to 0.72 (0.191)	2.1 (1.1)	2.1 (0.8)	−0.84 to 0.73 (0.522)	8.1 (2.7)	10.1 (4.3)	−4.84 to 0.95 (0.191)
	TVS	Add/Abd	6.7 (2.2)	5.7 (2.0)	−0.67 to 2.75 (0.223)	2.1 (0.9)	2.0 (0.8)	−0.60–0.76 (0.812)	2.6 (1.4)	2.4 (1.7)	−1.09 to 1.40 (0.522)	5.8 (2.6)	6.0 (4.0)	−2.93 to 2.90 (0.739)
Hallux	SAG	DF/PF	17.7 (5.7)	24.3 (13.5)	−14.96 to 1.08 (0.270)	3.6 (2.7)	5.8 (3.8)	−4.83 to 0.54 (0.077)	4.8 (1.8)	5.1 (2.3)	−3.74 to 2.96 (0.298)	39.2 (10.7)	41.4 (8.8)	−10.11 to 5.77 (0.577)

SD=standard deviation; CTRL=control group; CNLBP=chronic non-specific low back pain group; CI=confident interval of the difference; SAG=sagittal plane; FL=frontal plane; TVS=transverse plane; Add/Abb=adduction/abduction; IR/ER=internal rotation/external rotation; DF/PF=dorsiflexion/plantarflexion; Inv/Env=inversion/eversion; Sha-Cal=shank-calcaneus; Cal-Mid=calcaneus-midtarsus; Mid-Met=midtarsus-metatarsus; Cal-Met=calcaneus-metatarsus

* Significant level at $p<0.05$

extremity kinematics including the multisegmented foot joint between individuals with and without CNLBP during the stance phase. In the control group, the individuals with lower extremity pain were excluded for the internal validity of the study. The study group, which is the participants with CNLBP, were assessed while they had LBP and they did not progressively get worse during data collection.

In general, gait patterns were quite similar when observed and compared in all phases of gait between CNLBP and control groups. However, in the present study, the group with CNLBP had kinematic data different from those of the control group especially in the stance phase. There were significant differences in all subphases in each region, including the hip, knee, and foot.

The current results provided evidence for slower walking speed and more cautious walking pattern in CNLBP patients. This result was consistent with previous studies(14,15). For instance, Al-Obaidi et al. studied the influence of pain, pain-related fear, and disability on the walking speed among the patients with CLBP(14). They found that gait speed was decreased in the LBP patients who reported more fear of movement(14,15). Decreasing walking speed may be due to a protective mechanism, of which an individual attempts to reduce the ground reaction forces, minimizing the overload in the spine column, keeping the stability, and avoiding the pain. Furthermore, changes in walking speed may subsequently initiate changes in joint mechanics. When people walk slowly, they use less segmental energy to generate force, which results in a decrease in amplitude in spatiotemporal parameters, joint kinematics, and joint kinetics(26).

In ICP, significant differences between groups were found only in the multisegmented foot. The CNLBP group had lower forefoot motion in the sagittal plane. This difference might indicate a reduced amount of flexion-extension movement of the metatarsophalangeal joint (MTPJ) during heel strike in individuals with CNLBP. It could be assumed that CNLBP patients exhibit MTPJ limitations. Further investigation is needed to prove this motion.

Furthermore, CNLBP group might have compensatory motion at the hip and knee during walking. In the FFCP, the CNLBP group had lower hip motion in the sagittal plane, and lower knee motion in the transverse plane. According to Vogt et al., CLBP patients had lower hip motion in the sagittal plane during walking, which required an earlier and longer onset of erector spinae and gluteus maximus muscle compared to healthy people to maintain stability during movement(27). During the lower extremity initially transferred body weight from the rearfoot, less hip flexion/extension might lead to poor femoral alignment for weight-bearing posture, thus this could interrupt the completion of the skew-home mechanism of the knee joint, as lower knee motion in the transverse plane occurred in this subphase.

In FFP, this phase requires more stability of the lower extremities, pelvis, and trunk(28). The CNLBP group had more motion of the rearfoot in the frontal plane. According to the theoretically explained biomechanics of the FFP, this subphase is in relation to the mid-stance phase in which the foot settles at the lateral border. Foot supination in ICP changes to foot pronation in FFCP and then moves to a neutral position in FFP(28,29). In the current study, subjects with CNLBP had higher motion of the rearfoot in the frontal plane, indicating excessive supination to pronation of the subtalar joint to stabilize their foot arch, which might decrease stability to the distal joints. This finding is similar to the result of Anukoolkarn et al., who discovered that CNLBP patients walked with a higher frequency of average mean peak pressure in the medial side of the rearfoot area when compared to asymptomatic subjects in mid-stance(30).

In the FFPOP, the CNLBP group had lower hip motion in the sagittal plane. To perform an effective propulsion phase, the body needs to have sufficient body stability to produce an adequate propulsion force, especially the power of trunk and pelvic extensor muscles(28,31). Patients with CLBP were reported to have a weakening of the trunk and abdominal muscles, and the change in trunk muscle activity, particularly in the lumbar multifidus and transversus abdominis, that controls the mobility and stability of the lumbopelvic region(7,32). The alteration of coordination of trunk and pelvis may result in a poor performance of movement(18,32,33). It might be possible that the body required compensatory motion of the lower extremities in the propulsion phase. Participants in CNLBP group unconsciously compensated with less hip flexion/extension to create better core stability.

Limitations of the present study should be considered. For example, most of the participants were under 30 years old, which may limit the study's generalizability to other age groups. The current study only examined the kinematic data, however, the kinetic data or muscle activity during gait were not assessed or analyzed. This may lead to a misunderstanding among some aspects of the mechanism of their movement alteration. In addition, the kinematics change in CNLBP in the present study was processed in motion analysis software, which reported a lot of detail of joint excursion values with statistically significant comparisons, some of which were small differences that may not show clinically significant differences.

Despite the study's limitations, the current findings provide important clinical implications. Clinicians could obtain a greater understanding of gait characteristics in individuals with CNLBP. The present research used motion analysis to confirm a key role for biomechanics related to the lower extremities, and multisegmented foot in CNLBP during walking. To the authors' knowledge, this is the first study to investigate kinematic data of multiple segments of the foot in individuals with CNLBP. Additionally, the present study also showed the changes in the kinematics of the proximal segment of the foot that affected the distal motion in the distal joint in the foot. Further studies should provide a more comprehensive age of the subjects as well as information regarding the kinematic and kinetic values of CNLBP in gait.

Conclusion

The present study provides kinematic data that may be useful for clinicians or researchers to increase their understanding of the gait pattern of individuals with CNLBP. The joint motions of the hip, knee, ankle, and multisegmented foot on the dominant leg of the individuals with CNLBP were different from those of the healthy individuals in all subphases of the stance phase. Furthermore, the CNLBP exhibited slower walking speed than the healthy individuals. As a result, the CNLB might involuntarily modify their walking patterns.

What is already known on this topic?

CNLBP patients frequently exhibit functional impairment, such as an asymmetrical lower extremity walking pattern and decreased walking speed throughout the entire stance phase. Previous research on lower extremity kinematics while walking with CNLBP has produced inconclusive results. Furthermore, none of them have investigated kinematics in multisegmented foot and various subphases of the stance phase.

What does this study add?

The present study showed that individuals with CNLBP modified their lower extremity including hip, knee, ankle, and multisegmented foot during walking characteristics in all the subphase of stance phase. Understanding walking kinematics can help with examination and treatment of these patient population.

Acknowledgement

The authors would like to thank Mr. Poovasit Klinoubol, DPM, AACFAS for his comments that greatly improved the manuscript.

Funding disclosure

The Scholarship from the Graduate School, Chulalongkorn University to commemorate the 72nd anniversary of his Majesty King Bhumibol Adulyadej and The 90th Anniversary Chulalongkorn University Fund (Ratchadaphiseksomphot Endowment Fund) are gratefully acknowledged.

Conflicts of interest

The authors declare no conflicts of interest.

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