Lower-extremity Kinematics during Walking in Individuals with Non-specific Low Back Pain: A Pilot Study

ค่าคิเนมาติกของรยางค์ส่วนล่างในขณะเดินในผู้ที่ปวดหลังส่วนล่างแบบไม่เฉพาะเจาะจง: การศึกษานำร่อง

Chatanun Chinpeerasathian (ชาตนันท์ ชินพีระเสถียร)* Dr.Praneet Pensri (ดร.ปราณีต เพ็ญศรี)**

ABSTRACT

The present pilot study was carried out to examine the change of lower extremity and foot segment kinematics during walking in individuals with non-specific low back pain (NLBP). There were 10 subjects in this study including 5 subjects with chronic NLBP and 5 healthy subjects. To study the subjects' walking characteristics, the 3D motion analysis was applied. Each subject was attached with 47 retro-reflective markers and was asked to walk barefoot along a 10-meter walkway with the preferred walking speed. Joint range of motions (ROMs) in each subphase of stance phase were compared between two groups, using Mann Whitney U-test and independent t-test. The results showed that ROMs of the hip, knee, and ankle joints of the NLBP group were significantly ($p<0.05$) different from those of the control group in forefoot contact and push off phases. Meanwhile, ROM of foot segment of the NLBP group were significantly different from those of the control group in initial contact, forefoot contact and foot flat phases. Accordingly, there might be modification in walking characteristics of lower-extremity in NLBP patients compared with healthy persons.

บทคัดย่อ

การศึกษานำร่องนี้ศึกษาการเปลี่ยนแปลงค่าคิเนมาติกของรยางค์ส่วนล่างและเท้าในขณะเดินของผู้ป่วยที่มีปัญหาปวดหลังส่วนล่างแบบไม่เฉพาะเจาะจง มีผู้เข้าร่วมการศึกษานี้ 10 คนประกอบด้วยผู้ที่มีปัญหาปวดหลังแบบไม่เฉพาะเจาะจง 5 คนและคนปกติ 5 คน ในการศึกษาลักษณะการเดินของกลุ่มตัวอย่างใช้เครื่องวิเคราะห์การเคลื่อนไหวแบบ 3 มิติ โดยผู้เข้าร่วมการศึกษาถูกติดจุดระบุตำแหน่งของร่างกายแบบสะท้อนแสง 47 จุด จากนั้นเดินเท้าเปล่าเป็นระยะทาง 10 เมตรด้วยความเร็วปกติ การเปรียบเทียบค่าเฉลี่ยองศาการเคลื่อนไหวของข้อต่อที่วัดได้ในแต่ละระยะย่อยของช่วงเท้าลงน้ำหนักระหว่างกลุ่มตัวอย่างทั้งสองถูกวิเคราะห์ด้วยสถิติ Mann Whitney U-test และ independent t-test ผลการศึกษาพบว่าผู้ที่มีปัญหาปวดหลังส่วนล่างแบบไม่เฉพาะเจาะจงมีองศาการเคลื่อนไหวของข้อสะโพก, ข้อเข่าและข้อเท้า แตกต่างจากกลุ่มคนปกติ ในช่วงระยะ forefoot contact และ push off ($p<0.05$) ในขณะที่องศาการเคลื่อนไหวของเท้าของผู้ที่ปวดหลังมีความแตกต่างจากคนปกติอย่างมีนัยสำคัญ ในช่วงระยะ initial contact, forefoot contact และ foot flat สรุปว่าผู้ที่มีปัญหาปวดหลังส่วนล่างแบบไม่เฉพาะเจาะจงอาจปรับเปลี่ยนลักษณะการเคลื่อนไหวของรยางค์ส่วนล่างในขณะเดินเมื่อเทียบกับคนปกติ

Keywords: Lower-extremity kinematic, Foot-segment, Non-specific low back pain

คำสำคัญ: ค่าคิเนมาติกของรยางค์ส่วนล่าง ข้อต่อเท้า ปวดหลังส่วนล่างแบบไม่เฉพาะเจาะจง

** Student, Master of Science Program in Physical Therapy, Faculty of Allied Health Sciences, Chulalongkorn University*

*** Associate Professor, Department of Physical Therapy, Faculty of Allied Health Sciences, Chulalongkorn University*

Introduction

Non-specific low back pain (NLBP) is a diagnosis of LBP symptom that an individual has unidentified pain at lower back region with unknown pathological and anatomical causes, as well as no signs of a serious underlying condition (Maher et al., 2017). Most LBP sufferers are non-specific, only about 10% having a specific cause of pain (Krismer et al., 2007). The lifetime prevalence of LBP was 60-85% spanning. At any point of time, about 12-30% of adults have LBP (Anderson et al., 1997; Loney et al., 1999). In 2012, an epidemiological study of 165 studies from 54 countries reported that the mean point prevalence of LBP was estimated to be 18.3%, and 1-month prevalence was 30.8% (Hoy et al., 2012). It has been shown that the prevalence of NLBP in general population decreased with age; in contrast, LBP with radiating leg pain increased with age (Kaaria et al., 2009). While NLBP seldom pointed out a serious musculoskeletal condition, it is reported to be a major cause of pain, disability, and social cost (Atlas et al., 2001). Apparently, chronic NLBP patients with high level of pain and disability often reported their functional impairment to perform daily activities (Lacker et al., 1996; Lin et al., 2011).

Previous studies found that patients with chronic LBP moved with slower walking speed than the healthy control subjects (Muller et al., 2015; Al-Obaidi et al., 2003). It has been suggested that slower walking reflects the presence of pain associated with fear-avoidance behavior (Al-Obaidi et al., 2003). Patients who believe that walking can aggravate the symptom of LBP may alter their ability to perform normal gait at different velocities (Al-obaidi et al., 2003). In addition, they may avoid performing other activities that they believe that those movements can damage their spine and increase their pain (Bunzli et al., 2017). Al-Obaidi et al. (2003) studied the influence of pain, pain-related fear, and disability on the walking velocity among the patients with chronic LBP. They found that gait velocity was decreased in the LBP patients who reported more fear of movement (Al-Obaidi et al., 2003). The decreased walking speed may be due to a protective mechanism, of which an individual attempts to reduce the ground reaction forces, minimize the overload in the column, keep stability, and avoid pain. However, there may be the restriction of spinal movement in the chronic LBP patients to reduce their pain during walking, which leads to the reduction in velocity (Muller et al., 2015).

There are studies have shown the changes of spinal kinematics in patients with chronic LBP during gait (Cimolin et al., 2011; Muller et al., 2015). From a review of literature, there were, however, a few studies using the 3D motion analysis for gait assessment to investigate the alterations of lower extremity kinematics during walking in this specific group. Cimolin et al. (2011) investigated the effects of obesity and chronic LBP on gait by dividing the female participants into three groups i.e. obese with and without chronic LBP, and normal mass without chronic LBP. The spatio-temporal parameters indicated the longer stance duration and shorter step length in the obese with chronic LBP when compared with the others without LBP. In addition, the LBP patients had lower range of motion (ROM) of hip in the frontal plane and lower ROM of knee in the sagittal plane than the control without LBP (Cimolin et al., 2011). Muller et al. (2015) compared the gait kinematics between the patients with chronic LBP and the healthy controls during level and uneven walking. They found that the chronic LBP group had lower pelvic rotation while more knee extension at heel strike than the healthy group during level walking and uneven walking (Muller et al., 2015).

From literature review, some kinematic differences of hip and knee between individuals with and without chronic NLBP have been reported; however, there is a lack of information regarding the ankle and multi-segment foot kinematic differences between these two groups. Therefore, the current study aimed to compare hip, knee, ankle and foot segment kinematics during stance phase of walking between individuals with non-specific low back pain (NLBP) and healthy subjects.

Objective of the study

To determine the differences in lower-extremity kinematics between the subjects with and without NLBP during the stance phase.

Materials and methods

Subjects and preparation

The sample size of this pilot study is 10 persons, 5 were NLBP patients and 5 were healthy persons. All NLBP patients were recruited from the Health Sciences Service Unit (HSSU), Faculty of Allied Health Sciences, Chulalongkorn University. The screening process was carried out at the motion analysis research laboratory of the Faculty of Allied Health Sciences, Chulalongkorn University.

The gait analysis was conducted in the musculoskeletal biomechanics laboratory. Before the beginning of each gait trial, spherical retro-reflective markers were placed on anatomical landmark, following by the Helen Hayes marker set (Wilken et al., 2012) and multi-segment foot model (Leardini et al., 2007), respectively, as illustrated in Figure 1 and 2. After the attachment of the markers, the subjects were asked to walk barefoot along a 10-meter walkway with the preferred walking speed for five successful trials. Each trial was completed once both feet were in full weight-bearing on the force plate.

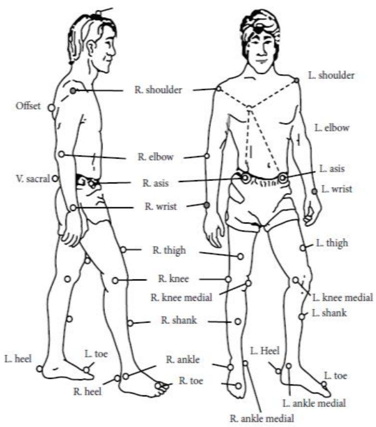

Figure 1 Helen Hayes marker set (Wilken et al., 2012)

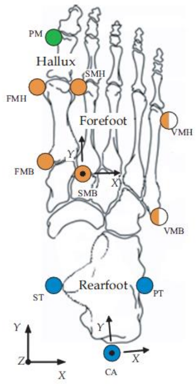

Figure 2 Foot-segmental marker set (Leardini et al., 2007)

The measuring instrument

Lower-extremity kinematics were collected from the eight-camera motion analysis system (Motion Analysis Corp., Santa Rosa, CA) with flash rate of 120 Hz. The cameras are synchronized with the two force transducers which are set to have a sampling frequency of 1,200 Hz. The software from motion analysis system (Cortex version 2.5) contains three major functions i.e. calibrating the capture volume, tracking and identifying marker locations in calibrated 3D space, and processing data for other packages. The Cortex 3.0 post processing software and Matlab analysis are used to process data with clinical gait evaluation. Static and dynamic calibrations must be performed before collecting the gait trials. Gait assessment in the present study was performed in stance phase period. The stance phase of the gait cycle is defined as the duration between first contact and last contact of the same foot. The stance phase contains 4 subphases including initial contact phase (ICP), forefoot contact phase (FFCP), foot flat phase (FFP), and forefoot push off phase (FFPOP). The ICP is the duration between first foot contact and first metatarsal contact; FFCP is the duration between first metatarsal contact and forefoot flat; FFP is the duration between the forefoot being flat and heel off; and FFPOP is the duration between heel off and last foot contact. The current study focused on the change of ROM of the hip, knee, ankle and multi-segment foot in each subphase of the stance phase.

Data processing

Kinematic data of the lower extremity during each phase of the gait cycle were computed from custom Matlab software (R2010a) in all three planes (sagittal, frontal, and transverse). The ROM 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 7 segment models were studied including pelvis-thigh (hip), thigh-shank (knee), shank-foot (ankle), shank-calcaneus (Sha-Cal), calcaneus-midtarsus (Cal-Mid), midtarsus-metatarsus (Mid-Met), and metatarsus-calcaneus (Met-Cal) (Leardini et al., 2007; Kadaba et al., 1990). The planar angles of the first metatarsophalangeal (MTP) joint and the medial longitudinal arch (MLA) were also computed from Matlab software. To determine excessive pronation of the foot, the calculation of the peak angle during the stance phase was performed at Sha-Cal and Cal-Mid segments.

Statistical analysis

The SPSS software version 22.0 was used for quantitative data analysis. Demographic data of the subjects in both groups were calculated by mean and standard deviations for numerical data. The comparison between groups was performed by using either the Independent T test (parametric statistics) or Mann Whitney U test (non-parametric statistics). A level of $p < 0.05$ was considered as statistically significant.

Result

A summary of the subject information confirmed that there was not statistical difference between the groups for age, height, weight and BMI as shown as in Table 1

Table 2 and 3 demonstrate and compare the results of kinematic values of hip, knee, ankle and multi-segment foot between NLBP and control subjects (CTRL). In Table 3, the multi-segment foot is divided into four regions i.e. rearfoot, midfoot, forefoot and hallux. Rearfoot contained shank-calcaneus (Sha-Cal) model. Midfoot contained calcaneus-midtarsus (Cal-Mid) model. Forefoot contained midtarsus-metatarsus (Mid-Met) and metatarsus-calcaneus (Met-Cal). Walking characteristics of both groups were different in all subphases.

Compared to the CTRL group at the initial contact phase, the NLBP significantly increased in rearfoot adduction (p=0.034), decreased in forefoot dorsiflexion (Mid-Met: p=0.007, Cal-Met: p=0.028), and decreased in forefoot eversion (p=0.046); while there was no difference in hip, knee and ankle ROM between groups.

Compared to the CTRL group at the forefoot contact phase, the NLBP significantly decreased in hip extension (p=0.37), decreased in knee extension (p=0.036), decreased in knee external rotation (p=0.09). Moreover, forefoot eversion in NLBP also significantly increased (p=0.040), while other regions in foot did not showed significantly change.

Compared to the CTRL group at the foot flat phase, the NLBP significantly decreased in midfoot dorsiflexion (p=0.037), while the motions of other joints proximal or distal to this joint did not change.

At the forefoot push off phase, the NLBP significantly increased in hip abduction (p=0.033), and increased in ankle abduction (p=0.017), while there was no difference in knee ROM and foot-segmental ROM between groups.

Table 1 Clinical characteristics of the studied groups

	Control	NLBP
Age (year)	23.8±1.1	24.4 ±15
Weight (kg)	59.8±6.8	57.8±5.6
Height (cm)	164.2±9.2	162.9±10.7
BMI (kg/m^2)	22.1±1.7	21.8±1.0

Data are expressed as mean (standard deviation).* p < 0.05 did not appear

Table 2 Summary of mean range of motion and standard deviation (in degrees) of hip, knee, and ankle during four subphases of stance for control and LBP groups

			Initial contact			**Forefoot contact**			**Foot flat**			**Forefoot push off**		
			CTRL	NLBP	p-value	CTRL	NLBP	p-value	CTRL	NLBP	p-value	CTRL	NLBP	p-value
Hip														
	Sagittal	E/F	6.8 (2.5)	7.9 (2.8)	.116	-14.4 (3.8)	-12.6 (2.8)	.037*	-13.9 (2.9)	-14.1 (3.6)	.787	8.5 (1.9)	8.5 (2.0)	.994
	Frontal	Add/Abd	7.4 (2.0)	6.9 (1.6)	.358	-2.7 (1.3)	-2.4 (1.1)	.451	-1.7 (0.8)	-2.1 (1.3)	.264	10.1 (2.8)	11.5 (2.3)	.033*
	Transverse	IR/ER	7.3 (3.1)	7.0 (3.3)	.468	-3.2 (1.2)	-3.1 (1.5)	.768	-2.9 (1.4)	-2.9 (1.2)	.726	6.4 (3.5)	7.0 (3.4)	.468
Knee														
	Sagittal	E/F	11.8 (4.8)	11.0 (4.2)	.491	-8.1 (3.8)	-6.2 (2.7)	.036*	-5.4 (2.0)	-4.9 (1.7)	.307	36.0 (3.5)	35.9 (4.1)	.713
	Frontal	Add/Abd	4.5 (1.7)	4.1 (1.5)	.359	1.7 (0.8)	1.5 (0.6)	.428	1.73(0.02)	3.33(1.08)	.083	3.6 (1.9)	4.1 (1.5)	.085
	Transverse	IR/ER	4.8 (1.6)	4.5 (1.8)	.319	2.9 (1.3)	2.2 (0.8)	.009*	2.4 (1.0)	2.0 (0.8)	.098	3.84(0.89)	5.68(0.93)	.083
Ankle														
	Sagittal	DF/PF	9.6 (2.3)	9.1 (1.2)	.619	-5.3 (2.0)	-5.6 (1.5)	.604	6.55(0.68)	4.53(0.95)	.050	26.3 (3.6)	26.7 (4.1)	.699
	Frontal	Inv/Eve	8.7 (2.6)	8.2 (2.6)	.427	2.2 (1.2)	2.1 (1.4)	.443	5.7 (1.6)	5.7 (2.0)	.985	-8.8 (3.2)	-8.8 (3.6)	.798
	Transverse	Add/Abd	-7.4 (2.8)	-7.7 (2.5)	.731	3.04(0.32)	7.46(0.96)	.050	4.1 (1.7)	4.9 (2.0)	.078	4.8 (1.6)	6.1 (2.7)	.017*

* Significant level at p-value < 0.05 [a] Non-parametric analysis

Hip and Knee: sagittal: -ve/+ve = extension/flexion, frontal: -ve/+ve = adduction/abduction, transverse: -ve/+ve = internal rotation/external rotation

Ankle: sagittal: -ve/+ve = dorsiflexion/plantarflexion, frontal: -ve/+ve = inversion/eversion, transverse: -ve/+ve = adduction/abduction

Table 3 Summary of mean range of motion and standard deviation (in degrees) of multi-segment foot during four subphases of stance for control and LBP groups

			Initial contact			**Forefoot contact**			**Foot flat**			**Forefoot push off**		
			CTRL	NLBP	p-value	CTRL	NLBP	p-value	CTRL	NLBP	p-value	CTRL	NLBP	p-value
Rearfoot														
Sha-Cal	Sagittal	DF/PF	-5.7 (2.0)	-5.9 (2.6)	.506	2.8 (1.0)	1.9 (3.4)	.282	-4.6 (2.0)	-5.3 (1.9)	.216	23.3 (2.5)	23.0 (3.1)	.728
	Frontal	Inv/Eve	5.3 (1.5)	5.0 (1.5)	.414	2.5 (1.1)	2.6 (1.2)	.726	4.2 (1.5)	4.5 (1.7)	.477	-5.3 (2.0)	-5.9 (2.0)	.247
	Transverse	Add/Abd	-5.4 (1.7)	-6.4 (1.9)	.034*	3.14(1.06)	6.49(1.08)	.050	3.5 (1.8)	3.9 (1.4)	.340	-5.6 (2.1)	-5.8 (2.3)	.770
Midfoot														
Cal-Mid	Sagittal	DF/PF	5.43(2.40)	2.56(0.81)	.083	-3.5 (1.8)	-3.6 (2.2)	.657	-5.9 (1.8)	-5.0 (1.6)	.037*	7.2 (2.5)	6.7 (1.8)	.319
	Frontal	Inv/Eve	4.8 (2.0)	4.0 (1.6)	.084	1.7 (0.8)	1.7 (0.8)	.972	2.5 (1.2)	2.6 (0.9)	.484	-3.9 (1.5)	-3.9 (1.1)	.992
	Transverse	Add/Abd	4.0 (1.6)	4.0 (1.8)	.050	5.54(0.94)	2.57(0.84)	.050	2.5 (0.8)	2.6 (1.4)	.706	-4.0 (1.9)	-3.8 (1.9)	.767
Forefoot														
Mid-Met	Sagittal	DF/PF	-8.0 (2.4)	-6.3 (2.0)	.007*[a]	-2.2 (1.1)	-2.6 (1.7)	.536	3.41(0.71)	2.33(0.06)	.050	11.9 (2.7)	10.8 (2.4)	.075
	Frontal	Inv/Eve	5.4 (2.7)	5.3 (2.4)	.050	1.4 (0.6)	2.0 (1.4)	.040*[a]	3.6 (1.4)	3.5 (1.4)	.667	-6.3 (2.1)	-6.1 (2.3)	.774
	Transverse	Add/Abd	-4.7 (1.6)	-4.7 (1.4)	.935	1.9 (1.0)	1.9 (1.0)	.968	4.1 (1.0)	4.2 (1.5)	.960	-8.8 (2.4)	-8.5 (2.6)	.579
Cal-Met	Sagittal	DF/PF	-8.5 (3.4)	-7.0 (2.6)	.028*[a]	-2.1 (1.0)	-2.1 (1.1)	.989	-3.3 (1.2)	-3.5 (1.2)	.475	12.1 (3.1)	11.4 (2.9)	.352
	Frontal	Inv/Eve	7.4 (1.8)	6.5 (2.3)	.046*[a]	1.6 (0.8)	1.4 (0.7)	.420	1.61(0.17)	2.66(1.26)	.050	-10.0 (2.7)	-10.2 (2.7)	.788
	Transverse	Add/Abd	6.5 (2.2)	6.5 (2.4)	.893	1.3 (0.6)	1.6 (0.7)	.090	2.7 (1.0)	2.6 (1.0)	.726	-6.5 (1.8)	-5.9 (1.6)	.138
Hallux	Sagittal	DF/PF	20.6 (6.3)	19.9 (7.0)	.693	2.17(0.34)	5.75(1.80)	.050	10.2 (4.0)	10.0 (3.3)	.861	39.42(4.63)	51.70(1.16)	.050

* Significant level at p-value < 0.05 [a] Non-parametric analysis

Multi-segment foot: sagittal: -ve/+ve = dorsiflexion/plantarflexion, frontal: -ve/+ve = inversion/eversion, transverse: -ve/+ve = adduction/abduction

Discussion

According to the results, NLBP patients showed lower limb movements during walking that differed from healthy CTRL subjects. In initial contact phase that involves the instant the heel comes in contact with the ground (Neumann, 2010), normal gait pattern is involved with hip flexion with abduction and external rotation, knee extension with little abduction and external rotation and ankle dorsiflexion with abduction (Whittle, 2007). In multi-segment of foot, rearfoot plantarflexes, supinates and adducted, while forefoot dorsiflexes and everses (Leardini et al., 1999; Jenkyn et al., 2009). However, subjects with NLBP in the present study showed more rearfoot adduction, less forefoot dorsiflexion and less eversion than CTRL. The greater rearfoot adduction in NLBP may contribute to small forefoot dorsiflexion and eversion in NLBP than CTRL subjects, because the rearfoot adduction commonly combined with forefoot plantarflexion and inversion (Arnold et al., 2017). The rearfoot adduction or calcaneal adduction in the initial contact phase may be due to the consequence of calcaneal position in the swing phase that subtalar joint is supinated. Shortly after heel contact, subtalar will change from supination to pronation. NLBP patients may have plantarflexor tightness or evertor weakness that inhibit normal calcaneal movements.

In forefoot contact phase, normal gait pattern is involved with hip extension, knee extension and ankle dorsiflexion with abduction (Whittle, 2007); while multi-segment foot is involved rearfoot plantarflexion with abduction, midfoot dorsiflexion with eversion, and forefoot eversion with abduction (Leardhini et al., 1999; Jenkyn et al., 2009). In the present study found that NLBP had less hip extension, less knee extension and more forefoot pronation than CTRL. Individual with less hip extension might walk with compensation by increasing movements of pelvis and lumbar spine instead of hip movements (Neumann, 2010). Individual with reduced hip motion might use an excessive posterior and anterior pelvic tilt in order to compensate for the limited hip motion in sagittal plane (Neumann, 2010). Apparent hip flexion might be accompanied with a posterior pelvic tilt and flat back. Apparent hip extension might be accompanied with and anterior pelvic tilt and increased lumbar lordosis. These abnormal alignments could ultimately irritate the structures within the lower back region, leading to LBP (Neumann, 2010). Moreover, the results of decreasing in hip and knee extension may be described by the center of pressure (COP) displacement in LBP patients. A previous study showed that LBP patients had more anteroposterior COP displacement than healthy subjects (Lee et al., 2011). The anteroposterior COP displacement might be contributed to the compensation of more forward bending of trunk in LBP patients, which may be a compensatory action to avoid pain (Lee et al., 2011). Therefore, the forward bending of trunk in LBP might lead to less hip and knee extension than healthy subjects. Another reason for explaining less knee extension in LBP was described by the study of Vogt et al (2003). A previous study showed the results that correlated with this study (Vogt et al., 2003). They found that at the end of the swing phase and at the early stance phase patients with chronic LBP commonly had biceps femoris muscle activation earlier and higher than healthy people, these abnormal muscle activities might be due to the weakness of gluteal muscle in LBP; and it can be decreased knee extension in early stance phase (Vogt et al., 2003). More forefoot eversion in this phase might be related to the overpronated mechanism on weight-bearing of LBP. The individual with excessive internal rotation of tibia and femur might walk pronated foot. Such mechanism might negatively affect the mechanical link between foot position and pelvic alignment by increasing in anterior pelvic tilt and LBP symptom (Menz et al., 2013). Apart from this, it might be due to the weakness of intrinsic foot muscles. The role of intrinsic foot muscles are to control and balance body weight on foot during gait, the weakness of these muscles could lead to the difficulty of maintaining foot structural alignment and its over the weight bearing phase, then leading to excessive foot eversion (Whitman, 2010).

In foot flat phase, normal gait pattern is involved with hip extension, knee extension, ankle dorsiflexion with abduction (Whittle, 2007), while multi-segment foot is involved with rearfoot dorsiflexion with abduction, midfoot dorsiflexion with eversion, and forefoot dorsiflexion with eversion. In this study, we found that the NLBP showed forefoot dorsiflexion less than the CTRL. For the foot flat phase, the midfoot is mainly responsible for maintaining the arch of foot during full weight-bearing (Jenkyn et al., 2009). It was possible that NLBP in this study were unable to hold the arch of foot during foot flat phase. Previous studies found that LBP patients with changing in the lumbar curvature including increased lumbar lordosis were correlated with the decrease of the plantar arch (Bricot, 2001). Decreasing the arch of foot caused by the weakness of the tibialis anterior, tibialis posterior, and peroneus longus muscles might result in flexible or hypermobile feet, and then could lead to the adaptation of proximal structures (Oliviera et al., 2004).

In forefoot push off phase, the body uses all lower-extremity power to push up and move forward. In normal gait pattern, normal gait is involved with hip flexion, knee flexion, and ankle plantarflexion with abduction (Whittle, 2007). While multi-segment foot is involved with rearfoot plantarflexion with adduction, midfoot plantarflexion with inversion, and forefoot plantarflexion with eversion (Leardhini et al., 1999; Jenkyn et al., 2009). In the present study showed that the NLBP had more hip abduction and ankle abduction than the CTRL. This results may be described by the poor coordination between trunk and pelvic in LBP patients. LBP patients commonly demonstrated that they had poor gluteal muscle power and poor core stability muscle, which led to poor coordination between trunk and pelvic during walking (Chang et al., 2013; Hodge et al., 1996). The greater hip abduction in NLBP might be one of the compensatory movements for helping the lower-extremity push up the body during gait. While the higher ankle abduction in NLBP might be caused by the situation that the NLBP subjects were unable to hold the arch of foot in foot flat phase toward push off phase. Actually, overpronated foot position often occurred with ankle abduction. It is important to evaluate the presence of foot pronation in LBP patients.

Some limitations of this study require consideration. First, the number of participants in this study was relatively small because this study was just a pilot study. However, significant differences were found between NLBP patients and healthy control group, which indicated that the study had sufficient power to detect differences, further study should have more sample size to confirm the results. Second, this study did not investigate other physical conditions of subjects e.g. leg length difference, arch height, and fear-avoidance belief behavior, etc. which may be related with the lower-extremity kinematics during walking. Future investigations should consider the body structures of subjects before gait testing.

Conclusion

This present study provides kinematic data that may be useful to clinicians or researchers to increase understanding about the gait pattern of LBP patients. The joint motions of the hip, knee, ankle, and multi-segment foot of the patients with NLBP were different from those of the healthy subjects in stance phase. Accordingly, there might be modification in walking patterns of patients with NLBP.

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