ผลของความเร็วในการเดินต่อการควบคุมการทรงตัว ความแปรปรวนของการเดินและ temporospatial ขณะเดินในผู้ที่มีอาการปวดหลังเรื้อรังแบบไม่เฉพาะเจาะจง

EFFECT OF WALKING SPEED ON POSTURAL SWAY, GAIT VARIABILITY AND TEMPOROSPATIAL GAIT IN PERSON WITH CHRONIC NON-SPECIFIC LOW BACK PAIN

NANTACHON RUJICHI

Graduate School Srinakharinwirot University

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นันทชนม์ รุจิฉาย

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EFFECT OF WALKING SPEED ON POSTURAL SWAY, GAIT VARIABILITY AND TEMPOROSPATIAL GAIT IN PERSON WITH CHRONIC NON-SPECIFIC LOW BACK PAIN

NANTACHON RUJICHI

A Thesis Submitted in partial Fulfillment of Requirements

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EFFECT OF WALKING SPEED ON POSTURAL SWAY, GAIT VARIABILITY AND TEMPOROSPATIAL GAIT IN PERSON WITH CHRONIC NON-SPECIFIC LOW BACK PAIN

BY

NANTACHON RUJICHI

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---------- Dean of Graduate School

(Assoc. Prof. Dr. Chatchai Ekpanyaskul, MD.)

ORAL DEFENSE COMMITTEE

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Title	EFFECT OF WALKING SPEED ON POSTURAL SWAY, GAIT VARIABILITY AND TEMPOROSPATIAL GAIT IN PERSON WITH CHRONIC NON-SPECIFIC LOW BACK PAIN
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Chronic lower back pain results in the alteration of proprioceptive sense and muscle control, which may disturb the automatic regulation postural control and gait stability. This is especially true in terms of fastest walking speed, which may aggravate poor postural control and gait instability This study aimed to investigate the effects of chronic lower back pain and walking speed on postural control, gait variability, and temporospatial gait. Twenty people with chronic and non-specific low back pain (CNSLBP) and twenty people with non-low back pain (NLBP) walked at their preferred and fastest walking speed on a treadmill. The temporospatial gait parameters and center of pressure (COP) variables were recorded for three minutes at walking condition and three minutes of rest between walking conditions. The factor of gait variability was used to determine the coefficient of variation (CV) of the temporospatial gait. The results of the current study found that the anterior-posterior (AP) COP excursion and medial-lateral (ML) COP deviation in CNSLBP were significantly greater at both walking speeds ($p<0.05$). Only in the NLBP group, the AP COP excursion and ML COP deviation were lower in FWS than those of PWS. The factor of gait variability in the CNSLBP group were significantly greater than those NLBP during PWS ($p<0.05$). Gait variability decreased during FWS in both groups. Gait velocity was slower in CNSLBP than in the control group during PWS ($p<0.05$), while there was not a significant difference between groups at FWS. In conclusion; CNSLBP exhibited poor postural control in AP direction and no adaptation of postural control at FWS. CNSLBP increased gait variability during PWS. However, the fastest walking speed should be concerned when applied in person with CNSLBP due to maladaptation of postural control.

Keyword : Chronic lower back pain, Postural sway, Gait variability, Walking speed

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CHAPTER 1 INTRODUCTION

Background

The prevalence of low back pain in adults have been reported as 18.3% (a point prevalence) and 30.8% (one-month prevalence), evidence were assessed from 165 studies in 54 countries. [1] Yiengprugsawa and colleagues in 2017 found 30% prevalence of Thai people with chronic low back (CLBP).[2] Persons with CLBP reported less participation with family or communities, increasing an enormous burden, diminishing working capacity, physical activity limitation, [2, 3] postural instability ,alteration of gait characteristic and gait control.[4-8]

Gait is a complex task that involves the control of whole body movement during dynamic stability on the motor task for coordination of numerous muscle activities and joint movement.[9] For gait control, movement during the steady-state is an autonomous process by cooperation of postural reflexes such as head eye coordination, appropriate alignment of body segments and optimal level of postural muscle tone. During walking, the body is a continuous state of imbalance; the center of mass (COM) translation ahead of a base of support to induce center of pressure (COP) shifting.[9, 10] Dynamic balance strategies to control ongoing walking must focus on the hip and spinal muscle strategies for controlling trunk and pelvic movement.[6, 9-13] Controlling balance during walking required sensory-motor system for adaptation of internal and external changes in various situations.[9, 14] The neuromuscular control would provide a proper

core muscles activation pattern and trunk muscle co-contraction for performing spinal equilibrium and stability, through an equalization of forces to provide proximal stability and extremity mobility.[3, 12, 15-17] Hence, core stability dysfunction can attribute to poor posture-gait control as well as alteration of gait ability.

Impairment of postural control has been reported in person with CLBP.[3, 18] Nociceptive activation from injury of the spine caused change in neuromuscular control leading to insufficiency of neural system from reduction and inaccuracy of proprioceptive signal input of spine.[13, 19] Changes in cortical function and sensory feedback in individual with CLBP were related to delay feedforward mechanism and decreased core muscle activation, which as a result, leading to spinal instability due to disruption of the postural adjustment mechanism.[3, 13, 19, 20] Moreover, person with CLBP indicated a hip abductor muscle weakness that may disturb the body balance during walking due to insufficiency of lumbo-pelvic control.[21] The previous study reported that the people with CLBP impaired balance control during walking; more increase of COP excursion than healthy control during a preferred walking speed (PWS).[18] However, these results are uncertain to represent postural control during walking at steady state of various gait speed in person with CLBP. Due to, at the steady state of ongoing walking where neither accelerating nor decelerating of body must reach approximately at least 5 steps.[9, 22]

Variability and temporospatial gait differ between person with CLBP and healthy control. Gait velocity, and stride frequency during PWS decreased in person with CLBP compared to individuals without LBP.[8, 23-26] Decreasing of walking speed; walking slowly and more carefully, might be compensated for more challenging motor control system.[5, 8] For gait variability, the stride-to-stride fluctuation in person with CLBP was showed higher variability for trunk movement velocity during cognitive dual task. [27] but the stride length variability was less during comfortable walking speed.[28] In addition, Lamoth and colleague in 2008 reported lower variability of trunk-pelvic movement in patients with CLBP due to lack of flexible gait.[8] This consequence may be the compensation of trunk muscle activity for stability and gait control during distraction task.[5, 8] However, controlling gait in individual with CLBP not only leads to an adaptive mechanism of motor control from distraction task but also change walking speed as challenge situation may aggravate different neuromuscular compensation on gait consistency or walking performance.[8]

Walking speed alters gait parameter and variability in person with CLBP.[8, 29] Walking in fast speed is commonly activity in a diary life where a fast walking speed (FWS) is related to increased more regular motor output.[30] Temporospatial gait in the person with CLBP have been reported as shorter stride length during fast walking speed.[31] Changing of trunk-pelvic movement variability were smaller in the transverse plane and more variable in the frontal plane cause by unclear counter-rotation between

pelvis and thorax when the speed is increased.[8] The lumbar erector spinae muscle is more activated in swing phase of fast walking speed in individuals with CLBP.[8] Alteration of gait speed is to move away from the attractor state causing gait instability that needed higher energy consumption.[8, 30, 32] The result is neuromuscular adaptation mechanism to prevent a loss of stability during walking.[8, 32] Although, previous study suggested several of adaptation mechanism to preserve balance during loss of stability but the effect of neuromuscular adaptation on controlling a balance of virtual body such as gait consistency are unclear in this challenge situation of fast speed.[5, 8, 32]

However, impairment of gait control during fast walking speed in patients with CLBP may aggravate recurrent injury of low back, lower extremity injury, disability, a risk of falling, walking ability limitation, a fear avoidance movement, and to decrease a quality of life in these populations. The effect of CLBP on a variability and temporospatial gait should be investigated for recommendation of assessment or management of person with CLBP.

Therefore, the purposes of this study were to investigate the effect of CLBP on COP excursion, gait variability and temporospatial gait and the effect of PWS and FWS on COP excursion, gait variability and temporospatial gait in person with CLBP.

Research question

Does the chronic low back pain affect to the COP variability, gait variability and temporospatial gait during preferred and fastest walking speed?

Does the walking speed affect to the COP variability, gait variability and temporospatial gait between person with chronic non-specific low back pain (CNLBP) and NLBP?

Objective of this study

1. To compare a COP, gait variability, and temporospatial gait between person with CNSLBP and NLBP during preferred walking speed (PWS) and fastest walking speed (FWS).

2. To compare a COP, gait variability, and temporospatial gait between PWS and FWS within person with CNSLBP and NLBP

Hypotheses of the study

. There was differences in COP, gait variability, and temporospatial gait during PWS and FWS between persons with CNSLBP and NLBP.

2. There was differences in COP, gait variability, and temporospatial gait ~~during~~ between PWS and FWS in both CNSLBP and NLBP.

Advantages of study

The challenging situation such as increasing a gait speed was usually applied for improvement of gait ability and physical activity in clinic. Thus, the clinician may use the information of gait variability, temporospatial gait parameters and postural control as well as COP excursion from this study for gait assessment or to advice the walking exercise in person with CNLBP.

Keywords

Chronic low back pain, Postural sway, Gait variability, Walking speed, Gait parameter

CHAPTER 2 LITERATURE REVIEW

The review of literature includes the following categories:

1. Characteristic of CLBP

2. Balance and the motor control impairment in persons with CLBP

3. Alteration of gait characteristic in persons with CLBP

4. Walking speed impact a gait performance

5. Factor affect gait characteristic

6. Assessment tool

    6.1 Temporospatial gait

    6.2 Gait variability assessment

    6.3 COP variability

    6.4 Low back pain disability

    6.5 Pain intensity

    6.6 Fear-Avoidance behavior

    6.7 Sahrmann lower abdominal core stability test

1. Characteristic and management of LBP

1.1 Definition and diagnostic classification of LBP

The lumbar spine consists of 5 vertebrae numbered L1-L5. The LBP was defined to pain between L1 vertebrae and sacrum region.[33] The period of LBP can categorize into three phase. Acute phase is a symptom presentation fewer than 6 weeks. Subacute, and chronic phase are pain presentation between 6 weeks to 3 months, and longer than 3 months and occurrence within less than 6 months, respectively.[34]

Diagnosis of non-specific LBP is a pain at low back without signs of a serious underlying condition and unknown cause of pathoanatomical and occurring of pain symptom.[34, 35] Specific LBP define to the origin of pain from either problems as underlying condition that include a leaking aortic aneurysm, epidural abscess, vertebral compression fracture, ankylosing spondylitis, malignancy, radiculopathy, infection, spondyloarthropathy, cauda equina syndrome, radicular pain, or numbness in same nerve root distribution, or spinal canal stenosis.[35, 36] Although, the imaging investigation indicate degenerative changes on lumbar spine, but a little pain symptoms can divided to non-specific group.[36]

Conclusion, LBP diagnosis is commonly recommended to three type that are non-specific LBP, radicular syndrome involved with radiculopathy or spinal stenosis, and serious pathology related with another specific spinal cause. However, red flag and

physical examination are used for screening and classification.[37, 38] Therefore, the diagnosis and treatment plan in non-specific LBP should more considers for the association between the chief complaint and currently pathological examination than the radiological findings.

1.2 Epidemiology of LBP

People with LBP in the word is increasing. The researchers surveyed from 165 studies from 54 countries, their reporting were the highest prevalence in female than male, aged 40–80 years.[1] A point prevalence and one-month prevalence were reported 18.3% and 30.8%, respectively. In Thailand, the LBP prevalence were reported for 33% of point prevalence and 55.7% of an annual prevalence in rubber farmers,[39] 61.5% of annual prevalence in nurse,[40] and mostly 83.5% prevalence in rice farmer with aged 20–59 years old[41]. The pain related the poor posture in working position and lack of back muscle exercise. Additional, the prevalence of CLBP was surveyed in 42,785 Thai people, majority aged 30 to 65 years. The result has shown 30% of CLBP prevalence and they reported limitation of activities and an enormous burdened from the suffering of back pain.[2]

1.3 Risk factor of LBP

Composition of a risk factors of low back pain are a psychosocial, occupational, and individual life style.[34, 36] Clinician must concern a risk factor for prevention a recurrent pain and provide appropriate the treatment in individual with LBP.

The risk factors could aggravated an occurrence and chronicity of low back pain, which was presented in the Table1.[34]

Table 1: Risk factors relate occurrence and chronicity of low back pain. [34]

Risk factors	Occurrence	Chronicity
Individual	Age, smoking, abdominal muscle weakness, back muscle, weakness of back and abdominal muscles, physical fitness	Obesity, disability, low educational level and high levels of pain
Psychosocial	Stress, anxiety, pain behavior, negative mood or emotions, cognitive functioning impairment	Depressive and distress and mood
Occupational	Bending and twisting, whole body vibration, job dissatisfaction, handle for manual material, monotonous tasks, less work relationships, poor social support	Job dissatisfaction, job requirement of lifting for three quarters of the day, unavailability of light duty on return to work

1.4 Physical examination in low back pain

The physical examination was commonly used to evaluate for low back pain patient. For clinician, identifications specific diagnoses related a physical examination, which included:

1.4.1 The Straight leg raising test (SLR test)

SLR test was used to exam the back and lower limb pain which related the nerve root disturbance due to lumbar disc herniation. The SLR test is the passive patient's hip flexed with knee extended, until the patients felt pain, strong stretching or

tingling in the posterior area of the lower limbs.[42] This hip angle was recorded for the data analysis. A positive test was indicated between 30 and 70 degrees of hip flexed.[35]

1.4.2 Neurologic examination

Neurologic examination includes evaluation of knee strength and reflexes (L4 nerve root), strength of great toe and foot dorsiflexion st (L5 nerve root), plantar flexion and ankle reflexes (S1 nerve root). Numbness or prickling sensation related the dermatome of nerve innervation. The positive test represented the nerve root dysfunction.[35],

1.4.3 The Adams's foreword bending test

The Adams's foreword bending test that evaluated the spinal scoliosis. A participant was asked to back forward flexion in standing position with relaxed both arms. The examiner observed the chest and trunk for asymmetry. The rib or spinal hump represents the trunk rotation as well as spinal scoliosis.[43]

1.4.4 Lumbar segmental instability

Lumbar segmental instability was assessed by the instability catch sign test. The subject was asked to bend his or her body forward as much as possible and then return to the erect position. The positive test; the subject was not able to return to erect position because of sudden low back pain. The instability catch sign test has reported good specificity (0.86, 95% CI: 0.77 - 0.92) for examining patients with lumbar spinal instability as well as spondylolisthesis.[44]

2. Balance and the motor control impairment in persons with CLBP

2.1 Concept of balance and postural control

Control of posture and balance system involve the ability to anticipate and move in ways, which will avoid instability of independence in activities.[9] Controlling posture and balance is ability to control the body's position in space from the interaction of musculoskeletal and neural systems. The action are performed by the synergy between the behavior of the individual, the task of postural control, and the environment on the task of posture.[9]

Body orientation and equilibrium in locomotion involve many destabilizing factors as external and internal perturbation for controlling postural.[45] The postural orientation define as ability to maintain vertical of orientation of body in the environment of functional task by using of the sensory reference as including; the gravity (the vestibular system), the support surface (somatosensory system), and the relationship to

environment (visual system).[9] The postural stability or equilibrium indicates the ability to maintain the position of the body or the center of mass (COM) within stability of limit or without changing the base of support. [9] Thus, the postural control is ability to maintain whole body in the functional position in static and dynamic movement, it is performed by optimal coordination between three sensory systems.

An appropriation of the cooperation of musculoskeletal and neurological system are demanded to controlling the posture.[9, 46, 47] Musculoskeletal system comprise such as joint range of motion, stability and flexibility of spine, muscle properties, and the relationship of biomechanical linked to the body segment.[9, 13] Neurological system as the multiple interaction of neural component indicate to the cooperation of sensory process and sensory strategies are the organization of the complexity of signal inputs. The internal representations are the mapping of sensation to action. The higher-level process is the essential for adaptation and anticipatory aspects of postural control. The motor process is neuromuscular response synergies. [9, 13] Commonly of the postural control is performed by the interaction of a various system which is illustrated in the Figure 2.

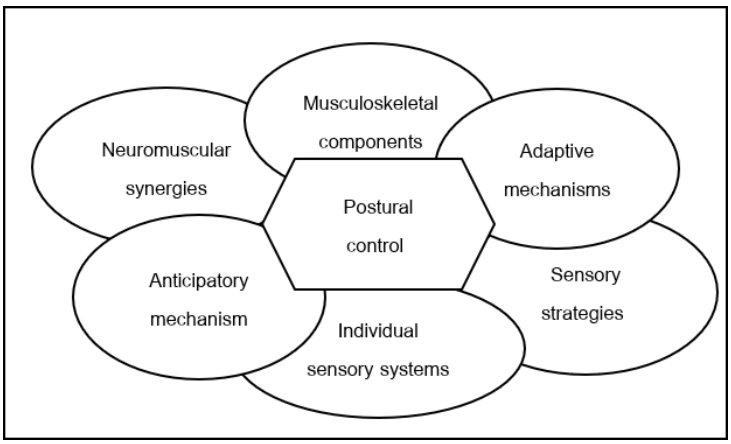


Figure 1: Conceptual model of systems contributing of the postural control. [9]

2.2 Motor control performance

Controlling of muscular activation are programmed in the central nervous system (CNS) and transmission by peripheral nerves. The corticospinal pathways transfer the signal of the motor command to activate voluntary movement.[9, 13] To complete tasks are performed by an activation of specific motor patterns; to produce a sequence to activate muscle onset, providing the amplitude of various muscle contraction during action, and generation the continuous changing of muscles recruitment pattern. [48] The motor control involved to control spinal movement, to generate a specific position of the task, contributing of breathing function, and maintaining whole body equilibrium. The importance of motor control must concern for the coordination between normal spine function and the effect of back pain. Trunk control must require for two biomechanics that consist the region orientation and individual motion segment translations during performing regional orientation.[13, 49] The

sensory system (e.g. a somatosensory, visual, and vestibular system) provides the information necessary for muscular activities in automatically and subconsciously to maintain the body during action that are generated by feedback and feedforward mechanism.[13, 50, 51] The feedback control is a continual processing of afferent information send along CNS for providing response control on a moment-to-moment basis. On the other hand, the feedforward likely as anticipatory control is generated by the CNS for earlier muscle reaction before the movement.[13, 19, 52] The proprioceptive sensation (e.g. muscle spindle, Golgi tendon) are primary sensory input for maintaining balance.[17, 53, 54] Hence, insufficiency of proprioceptive sensation caused the poor postural control.

2.3 Deficiency of balance and motor control in CLBP patients

Lumbo-pelvic muscles are important for providing a spinal stability during movement in a range of environment. Spinal stability as a neutral zone on spine is produced by three subsystems: the passive subsystem (e.g. spine, ligament, and disc), the active subsystem (trunk muscle) and neural control (e.g. nerve root and central nervous system (CNS)). [47, 55] The feedback and feed-forward mechanisms adapted the spinal muscles stiffness for internal and external forces control during body movements.[13]

Impairment of motor control in individuals with LBP was produced by an injury on a subsystems structural that led to a spinal instability.[12, 13, 56] Nociceptive

stimulation might involve a reducing of proprioceptive signals on spine, inaccuracy of proprioceptive input, fear avoidance pain or movement, and physical activities limitation.[3, 13, 49, 56, 57] The effect was a maladaptation of motor control in chronic muscular pain as well as a person with CLBP for prevent recurrent pain and injury by changing of muscle activity around the pain area. . Adaptation mechanism was performed by the CNS mechanism that induced the alteration of intention and inaccuracy of motor interpretation of demanding. These adaptation mechanism resulted in the decreased robustness of the motor planning.[13, 19, 51] A feedforward mechanism compensate in the deep abdominal muscle based on the speed of limb movement. The transversus abdominis muscles (TrA) activation delayed prior limbs movement. The onsets of TrA and internal oblique (IO)muscle delayed during fast speed in person with low back pain compared to healthy control.[19] The TrA muscle is a primary stability muscle. Thus, deficiency of TrA function led to increase an activity of the superficial spinal muscle for spinal stabilization. This affect to less of spinal segmental movement and flexibility during walking in person with CLBP.[5, 8]

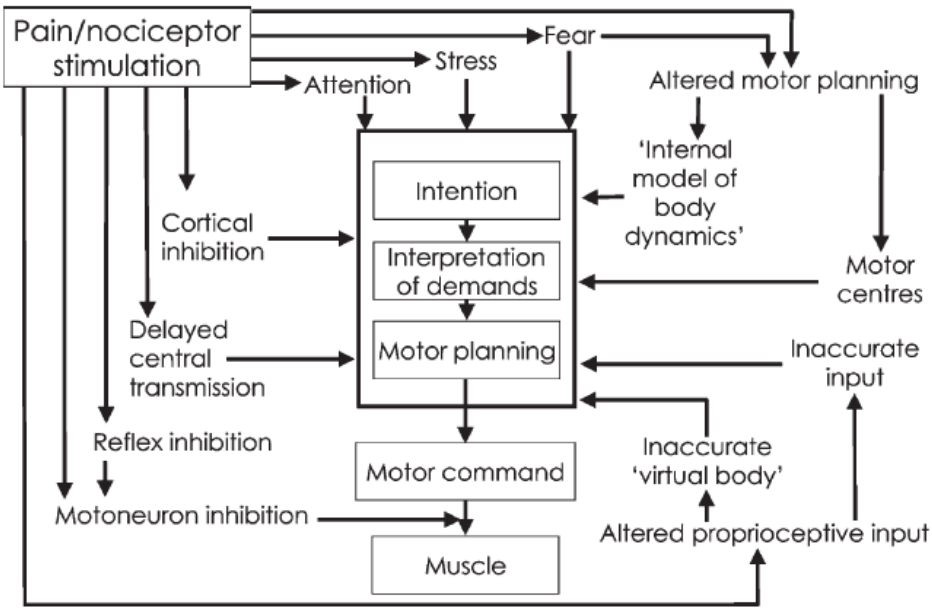


Figure 2: The mechanisms might probably indicate for pain to affect motor control[13]

Patients with CLBP presented a reorganization of sensorimotor network and promoted a maladaptive function of the supplementary motor area,[58] that the alteration of the neural system may produce a dysfunction of motor circuits. An approximate responsiveness of the core spinal muscles activity pattern was required for muscle co-contraction of trunk muscle that provided the spine equilibrium and mechanical stability.[47, 52] These consequences contributed to lumbo-pelvic stability during limbs mobility.[3, 12, 16, 53] Additionally, a lack of spinal ligament due to the injury on passive structure or trunk muscle strain might produce a spinal instability in CLBP patients.[55]

The fear avoidance belief of pain in person with chronic low back pain may contribute to a reducing of spinal movement as well as a lack of spinal flexibility, an anxieties, and lead to keeping away from activities such as sport activity, working or specific activity of daily life.[12, 13, 57]

3. Alteration of gait characteristic in persons with CLBP

Alteration of gait performances have been reported in individual with CLBP.[23, 59-62] The consequences are changing of kinematic, kinetic and balance control and trunk muscle activity during walking in CLBP patients. Impairment of motor control attributed to compensate on the temporospatial gait due to adaptation mechanism of trunk muscles activation. [18, 28, 29]

3.1 Trunk-pelvic kinematic during walking

The kinematic changed were the relative thorax-pelvic co-ordination, which altered during walking in person with CLBP.[8, 29, 63, 64] Low back pain attributed to poorly adjust the thorax-pelvic movement coordination and decreasing inter-segmental movement of spine.[5, 8, 29, 65] At the comfortable walking speed, the global residual pattern of trunk-pelvic in thoracic and lumbar rotations was lesser in participants with CLBP than controls.[8, 29] For all walking velocity, the trunk-pelvic residual pattern movement in person with LBP was shown to decrease in transverse plane rotations and to increase in frontal plane. The trunk-pelvic movement coordination in the sagittal plane was revealed more in-phase (two segments move in a similar fashion) and less

variability in the CLBP subjects.[5] Additional, changing of trunk-pelvic kinematic might linked to reducing the variable pelvis-thigh coordination over stance and swing phase.[5, 23, 28]

For increasing of the walking velocity, the transverse rotation of thorax-pelvic coordination moved toward the anti-phase coordination (synchronous thoracic-pelvis counter rotation) in healthy control group while the speed more than 3.8 km/h. In contrast, the several CLBP patients presented the in-phase coordination (synchronous thoracic-pelvic rotation in similarly direction) in fast velocity and all walking speed.[63] The variability of residual pattern in the person with CLBP altered during increasing speed more than 4.6 km/h. The CLBP presented less a transverse lumbar rotation and to increase the thoracic rotation toward the frontal plane. This adaptation mechanism might be compensated by to increase a rigid trunk rotation. [8]

Thus, the person with CLBP reduced the counter-rotation of trunk-pelvic movement and increased the inter-segmental coupling strength that were an adaptation strategies as the protective mechanism from a rotation perturbation.[8, 63] The effectiveness were an attempt to limit range of trunk-pelvic rotation as well as to produce trunk stiffness in CLBP patients.[5, 8, 59] These compensation of movement caused by diminishing of a precision of trunk postural control. The adaptation strategies may be possibly produced for preventing the recurrence injury of spine and future injury of lower

limb in the activity.[29, 59, 61, 62] The consequences lead to less flexibility in person with CLBP.[8, 28]

3.2 Trunk-pelvic muscle activities during walking

The normal trunk muscle activation during walking in healthy, that is, the trunk muscle activity (e.g. TrA, OI, OE, RA, and MF) associated lower limb movement as well as the hip movement in various directions (e.g. flexion, extension and abduction). First trunk muscle activation as feedforward responsibility during hip flexion is the contraction of the TrA muscle. This is likely as the contralateral weight shifting of the initiate gait.[66] Although the onset time the TrA, RA and OI appeared before gluteus maximus activity but the TrA activity go ahead the activation of other muscle such hip extensor and abductor during stance phase. Hence, the contraction of deep spinal muscles was required to control trunk stability, segmental movement of spine as approximately of trunk motion, variation in the speed, and the accuracy of foot place during movement.[66]

Trunk muscle activities in gait differ between the patients with CLBP and healthy control.[67] Low back pain lead to impair the preplanning of trunk muscle control as a delay of TrA activity prior limb movement.[13, 20] The patients with CLBP increased trunk muscle activity (e.g. multifidus (MF), erector spinae (ES), external oblique (EO), and rectus abdominis (RA)).[68] During swing phase, the multifidus activity was greater in CLBP than healthy control subjects.[67, 69] The ES and RA muscle activities was increased

during all periods of stride in CLBP.[62] Especially the ES muscle activation, increasing of the amplitude and prolong activity increased have been reported in patients with CLBP.[31] At the preferred walking velocity in swing pahse, the average of lumbar ES activity was increased approximately 51% in the ipsilateral and 68% in the contralateral, the activity thoracic erector spinea was increased 48% in the ipsilateral.[8] This effects might be compensated to stabilize the spine.[8] The ES contraction is used to diminish the deviation of trunk motion, maintaining balance, and to produce guarding relative trunk movement in locomotion.[29, 62] Moreover, modification of hip and knee movement over walking are induce by change on the lower extremity muscles activity alteration due to compensation of trunk movement over walking in participants with CLBP.[5] In the swing phase, the gluteus muscle is activated at the earlier state and the hamstring is activated at the end of swing phase in healthy control, but the CLBP more exhibited the hamstrings activation for coupling stage.[23]

For increasing walking speed in persons with CLBP, the velocity related the trunk muscles activity.[29, 68] The amplitude of lumbar ES during the ipsi-contralateral swing phase decreased when the velocity was increased up to 4.6 km/h. The lumbar ES activity was greater during swing phase in person with CLBP than control.[8] The variability of lumbar ES activity decreased in CLBP patients during increasing gait speed.[29] These changes in LES activity showed poor control of LES muscle activity due to low back pain. Thus, change in lumbar ES activity in CLBP might attempted to

stabilizer spine by to increase a stiffness in challenge situation or unexpected perturbation.[8, 29, 68]

3.3 Kinetic change during walking

The kinetic is the reaction force acting or exertion by the body. The participants with CLBP decreased the ground reaction force during preferred walking speed, particularly more decreased the early peak ground reaction force in the stance phase.[23] The plantar pressures distribution was unequal weight bearing in the mid-stance phase in this population.[70] This results may be generated by slow movement for avoidance pain at stance phase, and prevention the future spine and lower extremity injury.[23]

3.4 Gait variability and balance control during walking

Balance in gait is controlling of dynamic stability as automatic mechanism ongoing walking. For walking situation, the body is performed a continuous imbalance situation, resulting from the center of mass (COM) does not stay within base of support (BOS).[9, 10] Initiation state, the acceleration of COM move ahead of the base of support, then the COP move into posteriorly and laterally toward the swing limb then shifts toward the stance limb and forward, this effects might be generated a strategies for setting the COM in motion by the momentum from loss of balance or destabilization.[9, 71] Terminal of gait must perform to return the COG within the base of support for a re-stabilization.[11] A minimally vertical displacement of COM could reduce the energy cost of walking.[9, 11] The COP trace during walking in normal adult, the COP moves posteriorly and laterally

toward the swing limb prior movement and then shifts to the stance limb and forward on pre-swing phase. Then toe-off the swing limbs appear with the COP shifting from lateral to toward movement over the stance foot.[9]

Gait variability could indicate to inconsistency of the CNS for neuromuscular control during walking.[72] Balance and postural control during walking involved the regulation of the foot placement as control of the rhythmic walking mechanism.[73] Alteration in muscular control and a feedback of sensory systems might contributed to decrease automatic gait, this effect leaded to less of ability to regulate gait, reducing to maintain a steady walking pattern and increasing the COP moves over and beyond the base-of-support.[72] If the sensorimotor system impair in person with neuromuscular dysfunction or aging, a gait control might demand a cognitive supervision in order to properly integrate all of the sensory information and regulate dynamic balance.[74] This results associated the instability and risk of fall.[72, 74] Makki BE. 1997 has reported, the stride-to-stride variability in velocity could use to predict a falling and to classify the fall and non-faller in older adult by 71% accuracy, especially, the width significant for predict for measure postural sway.[75] Specially, challenge in gait by changing the velocity or executive task application interfered a control locomotion and the gait adaptation mechanism in neuromuscular disorder such as chronic ankle instability, CLBP and elderly.[76-78]

The stride-to-stride fluctuation in term of gait parameters was used to measure the gait variability in person with CLBP. Impairment of proprioceptive and pain interfered as a feedback, postural adjustment mechanism and motor control that could contributed to different of gait variability between people with CLBP and asymptomatic.[27, 77, 79] Dual task as application a cognitive task during walking interfered a stride-to-stride variability by increasing variability of stride length and stride time due to altered sensorimotor mechanisms as well as chronic pain.[27, 80] Causing of dual task in gait might diminish the automaticity mechanism during walking, that was attributed by cognitive attention task in person with CLBP.[27] Increasing of variability reflected a loss of automaticity during walking and reduced the ability to adapt to short term perturbations that probably induced instability and a more susceptible to falling.[28, 81] However, the fast walking speed is a challenge situation from inducing instability as well as the common activity of daily,[30, 73] but the gait variability as the stride to stride fluctuation in term of temporospatial gait is unclear in this population.

Moreover, balance control during preferred walking speed in CLBP has been reported by the COP movement. The trajectory of COP was investigated by the plantar pressure distribution for foot scan. The trajectory COP displacement more increased in CLBP. They leaned into anterior direction and less forward movement on the affected leg. There might compensated for avoidance pain during walking.[18]

However, the COP excursion during the fast gait speed should be regard in person with CLBP.

3.3 Temporospatial gait

Temporospatial gait were illustrated as slower a gait velocity and higher stride time in CLBP patients than control.[8, 29, 63] In fast speed, the stride length was decreased in CLBP patients.[29] The previous study has been reported that the gait speed and step width were increased in older adults with CLBP. The correlation between the step width, double limb support time and timing of stair ascent/descent in older with CLBP.[82] Changing of gait speed was compensated to preserver the body's balance during walking and they required to achieve the behavior goal.[8, 29, 32] This results related to change of lower extremity movement due to the alteration of trunk and hip extensor muscle activity and spinal instability.[5, 31, 83] Moreover, the walking velocity affected a fear avoidance movement in person with CLBP.[8]

Table 2: Evidence of previous studies that investigated the gait variability and temporospatial gait in participants with CLBP

Study	Participants	Walking procedure	Results	
			Temporospatial gait	Gait variability
Lamoth *et al.* (1976)[63]	CNLBP (N=39), a mean age of 38 years Control (N=19), a mean age of 41 years	Walking preferred speed and fast speed on treadmill in increments of 0.8 km/h from 1.4 km/h to a maximum of 5.4 km/h, collected the consecutive strides within 30 second, and 10 strides were left for analysis	SS; velocity of preferred speed lower in CNLBP (mean 3.2 km/h, range 2–4.5 km/h) than control (mean 4.5 km/h, range 3.5–5.3 km/h).	-
Lamoth *et al.* (2006)[31]	CLBP (N=12), a mean age 46.8 ± 10.9 years Healthy (N=12), a mean age 30 ± 8.1 years	Walking preferred speed fixed speed on treadmill (6.2, 1.4, 3.8, 5.4, 2.2, and 4.6 km/h) and collected data of the consecutive strides within 30 second in each speed.	SS; preferred walking velocity lower in CLBP (3.6 ± 0.98 km/h) than control (4.8 ± 0.68 km/h) SS; Stride length lesser in LBP at 6.2 km/h	-
Lamoth *et al.* (2006)[8]	CNLBP (N=22), a mean age of 38 years Healthy (N=17), a mean age of 31 years	Walking preferred speed on treadmill and fast speed; treadmill to increase of 0.8 km/h from 1.4 km/h until they indicated to too high speed as a maximally attainable walking velocity.	SS; velocity of preferred speed lower in CNLBP (3.3 ± 1.1 km/h) than control (4.7 ± 0.7 km/h). SS; stride length lesser in the CNLBP than the control at 1.4, 2.2, 3.0 and 6.2 km/h.	SS; variability of the coordination of trunk to pelvic rotations less in CLBP than controls. SS; variability of the coordination of trunk to pelvic movement in frontal plane less in CLBP than controls. SS; Increasing variability in frontal plane higher in increment walking speed than the preferred velocity.

SS; defined as the statistically significant and NS; defined as non-significant.

Table 2: (Continued)

Study	Participants	Walking procedure	Results	
			Temporospatial gait	Gait variability
Lamoth *et al.* (2008)[28]	CNLBP (N=12), age 45 ± 9.2 years Control (N=14) age 44 ± 7.4 years	Walking preferred speed on treadmill, 25 consecutive strides were analyzed	SS; preferred walking speed lower in CNLBP than control SS; stride length shorter in CNLBP (114 ± 0.29 cm) than control (133 ± 0.16 cm) NS; step frequency, step width	SS; variability of stride lengths LBP (3.6 cm) less variable gait than control (6.9 cm) NS; variability of step frequency and step width
Newell et al. (2009)[84]	CNLBP (N=12) Control (N=12), Age 18 - 50 years	Increment speed 0.1 km/h, first their report PWS, more increase 1.5 km/h, decrement speed until they felt their Walked on treadmill with preferred speed for 8 min	NS; Walking speed (m/s) in CNLBP (0.91 ± 0.15), control (0.97± 0.27) NS; stride length (m) in CNLBP (0.87 ±0.05), control (0.90 ± 0.08) NS; step length (m)	-

SS; defined as the statistically significant and NS; defined as non-significant.

Table 2: (Continued)

Study	Participants	Walking procedure	Results	
			Temporospatial gait	Gait variability
Hanada *et al.* (2011)[67]	CLBP (N=9), age 64.9 ± 8.8 years Control (N=9) age 61.4 ± 9.8, years	Walking preferred speed over a GAITRite mat, 4 m in length and 4 trial performing	NS; Walking speed (m/s) in CNLBP (0.91 ± 0.15), control (0.97± 0.27) NS; stride length (m) in CNLBP (0.87 ±0.05), control (0.90 ± 0.08) NS; step length (m) NS; gait velocity (cm/s) in CLBP (136.70 ± 21.4), control (135.00 ± 11.7) NS; Step length (cm) in CLBP (74.34 ± 8.96), control (71.72 ± 7.66) NS; Base of support (cm) in CLBP (6.91±2.17), control (8.32 ± 1.89) NS; Double support (s) in CLBP (25.49 ± 2.76), control (26.35 ± 3.72)	-

SS; defined as the statistically significant and NS; defined as non-significant.

Table 2: (Continued)

Study	Participants	Walking procedure	Results	
			Temporospatial gait	Gait variability
Zahraee *et al.* (2014)[25]	CNLBP (N=20), age 22-55 years Control (N=20)	Walking preferred speed on treadmill, 25 consecutive strides were analyzed	Walking preferred speed along the gait lab path, 5 successful trials were analyzed.	NS; walking velocity (cm/s) in CNLBP (9.2 ± 1.3), control (9.53 ± 0.99) NS; Cadence (steps/min) in CNLBP (97.7 ± 9), control (98.3 ± 7.1) NS; Stride length (cm) in CNLBP (1.13 ± 0.093), control (1.62 ± 0.77)
Muller *et al*. (2015)[23]	CNLBP (N=11) Control (N=11) (matched group)	Walked on tract along a 17 m with preferred speed, walkway with two consecutive force plates	SS; gait velocity lower in CNLBP (1.84 ± 0.13) than control (1.97 ± 0.13) NS; step length	-

SS; defined as the statistically significant and NS; defined as non-significant.

Table 2: (Continued)

Study	Participants	Walking procedure	Results	
			Temporospatial gait	Gait variability
Hamacher *et al.* (2016)[79]	CLBP (N=12), age 57 ± 14 years Control (N=12) age 55 ± 12 years	Walking preferred speed on a 25-meter-long track forth and back at their preferred walking speeds, 2minute	NS; stride length and stride time	SS; stride time variability higher in CLBP group (0.0203 ± 0.0128) than control (0.0170 ± 0.0054)
Hicks *et al.* (2017)[82]	Older adult with CLBP (N=54) Control matched age and sex (N=54)	Preferred walking speed Fast walking speed	SS; preferred and fast gait speed slower in CLBP than control SS; step width greater in CLBP than control at fast speed SS; stance time fewer in CLBP than control at fast speed	-

SS; defined as the statistically significant and NS; defined as non-significant.

4. Walking speed impact a gait performance

Walking speed affected the variability of gait parameter and kinematic of trunk, hip and knee motions.[85] Preferred walking speed is always selected, this speed reflects a stable attractor state of the motor system and low energy consumption.[86] Changing of gait speed (increasing or decreasing walking speed) is to move away from the attractor state causing gait instability and it is expected to loss of stability.[28, 30, 87] An amount of stride to stride fluctuation was increased if the walking speed differed from the self-selected walking speed.[85] The variability of stride time, hip abduction/adduction angle, knee varus/valgus angle, knee internal/external rotation, and all trunk motions were affected by walking speed.[85]

Fast speed affects the gait variability and kinematic movement due to changing of motor control recruitment. Fast speed related with increasing more regular motor output that needed higher energy consumption as well as adaptation mechanism due to loss of stability.[86] Variability of stride, step length increased while increasing gait speed.[87] The intra-limb coordination (thigh–shank and pelvis–thigh) reduced in dynamic phase and variability of inter-segmental movement during fast speed were diminished than preferred and slow walking speed due to alteration of motor control in fast speed, which could restrict a degrees of freedom of lower limb.(88) These changes may be adaptation mechanism of the CNS to adjust the control strategies, which leaded to maintain the stability, rhythmic, and smoothness during challenging situation.(88) During

fast speed has decreased a variability of trunk-pelvic in participants with CLBP.(8) This result might be generate from increasing of superficial trunk muscle activity.(29) Increasing of walking changed the % time of COP progression; to decrease in mid-stance and to increase in pre-swing and terminal phase.[89] Thus, changing the speed of locomotion may require additional force for damping the destabilizing effects.[87]

5. Factors affect the gait characteristic

Gender affected the gait parameter, kinematic and the COP during walking. The step length and stride length were greater in men than woman. During pre-swing the women had a knee extension limitation of the ipsilateral and also limits forward swing of the contralateral leg, that results might contributed to decrease a step length.[90] However, these different were dependent of height.[90] Men had a significantly larger deviation of COP progression angle than women.[89] The kinematic of hip, knee and ankle angle in sagittal plane difference between male and female. Women more take on the movement on the ankle angular but the men increased a hip angular movement.[90, 91] For female, the hip move more medially in frontal plane that might compensated for reducing hip abductor strength.[90]

Age influence on variability and temporospatial gait. Gait speed (e.g. preferred and fast speed) and step length difference between 10 to 79 years age groups.[92] The step length, stride length, ankle range of motion, pelvic obliquity, and velocity were significant lower in elderly than the younger women.[93] Variability of stride time, step

length related to age. Older adults has been reported greater variability for trunk roll, stride time and step length at all speeds than young adult. Additional, the trunk motion affected by age, greater of variability of trunk movement at all speed has been reported in older adult.[94] However, increasing of variability during walking might involve by the other factor related aging such as nervous system dysfunction.[94]

Sensorimotor dysfunction increased gait variability and altered temporospatial gait. Gait control depended on the inaccuracy of sensory system input (e.g. visual, vestibular, and somatosensation) and the motor output such as trunk or leg muscle activity.[9] Greater variability for temporal gait in aging associated a visual disturbance (eye closed), poor leg proprioception, slower reaction time, and weakness of quadriceps muscle.[95] Neuromuscular disorder affect gait control such as Parkinson's disease could induce postural sway during walking[96] or deterioration of cognitive associated the gait variability.[97]

Moreover, body weight, height, Body Mass Index, leg muscle strengthening and the range of motion (ROM) of lower limbs affected gait parameter and variability during walking. Body weight and height relate the step length in women.[98] Obese women (BMI between 30-40 kg/m^2) have slower at preferred and fast walking speeds and shorter stride lengths.[99] These different associated less powerful lower limbs.[99] Leg length associated the gait velocity. Decreasing of leg strength and passive ROM could induced greater gait variability.[85]

6. Assessment tool

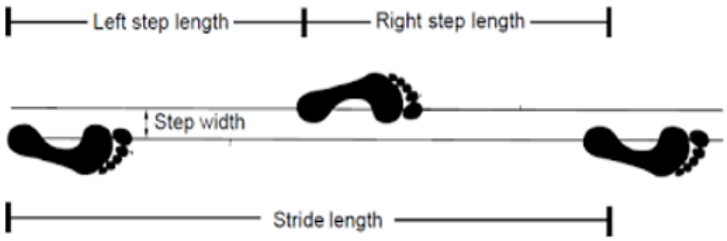
6.1 Temporospatial gait

Temporospatial gait parameters is described as the rhythmic or alteration movement of lower limbs during walking. The spatial parameters (distance parameters) include the step length, stride length, and step width. The temporal parameters (time parameters) include the speed, stride time, step time, swing phase, stance phase, single limb support, double limb support, and cadence.[29, 67, 81, 82, 84] Gait parameters are indicated as following:

- support time (% of gait cycle) or percentile of the mid-stance phase of each leg is the contralateral toe-off phase and the transfer of the body's center of gravity over the weight bearing foot
- step width (cm) is the distance between left and right foot
- step length (cm) is the distance between the heel contact of one side of the body and the heel contact of the contralateral side
- step time (sec) is the phase within a gait cycle between the heel contact of one side of the body and the heel contact of the contralateral side
- step length (cm) is the distance between the heel contact of one side of the body and the heel contact of the contralateral side
- stride length (cm) is the distance of the consecutive heel strikes of the same foot; stride time (sec) is the time interval as the time between consecutive heel strikes of the same foot

- cadence is a step frequency (step/minute)

A)



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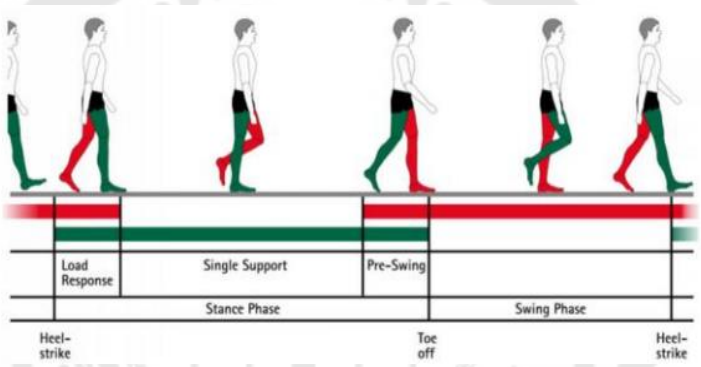

Figure 3: Demonstration the temporospatial gait parameters: A) step length, step width, and stride length; B) Percentile of single support is calculate from mid stance phase and the double support is calculated from the sum of loading response and pre-swing.

Normative gait parameters could categorize to five boundary of temporospatial gait performance: a rhythm boundary was defined by cadence, step time, stride time, swing time, stance time, and single support time; a phase domain was defined by the distinct divisions of the gait cycle (GC) such as double support (% GC) or swing phase (%GC); a variability domain was defined by the coefficient of variation

(%CV) for each of the temporospatial gait; a pace boundary was defined by a walking velocity, step length and stride length; and a base of support boundary was defined by step width and the variability of step width (SD).[81]

6.2 Gait variability assessment

Gait variability is defined as changes in gait parameters from one stride to the next stride. Balance and gait control involved variability of gait parameter that contain a support time, step width and length, and stride time and length.[72, 75, 76, 100, 101] Measures of variability have been defined by the standard deviation (SD) and the coefficiency of variance (CV) of the stride-to-stride fluctuations of gait parameters or kinematic movement.[8, 72, 74, 102] The SD can indicate the variability. The magnitude of variability as well as an amount of variability can defined by the CV; controlling of the rhythmic stepping mechanism associated to a variability of temporal stride kinematic.[72] CV is calculated by the ratio of the SD to the mean of gait parameter as following;

$$\text{Coefficiency of variance (CV)} = \frac{\text{Standard deviation (SD)}}{\text{Mean}} \times 100$$

6.3 COP measurement in gait

Postural stability and balance control during stance and walking could be assessed by continuous movement of the COP and COM positions.[3, 18, 103] The COM is defined to the position of the body's center of mass (COM) relative to the base of support.[103] The COP is the point of pressure of the body over the soles of feet and the point is concentrated on the one spot during standing.[3] In gait situation, the center of

pressure moves over and beyond the base-of-support continuous gait cycle. Measuring of COP location is performed by calculation the ground reaction forces and the ground reaction moments throughout each stance limb on the force platform or measuring of plantar pressure distribution from heel-strike to toe-off of each leg.[3, 18, 85] The trajectory of COP has been measured for the average of amplitude and velocity of COP excursion and trace of COP could detect the movement in the anterior-posterior and medial-lateral direction.[3, 85] The SD of COP displacement as a variability of COP movement could distinguish the older adult between the faller and non-fall.[104] Hence, controlling of COP movement has been represented the ability of the central neuromuscular control system to dynamic stability of gait control and maintaining a steady walking pattern.

The trajectory of COP during static stance or walking are integrated by the force signal of software of the FDM-T instrumented treadmill that represent the major spatiotemporal gait parameter in term of COP variability.[105-107] A symmetry in terms of weight shifting between legs included the deviation of a continuous trace of the COP movement during walking in sagittal and frontal plan, and lateral shifting. This could measure a gait variability in patients with neuromuscular disorder.[106]The software can generate a graphic pattern in term of a butterfly diagram that represents a continuous trace of the COP trajectory. A butterfly diagram can estimated a COP variability, which is derived from a SD of COP movement in anterior/posterior and lateral direction.[105, 106]

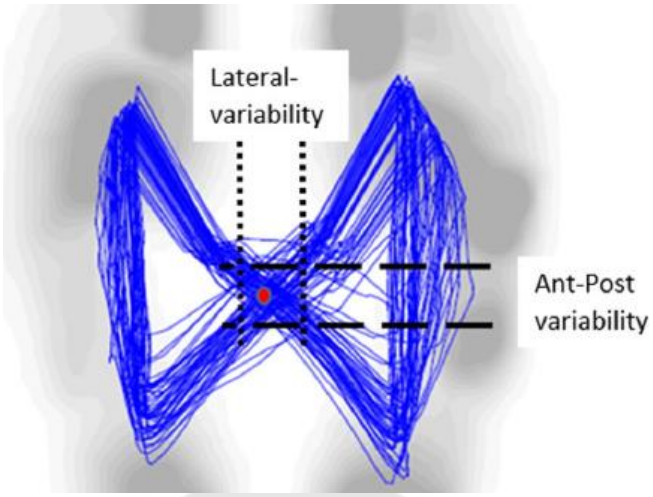

Figure 4: A butterfly diagram derived from the instrumented Zebris treadmill. Red dot is defined to the intersection point of the COP trajectory during walking. Dashed lines represent COP variability in AP and ML directions. [106]

6.4 Low back pain disability

Oswestry Low Back Pain Disability Questionnaire (ODQ)

Oswestry Low Back Pain Disability Questionnaire (ODQ) is a self-report instrument of specific symptom for function disability that relate a low back pain.[108, 109] The ODQ contain a 10-item questionnaire; the first section rates the intensity of pain and the others indicated the effect of pain intensity on the disability of the daily activities.[109, 110] The score of each item described in range from 0-5 and the total score is 50. The sum of score is showed in a percentage of maximum score: 0% is no disability and 100% is a maximum disability.[109] An ODQ showed high a reliability coefficient in person with low back pain as well as an intraclass correlation coefficient (ICC) over than 0.80.[108] In participants with sub-acute and CLBP, the ODQ showed accuracy of 71%, sensitivity of 76% and a specificity of 63% for discrimination of a disability improvement.[110]

Table 3: ODQ score and level of disability.[109]

Range of score	Level of disability
0-20	minimal disability
21-40	moderate disability
41-60	severe disability
61-80	crippled disability
81-100	bed bound or symptom magnified

However, the item of sex life was a problem in eastern society. The modified ODQ was removed an item of sex life and to replace the item of employment and housework. The modified ODQ has sufficient reliability to recommend it as a standardized measure of activity limitation and the ICC value was 0.84. The minimal detectable change (MCD) was at least 10.5 points in patients with chronic musculoskeletal pain.[110] The minimally clinically important change (MCIC) showed at least 10 points for all type of low back pain.[111]

The Thai version of modified ODQ was developed by Sakulsriprasert et al in 2006.[112] The test-retest reliability is assessed in patients with low back pain, age 40.1±10.7 years. The ICC value 0.98 that was calculated from two occasion separate by a time interval of 20-30 minutes.

The Roland-Morris Disability Questionnaire (RMDQ)

The Roland-Morris Disability Questionnaire (RMDQ) is measured the physical disability and activity limitation due to low back pain. The items in the RMDQ consisted of the yes-no response format. The questionnaire score is the sum of the “yes” responses. The score range 0 (no disability) and 24 (maximum disability). The MCIC value showed at least 3.5 point in patient with acute and chronic low back pain.[111]

Thai version of RMDQ was developed by Jirarattanaphochai et al in 2005.[113] One hundred participants with different duration of symptoms and type of low back pain were recruited for this study. The mean age of the patients was 46.8 + 12.42

years (range, 21-75). Thai version of the RMDQ showed the reliability for measurement the function disability of low back pain in Thai patients. The Cronbach's alpha coefficient value was 0.83 (range 0.71-0.93).

6.5 Pain intensity

Numeric rating scales (NRS)

Numeric rating scales is used to assess a pain intensity in chronic musculoskeletal pain.[114] The patients are asked to indicate the numeric pain score, which represents their pain intensity. The NRS consist of range from 0 to 10 or 0 to 100; 0 represents no pain and 10 or 100 represents a worst of pain imagination.[108, 110] The minimal clinically important difference (MCID) of NRS in the patients with chronic pain was 2.0 or a percent change score of 33.0%.[114] For patients with low back pain, The MCIC showed at least 3.5 and 2.5 points for patients with acute and chronic low back pain, respectively.[111]

Visual analog scale (VAS)

Visual analog scale (VAS) consists of a line, usually 100-mm long (e.g. 'no pain' to 'pain as bad as it could be'). The end of label is defined the extremes of pain. Patients are asked to mark along the line, which best represents their pain intensity. The pain intensity is indicated by the distance from the no-pain end to the mark point. The MCID value showed at least 35 and 20 millimeter for patient with acute and chronic low back pain.[111]

6.6 Fear-Avoidance behavior

A Fear-Avoidance Beliefs Questionnaire (FABQ) was used to assess the fear and avoidance behavior on the patients' belief, which was affected from their low back pain. The FABQ contain two factors: fear-avoidance beliefs about work and fear-avoidance beliefs about physical activity with internal consistency of 0.88 and 0.77, respectively.[115] The FABQ consist 16 items: 7 items on fear avoidance beliefs about work and 4 items on fear avoidance beliefs about physical activity. Scoring is a 7-point Likert scale of each item responses ranging from 0 (completely disagree) to 6 (completely agree). The total score is ranges from 0 to 42 and 0 to 24 for the total score of the FABQ work and physical activities scale, respectively. Higher scores indicate higher fear.[42, 115] Reliability of FABQ Thai version was investigated by Pensri et al in 2006.[116] Twenty participants with low back pain were included for test-retest reliability and the question separated by 24 hour interval was showed the high reliability,, ICC value of 0.85-0.96.

6.7 Sahrmann lower abdominal core stability test

The Sahrmann lower abdominal core stability test is a clinical assessment of isometric contraction of core stability muscle as a local abdominal muscle that provide the control of loading and supporting on the spine.[16, 117, 118] All positions start supine in the hook lying position and to maintain spine in a neutral position. The participants were instructed for abdominal contraction as well as maintaining abdominal control during leg movement. Previous study has reported the moderate reliability for Sahrmann core stability test in baseball athletes, the ICC value was 0.649 (95%CI 0.257 to 0.832).[117] The standard error of the measurement (SEM) value was 0.302, which would be described as low. [117]

The starting position is the supine with crook lying and progression to difficulty level by loading of leg movement with maintaining the natural spinal curve. The pressure biofeedback unit (PBU) was placed under lumbar spine. The PBU was inflated pressure 40 mmHg and maintaining the lumbopelvic position in each level with a change of not more than 5 mm Hg.[119] The participants was instructed for normal breathing during testing. If participant could complete each level they were allowed to move on to the next until unable to complete the test. The test comprised 5 levels and the difficulty increasing go ahead next level is illustrated;

Table 4: Demonstrated the five levels of the Sahrmann core stability test.[16]

The Sahrmann core stability test	
Level 1	Beginning in supine, in crook-lying position while abdominal hollowing* Slow raise one leg to 100˚ of hip flexed with point the tight toward the ceiling Opposite leg brought up to same position Lower the one leg turn to the table and the opposite leg to the starting position
Level 2	Lift one leg up until your hip is bent to 100 ˚and your thigh is pointing toward ceiling Lift alternate foot off the table and slide foot down with heel contact the table until straighten leg completely Slide foot back to the starting position, so both feet are on table Repeat starting with your opposite leg
Level 3	Perform the same movements as outlined in Level 2 except the following: Hold your foot off table while straightening leg out Set your leg down on table Bring your leg back to starting position by holding foot off the table Repeat with the opposite leg
Level 4	Bend your hips and knees and slide heels along the table Lift both feet off table when 100˚hips flexed Reverse the movement to return to the starting position
Level 5	Bend your hips and knees by lifting both feet off the table, bringing your knees to chest Hold your hips at 100˚and straighten your knees, lower legs to the table Returning to starting position

Beginning in supine crook-lying position while abdominal hollowing in each level*

CHAPTER 3 METHODOLOGY

Research Design

A research design is the cross-sectional study

Participants

Forty-participants were divided to two groups; 1) participants with chronic non-specific low back pain (CNSLBP) and 2) non-low back pain (NLBP). Age was between 20 to 59 years. They could walk without the assistive devices or assistance. Participants from the CNSLBP and NLBP groups were matched on sex, age range (5 year age group)[120], and BMI range[121]. The inclusion criteria for CNSLBP was a pain at low back at least 3 months. Their pain level based on Numeric Rating Scale (NRS) was at least 4, averaged in the last 7 days.[5, 79] The disability was identified by Thai version modified Oswestry Low Back Pain Disability Questionnaire (Thai ODQ) range over than 20%.[85] The NLBP group had no experience LBP within the past six months.[82] On the day of examination, the participants were required to avoid from the extream physical activity. They could followed the commanding of tester.

The exclusion criteria was a pregnancy, to present pain radiation in the lower leg, history of fractures or operative treatment related a spine or lower extremity, lower limb length discrepancy over than 1 centimeter (as measured by the distance from the anterior superior iliac spine to the ipsilateral medial malleolus of each leg, in a supine position),[122] to limited ankle and knee range of motion (ROM) in the sagittal plane, knee

deformity (bow leg), neurological disorder, lower extremity injury within the past 6 months,[78] structural scoliosis, severe kyphosis,[18] uncontrolled the cardiovascular/ pulmonary disorder such as dizziness or dyspnea, receiving the drugs that involved balance, signs or symptoms of vestibular disorders such as vertigo, nystagmus in the day of assessment, diabetes mellitus with sensory neuropathy , a neck pain as defined by NRS score approximately at least 4,[123] neuromuscular disorder, visual problem that cannot be corrected with glasses. If, the specific low back pain is suspected by red flag instruction they were excluded.[34, 35, 124] Participant were discontinued from this study if they reported increasing pain intensity more than 2 scores or occurring abnormal symptom during testing and disagreed to participate.

This study was approved by the ethic committee of the faculty of physical therapy, Srinakarinwirot University, Ongkharak, Nakhon-Nayok, Pathum Thani Medical and Sanitary Human Ethic Committee, Nakhon-Nayok Medical and Sanitary Human Ethic Committee, Thailand. All participants received the information sheet that comprised the objectives, procedures, benefit and harm from this study. Then, they were required to sign in the inform consent before participating in this study.

Setting

This study was performed at settings that include a physical therapy clinic in Nakhon-Nayok campus of Srinakarinwirot University, Bueng Sanan of Tambon Health Promoting Hospital, Thunyaburi Hospital and Khlong Luang in Pathumthani, Thailand.

Sample size

The sample size was calculated by program GPower 3.1.9.2 based on the previous study. The mean and SD of COP excursion, alpha and beta error was used to calculate the sample size The mean ± SD of COP excursion during walking in CLBP patients and control group were 0.70 ± 0.53 and 0.41 ± 0.29, respectively.(18) Alpha error probability (α) and power analysis (1-β) were set at 0.05 and 0.8, respectively. Total sample size from calculation was 72 participants. Thus, the minimum sample size was required 36 participants per group.

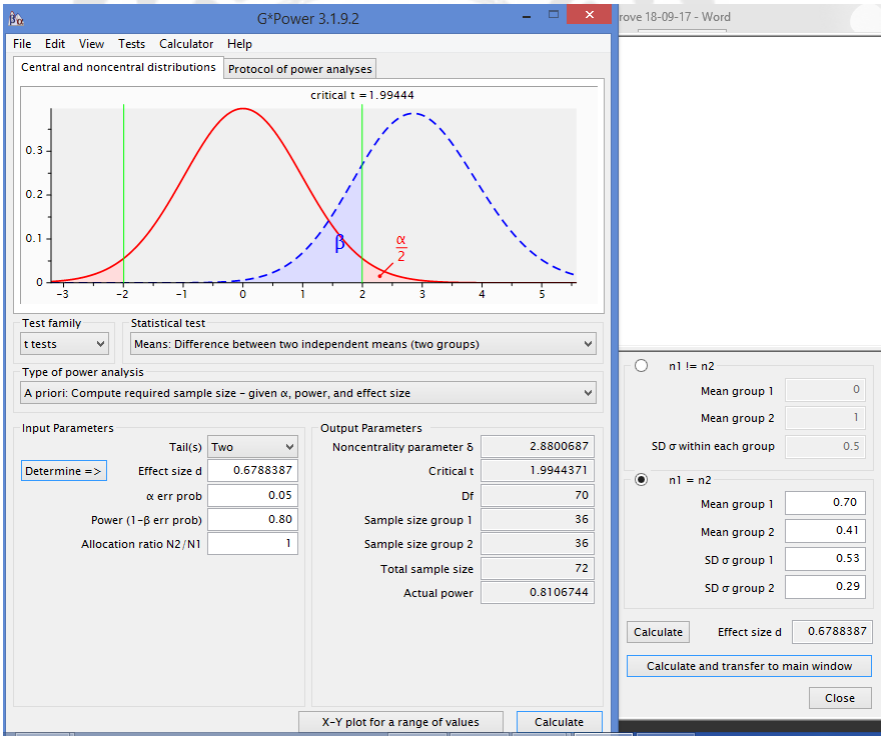

Figure 5: Sample size calculation by the GPower version 3.1.9.2

Study procedures

All participants were required to wear the comfortable clothing and sock. Participants were reported their information that considered for demographics and history of pathology same as the appendix A and B. For person with CNLBP, the low back pain related disability (appendix C) and fear avoidance belief were measured by the Thai ODQ and the Fear-Avoidance Belief Questionnaire (Appendix D), respectively. The NRS of pain level was assessed before walking test of each trial.

Clinical assessment was to measure the lower abdominal core stability,[16] hip muscle strength and hip muscle tightness. Thomas test was used to assess the hip flexor length as the appendix E. If the hip and knee remained and flatted on the table, the result was negative. The test was positive if the hip and the knee lifted off the examination table. The Ober test was used to assess the tensor fascia latea (TFL) tightness same as the appendix E. The thigh of testing limb in side lying position was defined a neutral position as 0˚ of hip abduction Hip abduction was measured by the digital protractor at the lateral epicondyle of femur the result was positive. The test was negative when the hip put on the table as hip adduction as a neutral position.[125, 126] The Sahrmann Core Stability test was used to measure the lower abdominal core stability by leg movement with maintaining the neutral spine, which is detected by the pressure biofeedback (±5 mmHq) same as the appendix F.[118, 119] The Trendelenburg test was used to indicate the hip muscle performance during single leg stance. The participants

were required to single leg stand for 30 seconds. The negative test, if the pelvis on the non-stance can be elevated as high as hip abduction on the stance side and they can maintained this posture for 30 seconds with the vertebra prominens centred over the hip and foot. The positive test was defined as the dropping of the pelvis on non-stance or the pelvis is maximally elevated on the non-stance side above the stance side and the pelvis could not be maintained in that position for 30 seconds.[127, 128] The five times sit to stand test was used to assess the lower limbs performance. Intra-rater reliability was assessed for each measurement which was presented in the appendix H. Before walking test, the researcher explained the safety procedure to the participants. The vital sign was measured in all participants. Back and leg stretching were applied to the subjects. Then, the participants practiced to familiarize with treadmill walking for 3 minutes. The experiment was performed on Zebris FDM-TDS-3i Treadmill (Zebris Medical GmbH, Germany) containing the treadmill with an electronic mat of 7168 miniature force sensors and 108.4 x 47.4 cm of each sensor area. The running surface is 150 x 50 cm. The treadmill velocity can be applied between 0.2 and 22 km/h, at interval of 0.1 km/h. The sensors at a sampling rate of 120 Hz was used to record a force exertion of feet during walking.

Participants were blinded to select treadmill speed during testing. They walked naturally in the middle of the treadmill, no holding or touching the handrail. The PWS and FWS were determined before collecting data of each walking condition. For PWS

condition, the participants walked by their self-selected as a comfortable speed. The velocity was increased by 0.1 km/h until the participants report their first comfortable speed and walk in this speed for 1 minute to familiarization. The treadmill velocity was increased until the participants reported an exceeding their comfortable speed. Then, the velocity was decreased by 0.1 km/h until participants confirm their preferred a comfortable walking speed. For FWS condition; the participants were required to walk as fast as possible without running and the speed was started at nearly their preferred-speed. When, the participants first report their fastest walking speed and walk continuously for 1 minute to familiarization. The velocity was increased until they report their running speed. Then, the velocity was decreased by 0.1 km/h until they confirm that their fastest speed.[26, 78] Their first and confirmed velocity were reported of each trial that were not different exceed 0.4 km/h.[87] The velocity were recorded for each walking condition. The determination of individual gait velocity was measured the intra-rater reliability that was shown in the appendix I. Participants were required to perform 3 minutes of each walking condition and 3 minutes rest interval.[28] The sequences of data collecting was randomized.

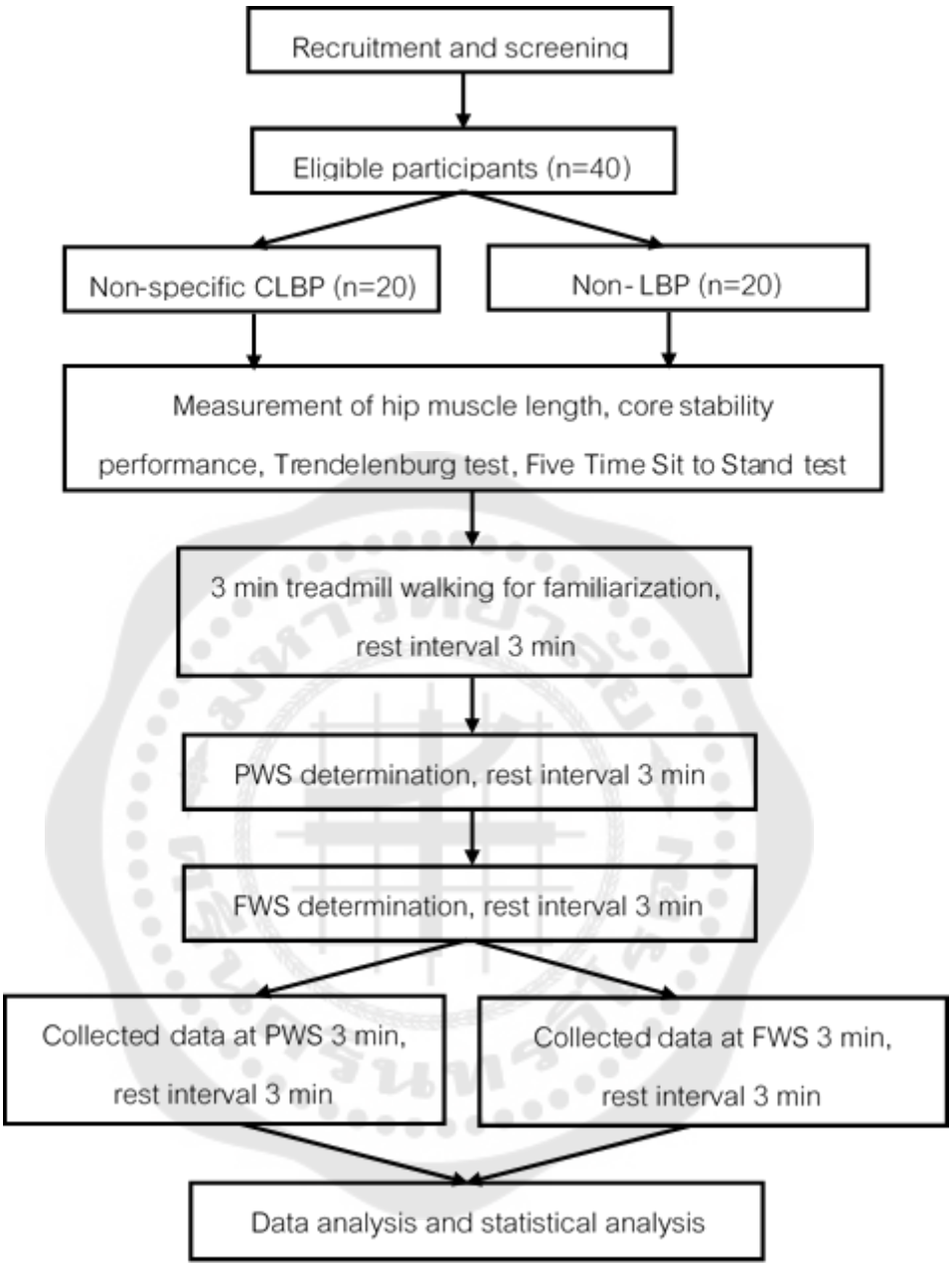

Figure 6: The diagram demonstrates the study procedure.

Data collection

The participants were instructed to walk on the treadmill for 3 minutes of each walking condition (e.g. PWS and FWS)[26, 129] at least 3 minutes of resting between trials. All steps within time period were calculated to a temporalspatial gait and COP by the treadmill software Zebris. Gait variability were calculated from stride to stride fluctuation of a temporospatial gait that considered to walking velocity, the step length, step width, stride time, % single support and double support time and stride length.[45, 73, 130, 131] The COP movement in anterior-posterior and medial-lateral direction derived from the butterfly diagram.[132, 133]

Data analysis

Temporospatial gait parameters

The temporospatial gait parameters were analyzed over 3 minutes of each walking condition. The temporospatial gait parameters was as following:

1) Gait speed (km/h) was defined as an average gait speed during the analysis measuring interval.

2) Step width (cm) was defined as the distance between right and left foot.

3) Stride length (cm) was defined as the distance between successive heel contacts of the same foot.

4) Step length (cm) was defined as the distance between the heel contact of one side of the body and the heel contact of the contralateral side.

5) Stride time (s) was defined as the time between the first contacts of two consecutive footfalls of the same foot, step length.

6) Step time (s) was defined as the phase within the gait cycle between the heel contact of one side of the body and the heel contact of the contralateral side.

7) Single support time (%) was defined as the percentile of the contralateral toe-off phase and the transfer of the body's center of gravity over the weight-bearing foot.

8) Double support time (%) was defined as a sum of the loading response phase and the pre-swing phase

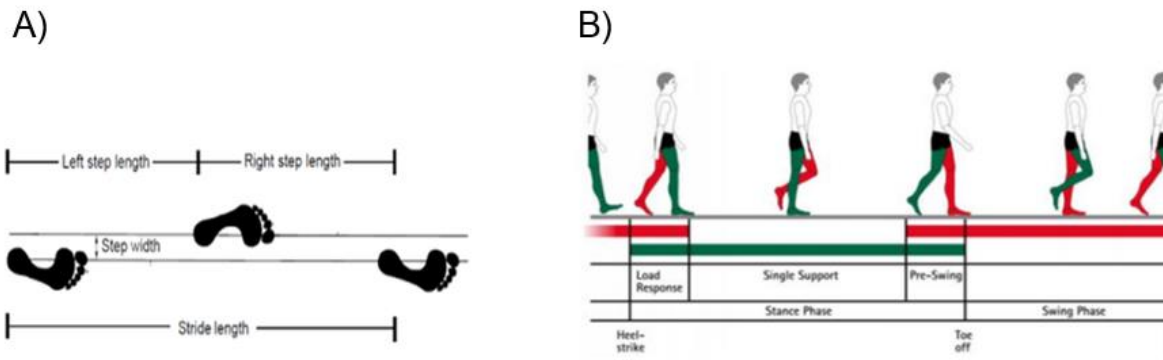

Figure 7: Demonstration the temporospatial gait parameters: A) step length, step width, and stride length; B) Percentile of single support time was calculated from mid stance phase and the double support time was calculated from the sum of loading response and pre-swing.

Gait variability

The gait variability was indicated to the constant of gait control and balance, which involved the fluctuation of step length, step width, stride time and length, and % gait cycle of single support time.[45, 73, 130, 131] The coefficient of variance (CV) of each variable represented an amount of gait variability. It was the ratio of the standard deviation to the mean of each variable as follows.[45, 73, 132]

$$\text{Coefficient of variance (CV)} = \frac{\text{Standard deviation (SD)}}{\text{Mean}} \times 100$$

COP

The trajectory of the COP was calculated from the typical of butterfly diagram of the force application points when the weight transfer in the double-standing phase. The COP variability were automatically derived from the butterfly diagram that presented a continuous trace of COP trajectory during walking (Figure 8) as following.[105, 106]

1) Lateral symmetry (mm): defined as left/right shift of the intersection point; zero position' is equivalent to perfect symmetry.

2) Lateral variability (mm): defined as the standard deviation (SD) of the intersection point in the lateral direction. Similar to the ant/post variability parameter; 'zero' is equivalent to constant strides in terms of width between the legs (Figure 8A).

3) Anterior/posterior position (cm): defined as the shift forwards or backwards of the COP intersection point, taking all the steps into consideration. The initial or zero position is the rearmost place where the heel contacts the ground

4) Anterior/posterior variability (mm): defined as the standard deviation of the intersection point in the anterior/posterior direction (Figure 8B).

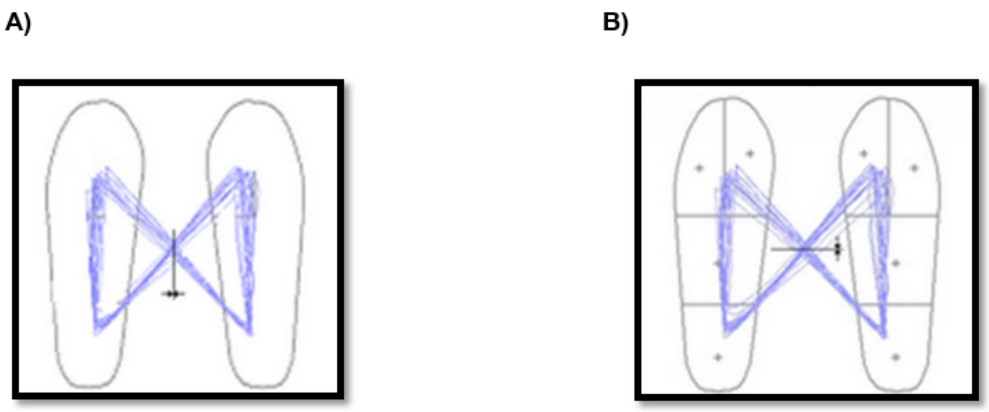

Figure 8: The COP variability was demonstrated from the deviation of inter-segmental of COP trajectory movement as the black dot excursion: A) lateral variability as deviation into medial-lateral direction; B) Anterior/posterior variability as deviation into anterior or posterior direction

Statistical analysis

The normal distribution of the demographic data (e.g. age, weight, height, BMI), pain intensity, disability in low back pain, gait variables (e.g. gait variability, temporospatial gait, and COP variables) were tested by a Kolmogorov-Smirnov test. The independent t-test was used to compare the demographic data and clinical assessment between the CLBP and NLBP group.

Independent t-test was used to compare the difference of the COP variables, gait variability and temporospatial between groups. Paired t-test was used to ~~evaluate~~ analyze the COP variables, gait variability and temporospatial gait for within group (between speeds). The level of significance was set at 0.05.

CHAPTER 4 RESULTS

Demographic and clinical characteristics

The characteristics of participants were presented in the Table 5. Regarding to age, height, weight, body mass index and gender, the data distribution were not significantly different between CNSLBP and NLBP group. The levels of the numeric rating scale and self-reported disability of the person with CNSLBP were in moderate.

Table 5 The demographic characteristics (mean ± SD)

Variables	CNSLBP	NLBP	p-value
Gender (male/female)	6/14	6/14	-
Age (years)	42.10±11.61	40.75±10.76	0.71
Weight (kg)	68.38±13.56	61.48±11.74	0.15
Height (cm)	161.85±8.80	159.00±8.61	0.31
BMI (kg/m^2)	25.60±3.67	24.24±3.71	0.25
Pain duration (months)	10.33±6.88	-	-
Numeric Rating Score (0-10)	5.55±1.28	-	-
ODQ (0-100)	24.50±12.53	-	-
FABQ			
Physical (0-24)	19.75±7.77	-	-
Work (0-42)	24.45±14.36	-	

CNSLBP; Chronic non-specific low back pain, NLBP; non-low back pain, ODQ; Oswestry Low Back Pain Disability Questionnaire, FABQ; Fear Avoidance Beliefs Questionnaire

The person with a core stability weakness (grade 0) was greater in CNSLBP than those NLBP group. The proportion of positive Trendelenburg test on the left leg was greater trend in CNSLBP group than those in NLBP group. The percentages of the TFL

and iliopsoas tightness were shown slightly higher in CNSLBP group as compared to those NLBP group. The duration of FTSTS test was significantly greater in CNSLBP group than those in NLBP group ($p<0.001$). The clinical assessment in CNSLBP and NLBP group were shown in the Table 6.

Table 6 Clinical assessment in CNSLBP and NLBP group.

Clinical assessment	CNSLBP	NLBP	p-value
FTSTS (sec)*	10.28±3.90	6.71±1.27	<0.001
Core stability strength (number of persons)			
Grade 0	17	10	
Grade 1	2	5	
Grade 2	0	2	
Grade 3	1	2	
Grade 4	0	1	
Grade 5	0	0	
% Positive of Lt. Trendelenburg test	60	15	
% Positive of Rt. Trendelenburg test	35	20	
Lt. iliopsoas muscle tightness (%)	50	20	
Rt. iliopsoas muscle tightness (%)	50	25	
Lt. TFL muscle tightness (%)	50	20	
Rt. TFL muscle tightness (%)	55	40	

Lt.; left side, Rt.; right side, FTSTS; five time sit to stand test, TFL; tensor fascia latae. *; a significant at $p<0.05$.

Center of pressure (COP) excursion and deviation

The results found that there were significant differences in COP variables between CNSLBP and control group. The COP excursion in AP direction and COP deviation in ML direction revealed significantly higher in CNSLBP than NLBP group at both walking speed conditions ($p<0.05$). At PWS, the AP COP excursion and ML COP deviation during PWS and FWS were significantly difference between CNSLBP group and control group. No significantly difference in the ML COP excursion and AP COP deviation were shown between CNSLBP and NLBP group. Comparison of COP variables between CNSLBP and control group were presented in Figure10.

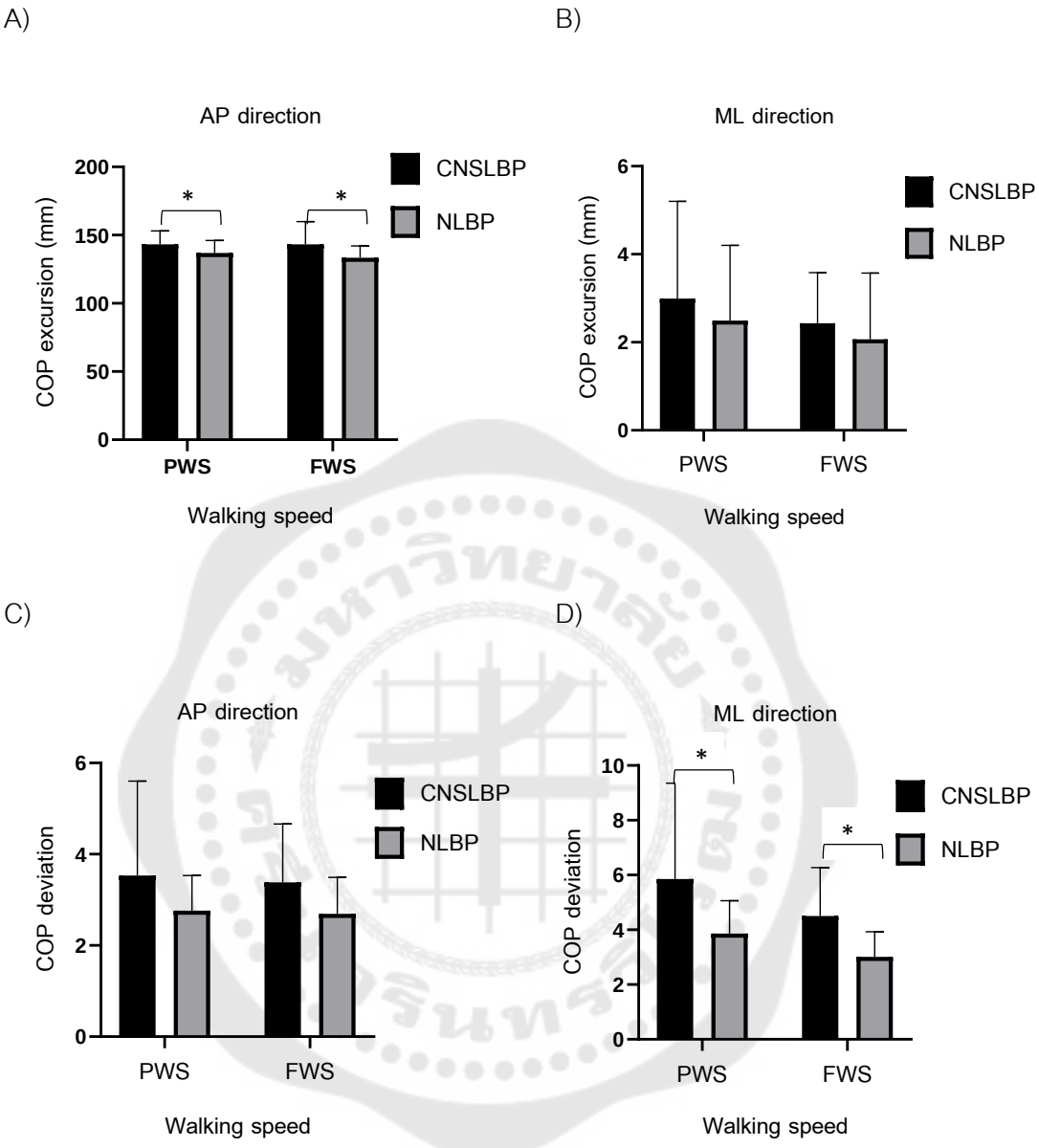

Figure 9 Comparison of COP variables during preferred walking speed (PWS) and fastest walking speed (FWS) between chronic non-specific low back pain (CNSLBP) and non-LBP (NLBP) group: A) COP excursion in anterior-posterior (AP) direction ; B) COP excursion in medial-lateral (ML) direction; C) COP deviation in AP direction; D) COP deviation in ML direction

As compared the COP variables between walking speeds in each group, only healthy control groups was found that the AP COP excursion and ML COP deviation significantly decreased during FWS than PWS. The AP COP excursion were 133.40±8.62 mm in FWS and 136.95±9.07 mm in PWS, $p<0.01$. The ML COP deviation were 3.01±0.92 in FWS and 3.86±1.20 mm in PWS, $p=0.04$. In CNSLBP, there were no significant differences in all COP variables between walking speed conditions. The COP variables were presented in the Figure 11

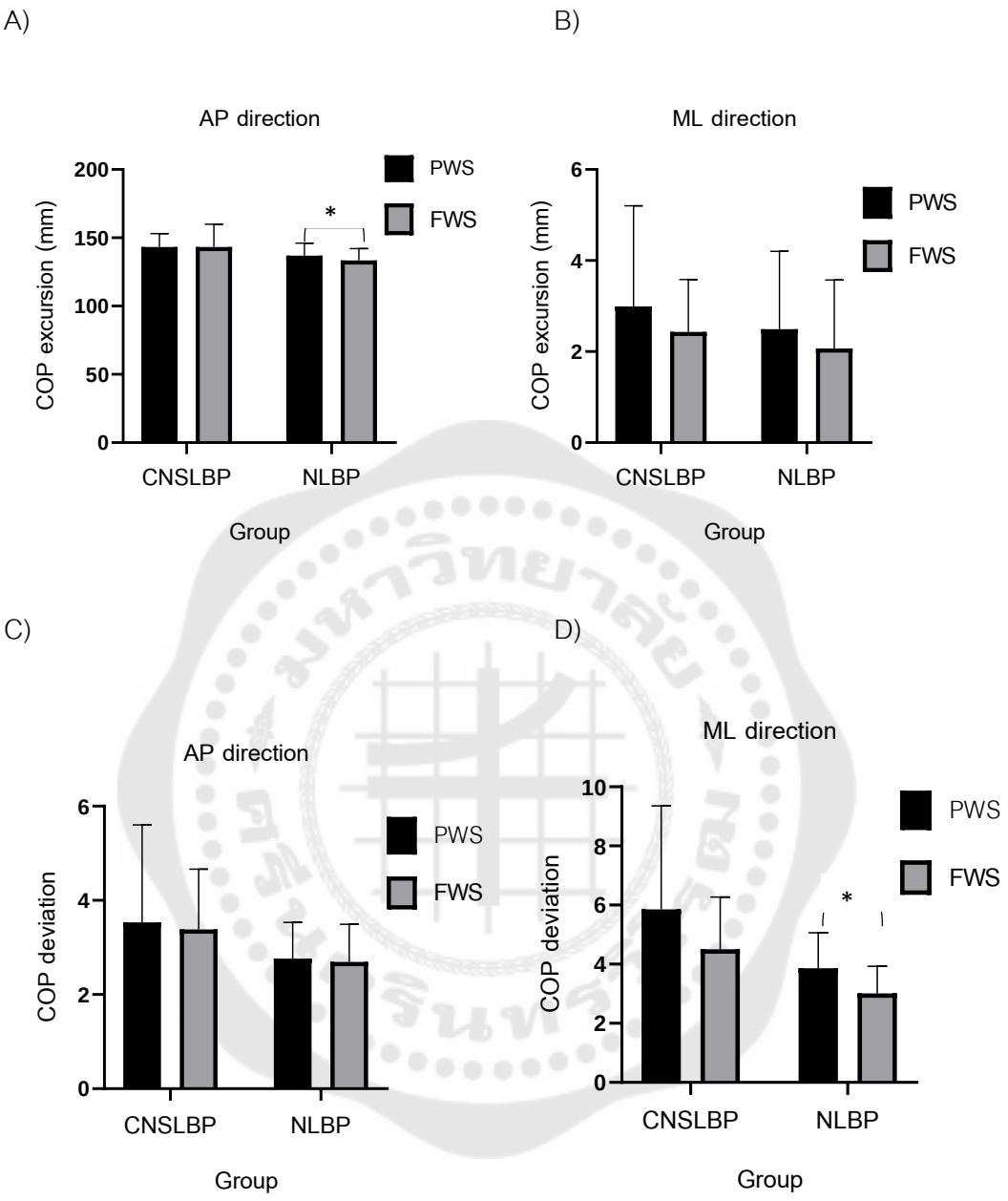

Figure 10 Comparison of COP variables between preferred walking speed (PWS) and fastest walking speed (FWS) in chronic non-specific low back pain (CNSLBP) and non-LBP (NLBP) group: A) COP excursion in anterior-posterior (AP) direction ; B) COP excursion in medial-lateral (ML) direction; C) COP deviation in AP direction; D) COP deviation in ML direction

Gait variability

Gait variability was calculated from the efficiency of variance of temporospatial gait parameters (step length, stride length, step width, stride time, and percentage of single support time) during 3 minutes at each walking speed condition. During preferred walking speed, a variability of step length, stride length, stride time, and single support time significantly increased in CNSLBP groups as compared to those in control group, except the step width variability was found no significant difference between groups. However, at fastest walking speed, all variables of gait variability were no significantly differences between groups as shown in the Table 7.

Gait variability was compared between preferred and fastest walking speed in each group. The results were shown that the variability of step length, stride length, stride time were significantly lower during fastest walking speed than preferred walking speed in both groups as shown in the Table 8.

Table 7 Comparison of gait variability (mean ± SD) between the CNSLBP and NLBP group during preferred and fastest walking speed conditions.

Walking speed	Gait parameter	Gait variability (%)		p-value
		CNSLBP	NLBP	
Preferred speed	Step length	3.58±1.02	2.96±0.64	0.03*
	Stride length	2.51±0.73	2.10±0.47	0.04*
	Stride time	2.24±0.60	1.78±0.44	0.008*
	Step width	28.09±20.71	21.40±9.43	0.20
	Single support time	3.46±1.05	2.79±0.72	0.02*
Fastest speed	Step length	2.81±1.05	2.39±0.57	0.12
	Stride length	2.09±0.91	1.70±0.53	0.11
	Stride time	1.83±0.69	1.49±0.51	0.09
	Step width	26.13±12.92	22.20±7.83	0.25
	Single support time	2.63±0.60	2.30±0.44	0.05

CNSLBP; Chronic non-specific low back pain, NLBP; non-low back pain; *; a significant at $p<0.05$.

Table 8 Comparison of gait variability (mean ± SD) between the CNSLBP and NLBP group during preferred and fastest walking speed conditions.

Group	Gait parameter	Gait variability (%)		p-value
		Preferred speed	Fastest speed	
CNSLBP	Lt. step length	3.58±1.02	2.81±1.05	0.001*
	Stride length	2.51±0.73	2.09±0.91	0.03*
	Stride time	2.24±0.60	1.83±0.69	0.02*
	Step width	28.09±20.71	26.13±12.92	0.50
	Single support time	3.46±1.05	2.63±0.60	0.0001*
NLBP	Lt. step length	2.96±0.64	2.39±0.57	0.0001*
	Stride length	2.10±0.47	1.70±0.53	0.001*
	Stride time	1.78±0.44	1.49±0.51	0.01*
	Step width	28.09±20.71	26.13±12.92	0.39
	Single support time	2.79±0.72	2.30±0.44	0.001*

CNSLBP; Chronic non-specific low back pain, NLBP; non-low back pain; *; a significant at $p<0.05$.

The temporospatial gait parameter

The gait velocity at preferred walking speed was significantly decreased in person with CNSLBP when compared to those NLBP group. However, the gait velocity at fastest walking speed was no significant difference between groups. The stride time and percentage of double support time were significantly increased in person with CNSLBP as compared to those NLBP group at both walking speeds. The cadence was significantly decreased in person with CNSLBP ($p<0.05$) at both walking speed conditions. Step time at preferred speed was significant higher in CNSLBP group than those in NLBP group. Only step width that there was significantly no difference between groups at both walking speeds. These results are presented in Table 9.

Table 9 Comparison of temporospatial gait (mean ± SD) between groups at both speed.

Walking speed	Gait parameter	CNSLBP	NLBP	p-value
Preferred speed	Gait velocity (km/h)	2.95±0.39	3.33±0.48	0.009*
	Step length (cm)	50.34±5.53	51.42±5.72	0.55
	Stride length (cm)	100.02±11.29	103.33±11.47	0.36
	Step width (cm)	9.31±4.25	9.14±3.12	0.88
	Step time (sec)	0.62±0.07	0.57±0.05	0.009*
	Stride time (sec)	1.23±0.14	1.13±0.09	0.008*
	Single support (%)	34.57±1.85	35.47±1.97	0.14
	Double support (%)	30.65±3.17	28.51±3.17	0.04*
	Cadence (steps/min)	98.64±11.40	107.21±8.57	0.01*
Fastest speed	Gait velocity (km/h)	4.07±0.59	4.30±0.60	0.22
	Step length (cm)	61.10±6.61	60.40±5.89	0.73
	Stride length (cm)	122.08±13.56	121.63±11.54	0.91
	Step width (cm)	9.66±3.43	8.65±2.54	0.30
	Step time (sec)	0.55±0.05	0.53±0.10	0.49
	Stride time (sec)	1.09±0.10	1.00±0.07	0.002*
	Single support (%)	36.66±1.36	37.75±1.18	0.05
	Double support (%)	26.94±2.73	24.81±2.74	0.008*
	Cadence (steps/min)	111.59±8.73	120.21±7.89	0.002*

CNSLBP; Chronic non-specific low back pain, NLBP; non-low back pain; *; a significant at $p<0.05$.

A comparison of the temporospatial gait parameter was demonstrated between a walking speed conditions in each group as summarized in Table 10. Gait speed, step length, stride length, single support time, and cadence were significant lower at preferred walking speed than fastest walking speed in both CNSLBP and NLBP group. The step time, stride time, and double support time were significantly decreased during fastest walking speed. No significant difference between walking speed conditions were found in step width.

Table 10 Comparison of temporospatial gait (mean ± SD) between speeds.

Walking speed	Gait parameter	Preferred speed	Fastest speed	p-value
CNSLBP	Gait velocity (km/h)	3.33±0.48	4.30±0.60	0.0001*
	Step length (cm)	51.42±5.72	60.40±5.89	0.0001*
	Stride length (mm)	103.33±11.47	121.63±11.54	0.0001*
	Step width (mm)	9.14±3.12	8.65±2.54	0.08
	Step time (s)	0.57±0.05	0.53±0.10	0.002*
	Stride time (s)	1.13±0.09	1.00±0.07	0.0001*
	Single support (%)	35.47±1.97	37.75±1.18	0.0001*
	Double support (%)	28.51±3.17	24.81±2.74	0.0001*
	Cadence (step/min)	107.21±8.57	120.21±7.89	0.0001*
NLBP	Gait velocity (km/h)	3.33±0.48	4.30±0.60	0.0001*
	Step length (cm)	51.42±5.72	60.40±5.89	0.0001*
	Stride length (mm)	103.33±11.47	121.63±11.54	0.0001*
	Step width (mm)	9.14±3.12	8.65±2.54	0.08
	Step time (s)	0.57±0.05	0.53±0.10	0.002*
	Stride time (s)	1.13±0.09	1.00±0.07	0.0001*
	Single support (%)	35.47±1.97	37.75±1.18	0.0001*
	Double support (%)	28.51±3.17	24.81±2.74	0.0001*
	Cadence (step/min)	107.21±8.57	120.21±7.89	0.0001*

CNSLBP; Chronic non-specific low back pain, NLBP; non-low back pain; *; a significant at $p<0.05$.

CHAPTER 5 DISCUSSION

The objective of this study aimed to investigate the effect of chronic low back pain and gait speed on postural sway, gait variability and temporospatial gait. The data were analyzed from the prolonged walking of steady state over three minutes at preferred and fastest speed. The postural sway was represented by the COP, which was derived from the butterfly diagram during walking. The current study found that the chronic low back pain symptom associated the impairment of postural control during walking. The gait speed indicated abnormal adaptive mechanism of postural control in CNSLBP group.

We hypothesized that there was difference in COP variables during PWS and FWS between person with CNLBP and NLBP. Our results related to the hypothesis that the AP COP excursion in CNSLBP group was greater than the NLBP group at preferred and fastest walking conditions. This result explained that person with CNSLBP increased postural sway as a shifting into the forward movement in both walking conditions which represented an insufficiency of postural control in person with CNSLBP.

The postural control is performed by three sensory systems (e.g. a somatosensory, visual, and vestibular system) which the somatosensory system mainly produce a good posture.[9] The proprioceptive sensation is a part of the somatosensory system that the proprioceptive sensation is a primary sensory input for balance control as well as a sense of position and movement.[17, 53, 54] The proprioceptive sensation

consists of a Golgi tendon and muscle spindle on the tendon, ligament, and skeletal muscle fibers. Injury on low back may disrupt the proprioceptive feedback as well as feed-forward on low back structure. This alteration contributed to inaccurate interpretation of higher center which lead to a disruption of balance control strategies and trunk-pelvic instability.[13, 49, 60, 134]

The participants in current study were excluded if they presented any problems of visual or vestibular system. Therefore, the difference of postural control between CNSLBP and NLBP group was possibly affected by the impairment of proprioceptive sensory on lumbar spinal muscles or ligament. However, the current study did not directly measure a proprioceptive sensory. Therefore, the effect of proprioceptive sensory impairment on postural control during walking should be clarified in person with CNSLBP.

The previous study reported that an alteration of proprioceptive sensory and spinal instability might contribute to the increasing of superficial trunk muscle activity. These results associated less variables of trunk-pelvic coordination in sagittal plane during walking in persons with low back pain.[5, 60] However, the maintained trunk-pelvic stability was the important for controlling the center of mass and the virtual balance. The efficiency of spinal stability and inter-segmental movement was performed by the core stability muscles.[13, 49] These muscles would contract for an optimal spinal inter-segmental movement before limbs movement lead to a trunk-pelvic stability during leg

movement.[19, 20, 66] The regular core muscle activation might induce the gait stability.[19, 20, 49, 66]

The current study also measured the clinical assessment at baseline which consisted of the performance of core muscles. Our results found that mostly CNSLBP group presented greater the core muscles grade 0 to 1 than non-low back pain group. Less core stability muscle performances in persons with CNSLBP may induce the insufficiency of lumbo-pelvic control during walking. The previous study reported that the persons with low back pain presented the delay of transversus abdominis muscle activity prior to limb movement.[13, 20] Decreasing the duration of deep fiber multifidus muscle activity was shown during fast walking speed.[19, 20, 135] Thus, the core muscle dysfunction in these CNSLBP may affect the postural control during preferred and fastest walking.

From literature reviews, in the challenging situation as the fastest walking speed was a continuous quickly COP shifting and a center of mass move ahead a base of support which demanded a high motor control and more regular motor output for producing of muscular co-contraction and to generate an optimal trunk and pelvic stability during limb movement.[86, 136] Consequently, an adaptive mechanism would be generated for the regular coordination of intra-limb movement (e.g. pelvis–thigh and thigh–shank) and effort to restrict a degrees of freedom of lower limb during increased speed.[88] The person with low back pain exhibited a co-contraction around the trunk

and ankle joint which was performed by the stiffness strategy during fast speed. [134] Increasing walking speed induced the rigidity of trunk-pelvic rotation,[29] that may induce the higher sway in AP direction to maintain the gait stability in persons with low back pain.

The current study was the first study that compared the COP variables between preferred and fastest speed in each CNSLBP and control group. Generally, an adaptive mechanism of postural control was performed by reducing of postural sway for gait stability improvement during fast speed. The current study found that the COP excursion in non-low back pain group was decreased in FWS compared to those in PWS. While the COP excursion was no difference between PWS and FWS in CNSLBP. These results could explain that CNSLBP exhibited no adaptive postural control during fastest walking speed.

Moreover, our study found no significant difference of the COP excursion in ML direction between CNSLBP group and control group during both walking conditions. Interestingly, only the COP deviation in ML direction was greater in CNSLBP than control group at both walking conditions, which COP deviation represented the variability of center of pressure trajectory in person with CNSLBP.[106] These results could explain that persons with CNSLBP were less prolong persistence or inconsistency of gait control while only non-low back pain group showed the ML COP deviation during FWS lower than those during PWS.

A higher of ML COP deviation during FWS in CNSLBP group represented a less of rhythm, and smoothness postural control that may associate with reducing of hip abductor performance during mid-stance phase. The current study found that the percentage of persons with positive Trendelenburg test in CNSLBP was higher than these in control group. This result represented an impairment of hip muscle performance in CNSLBP group which resulted in the poor hip-pelvic control and led to the contralateral pelvic drop during standing on one leg.[128]

For the secondary outcome, we hypothesized that there was difference in the temporospatial gait between persons with CNLBP and NLBP during PWS and FWS. The current study found significantly the differences in gait velocity between CNSLBP and control group during PWS but did not show the differences in gait velocity during FWS. Agree with the previous studies.[8, 23, 31, 82] PWS in the persons with CNSLBP was slower than PWS in NLBP. Consequently, persons with CNSLBP need to be more precise in the gait control. Their comfortable walking speed was adapted to a slower walking due to a pain symptom, avoidance of pain, and deficiency of their movement control.[8, 137] Reducing of preferred walking speed in persons with chronic low back pain may be used to deal with the postural instability and to prevent a risk of recurrent injury on low back and falling.[8]

On the contrary, our study showed that the gait velocity at FWS was not significant difference between CNSLBP and NLBP group which the persons with

CNSLBP did not apparently exacerbate the pain symptom during FWS. The current study found fear-avoidance belief about physical activity was higher in CNSLBP group that may restrict to gait velocity during PWS. A score of fear avoidance belief about physical activity was moderate to high that may activate to reduce a range and velocity of spinal movement as lack of spinal flexibility. [12, 13, 57] However, the fear avoidance pain may not affect on the gait velocity during FWS. Due to during FWS, the participants with CNSLBP may only focus walking as fast as their ability and possibly distract from a fear of avoidance pain. Thus, an automatic maladaptive mechanism of muscular control may be generated excessively to increase trunk muscle activity which resulted in the stability of trunk-pelvic prior to leg movement.[31]

Our result contrasted with Hick et al 2017, they reported a decreasing of gait velocity and increasing of step width during fastest walking speed in older chronic low back pain. Their participants were the elderly population who may have the degeneration of neural system led to the disturbance of the walking by slow walking with wide step width[82] Whereas the current study found that the gait velocity and step width were not significant difference between CNSLBP and those NLBP group. However, the participants in this study were younger than the participants in previous study (i.e., aged less than 60 years old). The neural degeneration may not affect on our participants.

Our study found that the stride time and double support time increased in persons with CNSLBP group at both walking speed conditions. The persons with

CNSLBP may require more timing to generate the trunk and leg muscle activity because of the musculoskeletal disorder and severity of pain symptom. Increasing of step or stride period may contribute to an optimal leg movement and improvement of gait ability. Moreover, increasing of the double support time in CNSLBP participants may be their attempt to stay longer on both legs for increasing gait stability.

For the third outcome, we hypothesized that there were differences in gait variability during PWS and FWS between persons with CNLBP and NLBP. The current study found the differences in gait variability only PWS condition. Walking in slower speed disturbed a muscular control of gait.[138] Persons with CNSLBP increased the variability of stride time, and single support time. Increasing of stride time variability represented the inconsistency of gait timing mechanism and the pattern generator of gait.[72, 139] Moreover, the increasing of gait variability was indicated the poor motor control.[72, 140] The proprioceptive sensory impairment in persons with CNSLBP may generate improperly the signal input and output for supraspinal control, which may result in the poor control of trunk muscle activity and trunk-pelvic movement coordination.[29, 31] The alteration of trunk-pelvic movement influenced on the lower limb movement coordination which may effect on the variability of stride time. In addition, the poor hip muscle and lower limb performances in CNSLBP may disturb the period of single support phase in each gait cycle due to the inconsistency of time spent in each stride which may effect on the variability of stride time and single support time.

The current study found that increasing of step length variability and stride length variability during PWS in person with CNSLBP. This changing may associate with hip and leg muscle length. From our study, the clinical assessment at baseline showed that the number of persons with hip flexor tightness and TFL tightness were higher in CNSLBP than those in control group. This hip flexor tightness in CNSLBP may disturb the hip extension in the terminal stance phase of gait cycle which may increase the step length and stride length variability. Possibly, walking with slow velocity needed to have the higher muscle control performance due to long period during weight bearing on one leg. Thus, persons with CNSLBP walked at PWS slower than control group, which may contribute to increasing the gait variability.

Walking speed had an effect on the gait variability in both groups. Variability of step length, stride length, and stride time was decreased while gait speed was increased. Increasing walking speed is the disturbance of cognitive function which seem an attention to demand task so the gait adaptation need to have an accuracy of motor performance. Thus the stride-to-stride fluctuation would be the regulation of motor control lead to reducing of trunk movement and less variability of stride time.[28, 72, 78] The fastest walking speed aggravated increasing in the muscle activities of the lumbar erector spinae, biceps femoris, and medial gastrocnemius as well as changing of lumbar motion.[141] Consequently, the compensation mechanism may activate a

consistency of lower limbs movement lead to diminished gait variability at fastest speed in both groups.

However, our results found that the chronic low back pain and walking speed had no effect on step width variability. There is the consistency distance left and right foot weight bearing. Interestingly, chronic low back pain impacted on the ML COP deviation during both walking speed conditions, which these results represented to increase an inconsistency in term of weight shifting between legs in frontal plane.

The current study found that slow walking velocity during PWS in persons with CNSLBP may be aggravated from the fear avoidance pain. Increasing of a variability of step length and stride length during PWS in CNSLBP group may result from hip flexor muscle tightness and reducing of hip muscle and lower limb muscle performance.

We found a postural sway in persons with CNSLBP during PWS and FWS. Generally, there was the adaptation of neuromuscular control to reduce postural sway during fast speed. However, persons with CNSLBP did not present a postural adaptive mechanism during fastest speed that indicated the impairment of adaptive mechanism for posture control strategies in CNSLBP. Thus, the application of the fast walking exercise in persons with CNSLBP should be concerned due to CNSLBP exhibited in the poor postural control. Consequently, CNSLBP may increase an activity of lumbar erector spinae and a spinal stiffness for controlling posture that may lead to more compression

or tension on spine which may cause the recurrent pain or injury on low back structure and increase risk of falling while unexpected perturbation.[8, 31, 47]

There were several limitations in the current study. The first limitation was increased postural sway during fastest walking speed could not be generalized in CNSLBP with mild pain intensity. The second limitation was walking on treadmill situation which may be different from walking on treadmill. In addition, this study did not measure a kinematic of trunk-pelvic movement which may associate with a whole balance control. Further studies should evaluate the effect of walking over ground at PWS and FWS on the postural control and gait variability in persons with CNSLBP. Moreover, the relationship between trunk-pelvic, hip muscle performance and postural control during fastest walking speed should be clarified.

Conclusion

Person with CNSLBP exhibited postural sway in anterior direction during PWS and FWS due to poor postural control. The COP excursion and deviation were not difference between PWS and FWS that indicated no postural control adaptation during FWS in CNSLBP group. For gait variability, the variability of stride time, step time, step length, and single support time increased in CNSLBP compared to those control due to gait instability in slower walking speed. Slow walking velocity at preferred speed in person with CNSLBP may associate the fear avoidance belief pain. The temporospatial (stride time and double support time) at both PWS and FWS were greater in person with CNSLBP than those control group. Thus, the application of fastest walking speed in persons with CNSLBP should be aware in a poor postural control.

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APPENDICES

เลขที่.....

APPENDIX A: **แบบสอบถามคัดกรองข้อมูลทั่วไป**
คณะกายภาพบำบัด มหาวิทยาลัยศรีนครินทรวิโรฒ

เรื่อง การเปรียบเทียบการแกว่งของร่างกายในขณะเดินหว่างผู้ที่มีอาการปวดหลังเรื้อรังกับผู้ที่ไม่มีอาการปวดหลัง

วัตถุประสงค์ 1.เพื่อเปรียบเทียบความสามารถในการควบคุมการทรงตัว ความแปรปรวนของการเดินและ temporospatial ระหว่างผู้ที่มีอาการปวดหลังเรื้อรังและผู้ที่ไม่มีอาการปวดหลังขณะเดินด้วยความเร็วปกติ

2.เพื่อเปรียบเทียบความสามารถในการควบคุมการทรงตัว ความแปรปรวนของการเดินและ temporospatial ระหว่างผู้ที่มีอาการปวดหลังเรื้อรังและผู้ที่ไม่มีอาการปวดหลังขณะเดินด้วยความเร็วสูงสุด ข้อมูลจะนำมาใช้ในการคัดกรองอาสาสมัครเข้าร่วมโครงการวิจัยและนำมาวิเคราะห์เพื่อใช้เป็นแนวทางในการให้การรักษาทางกายภาพบำบัดในผู้ที่มีอาการปวดหลังส่วนล่าง ผู้วิจัยจึงใคร่ขอความร่วมมือจากท่านในเสียสละเวลาเพื่อตอบแบบสอบถามตามความเป็นจริงและขอรับรองว่าข้อมูลทั้งหมดจะถูกเก็บไว้เป็นความลับ

คำอธิบาย : โปรดทำเครื่องหมาย √ ในช่อง □ ที่ตรงกับข้อมูลของคุณมากที่สุดและกรณีที่เป็นคำถามเปิด กรุณากรอกข้อมูลตามจริงในช่องว่าง.....ที่กำหนดให้

1. ข้อมูลส่วนตัว

ชื่อ.....นามสกุล.....

อายุ.....ปี

เพศ

□ ชาย □ หญิง

การศึกษาสูงสุด

□ ไม่ได้ศึกษา □ เทียบเท่าประถมศึกษา

□ เทียบเท่ามัธยมศึกษา □เทียบเท่าอนุปริญ

□ เทียบเท่าปริญญาตรี □ เทียบเท่าปริญญาโทหรือสูงกว่า

อาชีพ

□ ไม่ได้ประกอบอาชีพ □ ข้าราชการ/รัฐวิสาหกิจ

□ รับจ้าง/ลูกจ้าง □ ทำสวน/ทำไร่

□ แม่บ้าน □ ค้าขาย

□ นักศึกษา □ อื่นๆ โปรดระบุ.....

ส่วนสูง .....เซนติเมตร, น้ำหนัก.....กิโลกรัม

ที่อยู่ที่ติดต่อได้.....

.....

เบอร์โทรศัพท์ที่ติดต่อได้.....

2. ข้อมูลสุขภาพ

2.1 ขณะนี้คุณมีอาการปวดบริเวณหลังส่วนล่างหรือเชิงกราน ใช่หรือไม่ (ถ้าตอบว่า “ไม่ใช่” ไม่ต้องตอบข้อ 2.1-2.5)

☐ ไม่ใช่ ☐ใช่

2.2 ท่านมีอาการปวดหลังส่วนล่างในช่วงเวลานานกว่า 12 สัปดาห์ ใช่หรือไม่

☐ ไม่ใช่ ☐ใช่โปรดระบุระยะเวลาการปวด.....สัปดาห์

2.3 ความถี่ของอาการปวดหลังส่วนล่างมีลักษณะเป็นอย่างไร

☐ ปวดทุกวัน ☐ มากกว่า 3 วันต่อสัปดาห์

☐ น้อยกว่า 3 วันต่อสัปดาห์

2.4 วิธีการใดที่คุณมักจะใช้อยู่เป็นประจำเพื่อลดอาการปวดหลัง

☐ พักหรือหลีกเลี่ยงท่าทางที่ทำให้ปวด

☐ รับประทานยาลดปวดหรือลดอักเสบกล้ามเนื้อ หรือทายาบริเวณที่ปวด

☐ อื่นๆ โปรดระบุ.....

2.5 กรุณาระบุระดับความรุนแรงของอาการปวดหลังส่วนล่างแบ่งระดับความปวดตั้งแต่ 0-10 โดย 0 หมายถึง ไม่มีอาการปวดเลยและ 10 หมายถึง ปวดรุนแรงที่สุด (กรุณา◯ ตัวเลขที่เป็นคำตอบ)

0 1 2 3 4 5 6 7 8 9 10

ไม่ปวดเลย ปวดปานกลาง ปวดรุนแรงที่สุด

2.6 ขณะนี้คุณกำลังอยู่ในช่วงตั้งครรภ์ (เฉพาะเพศหญิง)

☐ ไม่ใช่ ☐ใช่

2.7 คุณมีโรคประจำตัว หรือความผิดปกติของร่างกายมาแต่กำเนิด ที่ได้รับการวินิจฉัยจากแพทย์หรือไม่

☐ ไม่มี

☐ มีโรคเกี่ยวกับระบบทางเดินหายใจ เช่น หอบหืด

☐ มีโรคเกี่ยวกับระบบทางหัวใจและหลอดเลือดเช่น เส้นเลือดหัวใจตีบ กล้ามเนื้อหัวใจตาย หลอดเลือดในช่องท้องโป่งพอง

☐ มีโรคเกี่ยวกับระบบประสาท เช่น มีอาการชา แขนขาอ่อนแรงหรือกล้ามเนื้อฝ่อลีบ

☐ กระดูกพรุน หรือเก๊าท์

☐ มีโรคเกี่ยวกับภูมิคุ้มกันเช่น โรครูมาตอยด์ โรคเอสแอลอี

☐ มีโรคเบาหวานเรื้อรัง

☐ มีความผิดปกติของร่างกายมาแต่กำเนิด

☐ อื่นๆ โปรดระบุ……

2.8 คุณมีประวัติเกี่ยวกับโรคมะเร็ง หรือเนื้องอก หรือไม่

☐ ไม่มี ☐ มี โปรดระบุ เดือน...../ปี.....

2.9 ในช่วง 1 เดือนที่ผ่านมา คุณน้ำหนักมีการลดลงอย่างผิดปกติหรือไม่

☐ ไม่มี ☐ มี

2.10 คุณมีอาการเวียนศีรษะคล้ายบ้านหมุนอยู่อยู่เป็นประจำ หรือไม่

☐ ไม่มี ☐ มี

2.11 คุณมียาที่รับประทาน อยู่เป็นประจำ หรือไม่

☐ ไม่มี ☐ มี โปรดระบุ.....

2.12 ปัจจุบันคุณดื่มเครื่องแอลกอฮอล์ หรือไม่

☐ ไม่ดื่ม ☐ ดื่มทุกวัน

☐ ดื่มเป็นบางวัน โปรดระบุ…วัน/สัปดาห์

2.13 คุณเคยมีกระดูกสันหลังหรือกระดูกขาหัก หรือไม่

☐ ไม่มี ☐ มี

2.14 คุณเคยผ่าตัดที่กระดูกสันหลังหรือขา หรือไม่

☐ ไม่มี ☐ มี

2.15 ในช่วง 2 สัปดาห์ที่ผ่านมาคุณมีอาการเจ็บบริเวณข้อเข่า หรือข้อเท้าหรือไม่

☐ ไม่มี ☐ มี

<u>3. ข้อมูลเกี่ยวกับกิจกรรมที่ทำเป็นประจำ</u>

3.1 ในแต่ละวันท่านมักจะอยู่ในท่าทางใดมากที่สุด?

☐ยืน ☐เดิน

☐นั่ง ☐นอน ☐อื่นๆ โปรดระบุ……..

3.2 ท่านมักจะมีอาการปวดหลังเป็นประจำเมื่ออยู่ท่าทางใด?

☐ยืน ☐เดิน

☐นั่ง ☐นอน ☐อื่นๆ โปรดระบุ.....

3.3 ท่านมักจะต้องยกของหนักเป็นประจำในแต่ละวัน หรือไม่

☐ไม่ใช่ ☐ใช่

3.4 ในแต่ละวันท่านมักจะต้องทำงานในท่าทางที่มีการก้มหรือแอ่นหลังบ่อยๆ หรือไม่

☐ไม่ใช่ ☐ใช่

3.5 ท่านมักจะต้องอยู่ในท่าใดท่าหนึ่งเป็นระยะเวลานานเกินกว่า 1 ชั่วโมง หรือไม่

☐ไม่ใช่ ☐ใช่

3.6 ท่านเล่นกีฬาหรือออกกำลังกาย หรือไม่?

☐ไม่เล่น ☐เล่น

<u>ถ้าเล่น</u>

- กีฬาหรือการออกกำลังกายที่ท่านเล่นบ่อยที่สุด คือ.....
- เวลาในการเล่นละครั้งประมาณ.....
- ท่านเล่นกี่ครั้งต่อสัปดาห์.....

3.7 ท่านเคยออกกำลังกายกล้ามเนื้อหลังหรือกล้ามเนื้อท้อง หรือไม่

☐ไม่เคย ☐เคย

<u>ถ้าเคย</u>

ท่านออกกำลังกายดังกล่าวรวมประมาณสัปดาห์ละกี่ครั้ง.....ครั้ง

ในช่วง 5 สัปดาห์ที่ผ่านมาท่านออกกำลังกายดังกล่าว หรือไม่

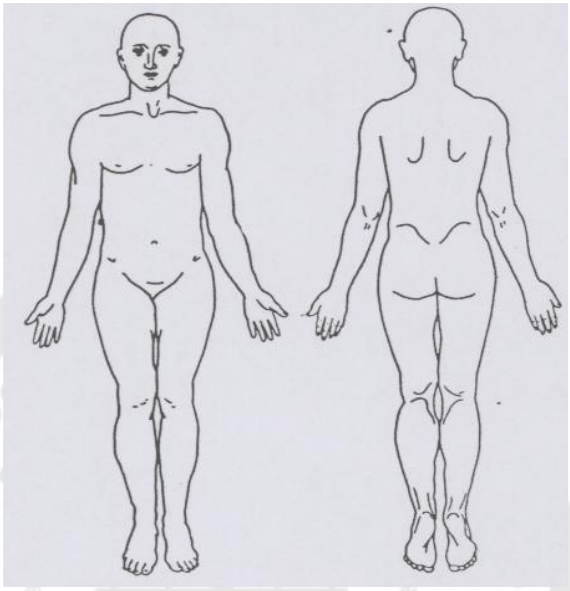
☐ไม่ใช่ ☐ใช่

APPENDIX B: **แบบบันทึกการตรวจร่างกายเพื่อคัดกรองอาสาสมัคร**

1. ชื่อ-สกุล…….…… อายุ…… เพศ……

น้ำหนัก…….. กิโลกรัม ส่วนสูง……เซนติเมตร BMI……kg/m^2

2. บริเวณที่มีอาการปวด (ด้านที่ปวด Lt / middle / Rt.)



3. Pain intensity……..

4. Thai ODQ……..

5. FABQ (physical/ work)……

6. ตารางการตรวจประเมิน

การตรวจประเมิน	ผลการตรวจประเมิน	
	Positive	Negative
1. ความแตกต่างของความยาวขาทั้ง 2 ข้าง (>1cm.)		
2. ข้อเข่าผิดรูป		
3. การจำกัดการเคลื่อนไหวของข้อเท้า ข้อเข่า ช่วง inner-range ในแนว sagittal plane		
6. Structural scoliosis/ hyperkyphosis		
7. Radicular pain/refer pain		
8.การกดทับเส้นประสาทแสดงอาการ 2 จาก 3อย่างคือ weakness/reflex changes/sensation loss โดยสัมพันธ์กับเส้นประสาทที่ทำการประเมิน		

7. แบบประเมินเพื่อคัดกรองอาการปวดหลังแบบ specific low back pain

ข้อบ่งชี้ (Red flag)	ลักษณะที่พบ	(√, ×)
1. การบาดเจ็บ	มีประวัติการบาดเจ็บจากอุบัติเหตุการใช้ยานพาหนะ, การตกจากที่สูง หรือยกของหนัก	
2. อายุ	อายุ ≥ 50 ปี	
3. เกี่ยวกับโรคมะเร็ง	มีประวัติโรคหรือมีอาการป่วยเป็นโรคมะเร็งในปัจจุบัน	
4. มีไข้ หนาวสั่น หรือเหงื่อออกตอนกลางคืน	มีไข้สูงกว่า 38° C, รู้สึกหนาวเย็น, ตื่นในเวลากลางคืน และมีเหงื่อออกมากผิดปกติ, อุณภูมิร่างกายเปลียนแปลงในเวลากลางคืน	
5. น้ำหนักลด	น้ำหนักลดมากกว่า 4.5 กก. ภายในเวลา 3 เดือน โดยไม่ทราบสาเหตุ และไม่สัมพันธ์กับการเปลี่ยแปลงกิจกรรมหรือการควบคุมอาหาร	
6. การรบกวนเส้นประสาท	มีอาการชาหรือปวดร้าวไปบริเวณขา เท้า ฝีเย็บ หรือรอบทวาหนัก,	

ข้อบ่งชี้ (Red flag)	ลักษณะที่พบ	(√, ×)
	มีอาการชา ปวดร้าวไปบริเวณขาหรือเท้าในขณะไอ จาม, กล้ามเนื้อขาอ่อนแรงหรือมีการฝ่อลีบ	
7. การวินิจฉัยจากแพทย์	หมอนรองกระดูกทับเส้นประสาท, กระดูกสันหลังแตกและเคลื่อนทับเส้นประสาท, โรคโพรงระดูกสันหลังตีบแคบ, โรคข้อสันหลังอักเสบและยึดติด	
8. ประวัติการติดเชื้อ	ที่ผ่านมาไม่นานมีประวัติการติดเชื้อแบคทีเรีย เช่นการติดเชื้อในทางเดินปัสสาวะ	
9. การได้รับสารกดภูมิ	ได้รับสารกดภูมิจากการปลูกถ่ายอวัยวะ, การใช้สเตียรอยด์นานๆ	
10. เกี่ยวกับอาการปวด	อาการปวดไม่ลดลงเมื่อหยุดพักหรือปรับเปลี่ยนท่าทาง, อาการปวดทำให้ตื่นช่วงกลางคืน, อาการปวดไม่สัมพันธ์กับ ท่าทางการเคลื่อนไหว	
11. กระเพาะปัสสาวะ ทำงานผิดปกติ	ปัสสาวะลำบากหรือมีปัสสาวะค้างในกระเพาะปัสสาวะบ่อย, กลั้นปัสสาวะไม่ได้, ปัสสาวะมีเลือดปน	

ผลการตรวจร่างกาย: □ ผ่าน □ ไม่ผ่าน

APPENDIX C: Modified Oswestry Disability Index questionnaire (Thai version)

แบบประเมินผลกระทบของอาการปวดหลังที่มีต่อการใช้ชีวิตประจำวัน

คำชี้แจง แบบสอบถามนี้จัดทำเพื่อให้ผู้รักษาของท่านเข้าใจผลกระทบของอาการปวดหลังของท่านที่มีต่อชีวิตประจำวัน กรุณาตอบคำถามทุกข้อโดยการขีด □ ในช่อง □ หน้าข้อความเพียงข้อเดียวที่จะบอกสภาพของคุณในวันนี้ได้ดีที่สุด

1. ระดับความเจ็บปวด

□ สามารถทนปวดได้โดยไม่ต้องใช้ยาแก้ปวด

□ มีอาการปวดมากแต่จัดการได้โดยไม่ต้องใช้ยาแก้ปวด

□ ยาแก้ปวดทำให้หายปวดโดยสิ้นเชิง

□ ยาแก้ปวดทำให้หายปวดได้ในระดับปานกลาง

□ ยาแก้ปวดทำให้หายปวดได้เล็กน้อย

□ ยาแก้ปวดไม่มีผลต่ออาการปวด

2. การดูแลตัวเอง (อาทิเช่น การทำความสะอาด, การแต่งตัว)

□ ดูแลตัวเองได้ตามปกติโดยไม่ทำให้อาการปวดเพิ่มขึ้น

□ ดูแลตัวเองได้ตามปกติ แต่มันทำให้อาการปวดเพิ่มขึ้น

□ ปฏิบัติได้ช้าๆ โดยมีอาการปวด และต้องระมัดระวัง

□ ต้องการความช่วยเหลือ แต่ก็สามารถจัดการธุระส่วนตัวส่วนใหญ่ได้

□ ต้องการความช่วยเหลือทุกวัน สำหรับธุระส่วนตัวเกือบทุกเรื่อง

□ แต่งตัวไม่ได้เลย อาบน้ำด้วยความลำบาก และอยู่แต่ที่เตียงนอน

3. การยกของ

□ ยกของหนักได้โดยที่อาการปวดไม่เพิ่มขึ้น

□ ยกของหนักได้ แต่มันทำให้อาการปวดเพิ่มขึ้น

□ อาการปวดเป็นอุปสรรคในการยกของหนักขึ้นจากพื้น แต่ก็ยกได้ ถ้าของที่มีน้ำหนักมากถูกจัดวางให้สะดวกในการยก (เช่นของตั้งบนโต๊ะ)

□ อาการปวดเป็นอุปสรรคในการยกของหนักแต่ก็ยกได้ ถ้าของที่มีน้ำหนักไม่มากนักถูกจัดวางให้สะดวกในการยก

□ ยกได้แต่ของที่เบามาก

□ ไม่สามารถยกหรือถืออะไรได้เลย

4. การเดิน

- ☐ อาการปวดไม่เป็นอุปสรรคในการเดินไกลๆ
- ☐ อาการปวดทำให้เดินได้ไม่เกิน 1 กิโลเมตร
- ☐ อาการปวดทำให้เดินได้ไม่เกิน 500 เมตร
- ☐ อาการปวดทำให้เดินได้ไม่เกิน 250 เมตร
- ☐ เดินได้โดยใช้ไม้ค้ำยันหรือไม้เท้าเท่านั้น
- ☐ อยู่ที่เตียงเกือบตลอดเวลาและต้องคลานไปเข้าห้องน้ำ

5. การนั่ง

- ☐ นั่งบนเก้าอี้แบบไหนก็ได้ นานเท่าที่ต้องการ
- ☐ นั่งบนเก้าอี้แบบที่ชอบเท่านั้น นานเท่าที่ต้องการ
- ☐ อาการปวดทำให้นั่งได้นานไม่เกิน 1 ชั่วโมง
- ☐ อาการปวดทำให้นั่งได้นานไม่เกิน ครึ่งชั่วโมง
- ☐ อาการปวดทำให้นั่งได้นานไม่เกิน 10 นาที
- ☐ อาการปวดทำให้นั่งไม่ได้เลย

6. การยืน

- ☐ ยืนได้นานเท่าที่ต้องการโดยที่อาการปวดไม่เพิ่มขึ้น
- ☐ ยืนได้นานเท่าที่ต้องการ แต่มันทำให้อาการปวดเพิ่มขึ้น
- ☐ อาการปวดทำให้ยืนได้นานไม่เกิน 1 ชั่วโมง
- ☐ อาการปวดทำให้ยืนได้นานไม่เกิน ครึ่งชั่วโมง
- ☐ อาการปวดทำให้ยืนได้นานไม่เกิน 10 นาที
- ☐ อาการปวดทำให้ยืนไม่ได้เลย

7. การนอน

- ☐ อาการปวดไม่เป็นอุปสรรคต่อการนอนเต็มอิ่ม
- ☐ นอนได้เต็มอิ่ม แต่ต้องทานยาแก้ปวด
- ☐ แม้ว่าได้ทานยา ก็นอนได้น้อยกว่า 6 ชั่วโมง
- ☐ แม้ว่าได้ทานยา ก็นอนได้น้อยกว่า 4 ชั่วโมง
- ☐ แม้ว่าได้ทานยา ก็นอนได้น้อยกว่า 2 ชั่วโมง
- ☐ อาการปวดทำให้นอนไม่หลับเลย

8. การเข้าสังคม

- ☐ การใช้ชีวิตในสังคมเป็นปกติ และไม่ทำให้อาการปวดเพิ่มขึ้น

☐ การใช้ชีวิตในสังคมเป็นปกติ แต่มันเพิ่มระดับความเจ็บปวด

☐ อาการปวดเป็นอุปสรรคในการทำกิจกรรมที่ต้องออกแรงมาก (เช่น กีฬา, การเต้นรำ)

☐ อาการปวดเป็นอุปสรรคในการออกไปข้างนอกบ่อยๆ

☐ อาการปวดจำกัดการใช้ชีวิตในสังคม ให้อยู่แต่ในบ้าน

☐ แทบไม่มีการเข้าสังคม เนื่องจากอาการปวด

9. การเดินทาง

☐ เดินทางไปได้ทุกแห่งโดยอาการปวดไม่เพิ่มขึ้น

☐ เดินทางไปได้ทุกแห่ง แต่มันทำให้อาการปวดเพิ่มขึ้น

☐ อาการปวดจำกัดการเดินทางที่เกิน 2 ชั่วโมง

☐ อาการปวดจำกัดการเดินทางที่เกิน 1 ชั่วโมง

☐ อาการปวดจำกัดการเดินทาง โดยเดินทางได้ในระยะสั้นที่ไม่เกินครึ่งชั่วโมง

☐ อาการปวดเป็นอุปสรรคต่อการเดินทางทั้งหมด ยกเว้นการไปพบแพทย์ / นักกายภาพบำบัด หรือไปโรงพยาบาล

10. การทำงาน / งานบ้าน

☐ งานบ้าน / กิจกรรมทางการงาน ไม่ทำให้เกิดอาการปวด

☐ งานบ้าน / กิจกรรมทางการงาน เพิ่มอาการปวด แต่สามารถทำงานที่ต้องการทำทั้งหมดได้

☐ ทำงานบ้าน / ภาระงานส่วนใหญ่ได้ แต่อาการปวดเป็นอุปสรรคต่อการทำกิจกรรมที่มีความเครียดทางกายเพิ่มขึ้น (เช่น การยกของ, การดูดฝุ่น)

☐ อาการปวดเป็นอุปสรรคในการทำสิ่งใดๆ ยกเว้นภาระงานที่เบา

☐ อาการปวดเป็นอุปสรรค แม้แต่ภาระงานที่เบา

☐ อาการปวดเป็นอุปสรรคในการทำงานใดๆหรืองานบ้านประจำ

รวมคะแนน = ... คะแนน

คิดเป็นร้อยละ ..... เปอร์เซ็นต์

APPENDIX D: A Fear-Avoidance Beliefs Questionnaire (Thai version)

แบบสอบถามพฤติกรรมที่เกี่ยวข้องกับอาการปวดหลัง

คำชี้แจง แบบสอบถามนี้มีทั้งหมด 16 ข้อความ เมื่อท่านอ่านแต่ละข้อความแล้วขอให้ท่านเลือกวงกลมล้อมรอบตัวเลขในข้อความนั้นที่สามารถระบุว่ากิจกรรรมต่างๆได้ส่งผลกระทบหรืออาจส่งผลกระทบต่ออาการปวดหลังของท่านมากน้อยเพียงใด โดยให้ท่าเลือกตัวเลขที่ตรงกับความรู้สึกของท่านในขณะนี้มากที่สุด

ตอนที่1 คำถาม: ท่านคิดว่าการเคลื่อนไหวร่างกายในกิจวัตรประจำวัน เช่น เดิน ก้มตัว ยกของ ฯลฯ มีผลต่ออาการปวดหลังของท่านอย่างไร (ให้ตอบว่าเห็นด้วยมากน้อยเพียงใดต่อข้อความในข้อ 1-5) โดย 0 หมายถึง ไม่เห็นด้วยอย่างยิ่ง ⟶ 6 หมายถึง เห็นด้วยอย่างยิ่ง

	ไม่เห็นด้วยอย่างยิ่ง			ไม่แน่ใจ			เห็นด้วยอย่างยิ่ง
1. อาการปวดของฉันเกิดจากการเคลื่อนไหวร่างกาย	0	1	2	3	4	5	6
2.เมื่อฉันเคลื่อนไหวร่างกายอาการปวดของฉันเพิ่มมากขึ้น	0	1	2	3	4	5	6
3.การเคลื่อนไหวร่างกายน่าจะเป็นสาเหตุที่ทำให้หลังของฉันบาดเจ็บ	0	1	2	3	4	5	6
4.ฉันไม่ควรเคลื่อนไหวร่างกายในท่าที่จะทำให้ฉันปวดมากขึ้น	0	1	2	3	4	5	6
5.ฉันไม่สามารถเคลื่อนไหวร่างกายในบางท่าเพราะทำให้มีอาการปวดมากขึ้น	0	1	2	3	4	5	6

ตอนที่ 2 คำถาม: ท่านคิดว่างานของท่านมีผลต่ออาการปวดหลังของท่านหรือไม่ (ให้ตอบว่าเห็นด้วยมากน้อยเพียงใดต่อข้อความในข้อ 6-16)

	ไม่เห็นด้วยอย่างยิ่ง			ไม่แน่ใจ			เห็นด้วยอย่างยิ่ง
6. อาการปวดของฉันมีสาเหตุมาจากงานที่ทำ หรืออุบัติเหตุที่เกิดขึ้นในขณะทำงาน	0	1	2	3	4	5	6
7. ฉันมีอาการปวดมากขึ้นเมื่อทำงาน	0	1	2	3	4	5	6
8. ฉันได้เรียกร้องเงินชดเชยจากการที่ฉันมีอาการปวด	0	1	2	3	4	5	6
9. งานที่ทำอยู่หนักเกินไปสำหรับฉัน	0	1	2	3	4	5	6
10. งานที่ทำอยู่ทำให้อาการปวดของฉันแย่ลง	0	1	2	3	4	5	6
11. งานของฉันอาจทำให้หลังของฉันบาดเจ็บมากขึ้น	0	1	2	3	4	5	6
12. ฉันไม่ควรทำงานตามปกติหากยังมีอาการปวดอย่างนี้อยู่	0	1	2	3	4	5	6
13. ฉันไม่สามารถทำงานตามปกติได้เพราะอาการปวดที่มีอยู่	0	1	2	3	4	5	6
14. ฉันไม่สามารถทำงานตามปกติได้จนกว่าอาการปวดที่เป็นอยู่จะได้รับการรักษา	0	1	2	3	4	5	6
15. ฉันคิดว่าฉันคงไม่สามารถกลับไปทำงานตามปกติได้ภายใน 3 เดือน	0	1	2	3	4	5	6
16. ฉันคิดว่าฉันไม่สามารถกลับไปทำงานได้อีก	0	1	2	3	4	5	6

คะแนน Physical activity……

คะแนน Work …….

APPENDIX E: Hip muscle length test

1. Thomas test

Thomas test was use as assessment tool for evaluation an hip flexor muscle flexibility and hip joint ROM. The procedure is following:

1.1 The participant was positioned supine on the examination table, and the examiner passively at least 90˚ of one hip flexed.

1.2 The participants would be instructed to taking the knee up to the chest in order to neutral posture of the lumbar spine and pelvis.

1.3 During testing, the examiner would fix the pelvic on the ASIS for pelvic stabilization, whereas, the participant was be instructed to hold the hip flexed against the chest.

1.4 Positive score defined as the opposite hip flex, and the knee lift off the examination table, negative score define as the opposite hip and knee maintain stationary and positioned flat against the examination table.

Figure. Presentation of hip flexor length test

2. Ober's test

The Ober test was used to measure the tightness of the iliotibial (IT) band that attached between the band of the gluteus maximus and tensor fascia lata muscles to the linea aspera and lateral epicondylar line of the femur via the lateral intermuscular septum. The procedure is following:

2.1 Participant was required to side lying position without backward or forward leaning of trunk to pelvic.

2.2 The examiner flexes the knee straight and abducts and extends the hip so that the hip is in line with the trunk, which is defined by the inclinometer at the lateral malleolus.

2.3 At this point, the examiner allows the force of gravity to cause the extremity to adduct as far as possible.

2.4 The tightness levels are described by the position of the lower extremity relative to the horizontal body plane as following in the table;

2.5 Positive score define as the limb abducted beyond horizontal and negative score if the limb adducted past horizontal.

Figure. Presentation of the TFL and IT band length testing by the Ober test.

APPENDIX F: The Sahrmann core stability test

1. A beginning position in supine crook-lying position as 70˚ hip flexed with placed a pressure biofeedback unit beneath the back at the level umbilicus or from L1-S1.

2. The participants is required to breathe in and out, then hold the abdominal hollowing action throughout and beginning the test movement on the end of exhalation.

3. Draw in the lower abdomen with stable neutral spinal and pelvic position while to maintain the target pressure at 40 mmHg.

4. The difficult level will be progressed only if the participant able to sustain a deviation of not more than 5 mmHg on the previous level.

5. The test contain five level as showing in the table:

The Sahrmann core stability test	
Level 1	Beginning in supine, in crook-lying position while abdominal hollowing* Slow raise one leg to 90˚ of hip flexed with point the tight toward the ceiling Opposite leg brought up to same position Lower the one leg turn to the table and the opposite leg to the starting position
Level 2	Lift one leg up until your hip is bent to 90 ˚and your thigh is pointing toward ceiling Lift alternate foot off the table and slide foot down with heel contact the table Until straighten leg completely Slide your foot back to the starting position and lower nonmoving leg to table, so both feet are on table Repeat starting with your opposite leg
Level 3	Perform the same movements as outlined in Level 2 except the following: Hold your foot off table (12 cm above ground) while straightening leg out Set your leg down on table Bring your leg back to starting position by holding foot off the table Repeat with the opposite leg
evel 4	Bend your hips and knees and slide heels along the table Lift both feet off table when 90˚hips flexed Reverse the movement to return to the starting position

The Sahrmann core stability test	
evel 5	Bend your hips and knees by lifting both feet off the table, bringing your knees to chest Hold your hips at 90˚and straighten your knees Lower your legs to the table Returning to starting position

* Subsequence level begin in this hip flexed position

APPENDIX G: Clinical assessment and gait analysis

ชื่อ…… อายุ……

เพศ…… น้ำหนัก…….. กิโลกรัม ส่วนสูง……เซนติเมตร

ความยาวขา(Lt./Rt.)……เซนติเมตร BMI……..kg/m^2

ที่อยู่.....

โทร. …… ID Line……Email……

วันที่เก็บข้อมูล……เวลา……

1.ตารางบันทึกข้อมูลการตรวจประเมิน (Clinical assessment)

Assessment	Result
Pain scale (NRS)	
Modified Oswestry Disability Index	
Fear Avoidance Belief Questionnaire (physical activity/work)	
The Sahrmann core stability test	
Thomas test (positive/negative)	
Ober test (positive/negative)	

2. ตารางบันทึกข้อมูลการตรวจประเมินการเดิน COP variability

COP	PWS	FWS
AP position (cm)		
AP variability (mm)		
ML position (mm)		
ML variability (mm)		

3. ตารางบันทึกข้อมูลการตรวจประเมินการเดิน Temporospatial gait

Temporospatial	PWS (Mean ± SD)	FWS (Mean ± SD)
Gait speed (km/h)		
Step width (cm)		
Stride length (cm)		
Stride time (s)		
Step length Lt. leg (cm)		
Step length Rt. leg (cm)		
Step time Lt. leg (s)		
Step time Rt. leg (s)		
Single support (%)		
Double support (%)		

4. ตารางบันทึกข้อมูลการตรวจประเมินการเดิน Gait variability

Gait variability	PWS	FWS
Step length		
Stride length		
Stride time		
Step width		
Single support (%)		

APPENDIX H: Intra-rater reliability of clinical assessment

1. Core stability test

The core muscle strength was determined the intra-rater reliability. The ICC $_{3, 1}$ was 1.00 (95%CI: 1.000-1.000; p <0.001). The data collection was shown in Table 1H.

Table 1H. The core muscle strength in the first and second test

Subjects	1st Test (grade)	2nd Test (grade)
1	2	2
2	2	2
3	3	3
4	0	0
5	3	3
6	0	0
7	0	0
8	0	0
9	0	0
10	4	4

0-5: a grade of core stability muscle

2. Trendelenburg test

The Trendelenburg test was determined the intra-rater reliability. The $ICC_{3,1}$ was 1.00 (95%CI: 1.000-1.000; p <0.001). The data collection was shown in Table 2H.

Table 2H. The Trendelenburg test in the first and second test

Subjects	1st Test	2nd Test
1	0	0
2	0	0
3	1	1
4	0	0
5	0	0
6	0	0
7	1	1
8	1	1
9	0	0
10	0	0

0: a negative test; 1: a positive test

3. Five-Time-Sit-To-Stand test

The Five-Time-Sit-To-Stand test was determined the intra-rater reliability. The ICC $_{3,1}$ was 0.99 (95%CI: 0.976-0.999; p <0.001). The data collection was shown in Table 3H.

Table 3H. The Five-Time-Sit-To-Stand test in the first and second test

Subjects	1st Test (sec)	2nd Test (sec)
1	7.54	7.12
2	6.07	5.89
3	6.59	6.37
4	6.73	6.51
5	5.88	5.68
6	7.31	7.06
7	6.68	6.53
8	10.65	10.91
9	9.62	9.57
10	8.45	8.19

4. Hip flexor muscle length test (Thomas's test)

The Iliopsoas muscle tightness test was determined the intra-rater reliability. The $ICC_{3,1}$ was 0.76 (95%CI: 0.284-0.934; p =0.004). The data collection was shown in Table 4H.

Table 4H. The Iliopsoas muscle tightness test in the first and second test

Subjects	1st Test	2nd Test
1	1	1
2	0	1
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	1	1

0: a negative test; 1: a positive test

5. The tensor fascia latae length test (Ober's test)

The Iliopsoas muscle tightness test was determined the intra-rater reliability. The $ICC_{3,1}$ was 0.82 (95%CI: 0.421-0.951; p =0.001). The data collection was shown in Table 5H.

Table 5H. The Iliopsoas muscle tightness test in the first and second test

Subjects	1st Test	2nd Test
1	1	1
2	0	0
3	1	1
4	1	1
5	1	0
6	0	0
7	0	0
8	1	1
9	0	0
10	1	1

0: a negative test; 1: a positive test

APPENDIX I: Intra-rater reliability of gait velocity determination

1. Determination of preferred walking speed

The processing determination of individual gait velocity at preferred walking speed condition was measured the intra-rater reliability. The $ICC_{3,1}$ was 0.88 (95%CI: 0.578-0.968; p <0.001).

The data collection was shown in Table 1I.

Table 1I. The determination of preferred walking speed in the first and second walking test

Subjects	1st Walking test (km/hr.)	2nd Walking test (km/hr.)
1	2.4	2.6
2	2.6	3.0
3	4.0	4.2
4	3.4	3.7
5	2.2	2.3
6	1.9	2.4
7	2.9	2.2
8	3.4	3.5
9	3.4	3.5
10	3.1	3.5

2. Determination of fastest walking speed

The processing determination of individual gait velocity at fastest walking speed condition was measured the intra-rater reliability. The $ICC_{3,1}$ was 0.94 (95%CI: 0.764-0.984; p <0.001).

The data collection was shown in Table 2I.

Table 2I. The determination of fastest walking speed in the first and second walking test

Subjects	1st Walking test (km/hr.)	2nd Walking test (km/hr.)
1	4.0	4.2
2	4.0	3.9
3	5.5	5.5
4	5.1	4.7
5	4.3	4.2
6	3.8	3.8
7	5.0	5.0
8	4.7	4.6
9	5.3	5.0
10	4.1	4.4

VITA

NAME	Nantachon Rujichi
DATE OF BIRTH	11 May 1981
PLACE OF BIRTH	Pathum thani Province
INSTITUTIONS ATTENDED	Srinakharinwirot university
HOME ADDRESS	36/1 Rangsit Nakhon Nayok 13 soi 15 Prachathipat Thanyaburi Pathum thani 12130
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