THE EFFECT OF NEUROMUSCULAR TRAINING BY LASER GUIDANCE ON HIP AND KNEE KINEMATICS ALTERATION IN PATIENTS WITH PATELLOFEMORAL PAIN SYNDROME: A RANDOMIZED CONTROLLED TRIAL

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ผลของการฝึกโดยใช้แสงเลเซอร์เป็นตัวนำทางต่อการเปลี่ยนแปลงการเคลื่อนไหวของข้อสะโพกและข้อเข่าในผู้ป่วยที่มีอาการปวดเข่าทางด้านหน้า: การทดลองแบบสุ่มมีกลุ่มควบคุม

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THE EFFECT OF NEUROMUSCULAR TRAINING BY LASER GUIDANCE

ON HIP AND KNEE KINEMATICS ALTERATION

IN PATIENTS WITH PATELLOFEMORAL PAIN SYNDROME:

A RANDOMIZED CONTROLLED TRIAL

THANAPAT WITHAYAWARAPONG

A Thesis Submitted in Partial Fulfillment of the Requirements

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BY

THANAPAT WITHAYAWARAPONG

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OF THE REQUIREMENTS FOR THE MASTER OF SCIENCE
IN PHYSICAL THERAPY AT SRINAKHARINWIROT UNIVERSITY

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Title	THE EFFECT OF NEUROMUSCULAR TRAINING BY LASER GUIDANCE ON HIP AND KNEE KINEMATICS ALTERATION IN PATIENTS WITH PATELLOFEMORAL PAIN SYNDROME: A RANDOMIZED CONTROLLED TRIAL
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Abnormal kinematics is a contributing factor to patellofemoral pain syndrome (PFPs). The aim of this study was to investigate the effect of the laser guidance retraining (LASER) and the conventional physical therapy (control) on kinematics, pain and functional ability in PFPs. Twenty PFPs, aged 18-49, were randomized into LASER (n=10) and control (n=10) groups. Both groups received their intervention in 12 sessions for three weeks. Their hip and knee kinematics during a single leg squat were assessed by the motion analysis system. The pain and functional ability were evaluated by a 10 cm VAS and Kujala score, respectively. An independent sample t-test and a paired sample t-test were used to analyze the data. The LASER showed significantly decreased hip adduction (p=0.002) greater than the control group (p=0.001). However, there were no significant differences in pain reduction and functional ability between the groups (p=0.102 and 0.243). Both groups showed a significant pain reduction (LASER; p=0.005 and control; p=0.022). Only the LASER group showed functional ability improvement (p=0.0001). The laser guidance retraining was effective to reduce hip adduction, relieve pain and improve functional ability.

Keyword : Neuromuscular training, Laser guidance, Hip and knee kinematics alteration, patellofemoral pain

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Introduction

Background

Patellofemoral pain syndrome (PFPs) is one of the most common chronic injuries in musculoskeletal system. PFPs was reported 331 of 2002 runners with overuse injuries. (1) The incidence rate of the PFPs persons was found 22 persons per years, and risk in female more than male 2.23 times. (2) Sign and symptom of patellofemoral pain presented pain surround or behind of the patella during knee flexion, especially during weight bearing task e.g. prolong sitting, squatting, stair ascent/descent, jogging/running, hopping/jumping and/or kneeling. (3-5)

Dynamic malalignment or abnormal kinematics is an important underlying factor to contribute to PFPs. Persons with PFPs has exhibited greater contralateral pelvic drop, hip adduction and hip internal rotation especially in female with PFPs during single leg squat and stair ascent task. (6-9) In the running task, PFPs persons have also shown the greater hip internal rotation (8) and hip adduction. (9) The hip adduction related to knee valgus ($r = 0.755$, $P = 0.001$) during weight bearing activity (10) can contribute to increased pressure on the cartilage of lateral patella facet to femoral trochlea. (11) Additionally, hip or femoral internal rotation underneath a stable patella was the primary contributor to lateral patella tilt and displacement during weight bearing condition which was secondary contributor to decreased patellofemoral contact area and increased the patellofemoral joint stress. (12-15) Therefore, these abnormal kinematics during daily activities have been the contributing factors to increased patellofemoral joint reaction forces and decreased patellofemoral contact area that lead to elevated patellofemoral joint stress and result in the patellofemoral joint pain.

Hip muscle strength deficit and abnormal hip muscle activity pattern have been found in patellofemoral pain that may influence to abnormal hip kinematics during functional task. The hip abductor and external rotator muscles are play role to stabilize hip mechanics. Decreased hip abductor and external rotator muscle strength have been reported in persons with PFPs, (16, 17) especially the isometric and eccentric strengthening. PFPs presented less isometric and eccentric strength than persons without PFPs. (7, 8, 18) These hip muscle strengthening of the affected sides were also less than the unaffected sides in unilateral PFPs persons. (19) Muscle strength and endurance in controlling pelvic drop and hip external rotation have shown lower in PFPs group than those in free-pain group. (8) Several studies have demonstrated the effectiveness of hip and quadriceps muscle strengthening exercise intervention in PFPs. (20-25) Most of these studies have suggested the duration of exercise program around 8 - 12 weeks for strengthening programs that was longer than neuromuscular training intervention. (20-27) Although, many studies have reported that the strengthening exercise would reduce pain severity, but some studies would not be effective. (21, 24, 25) In addition, these exercises did not improve properly hip kinematics that was a contributing factor to develop into PFPs. (20, 22, 23) It is possible that persons with PFPs may exhibit poor neuromuscular control of hip muscle.

Hip muscle activity is an important role to control hip kinematics. In task of stair ambulation and single leg squat, many studies have found delay onset, shorter duration and lower activation of gluteus medius electromyography (EMG) activity in anterior knee pain or PFPs subjects, (7, 28) and this muscle has shown delay onset and shorter duration of muscle activity more than adductor longus muscle. (29) The systematic review has reported moderate to strong evidence for gluteus medius muscle activity in PFPs persons (30) that supported the alteration of neuromuscular control related to abnormal hip function control especially hip adduction in persons with PFPs. Furthermore, PFPs persons also presented insufficiently a proprioceptive sense. (31, 32) Proprioception is one of somatosensory system of sensorimotor system. (33) Faulty proprioception is possible to disturb afferent signal to central nervous system and efferent signal to motor control that result in the irregular neuromuscular control. Consequently, the neuromuscular training by using sensory feedback (34) or feed-forward to correct the abnormal movement pattern may be an effective sensorimotor control relearning to alter the lower extremity kinematics and contribute to reduce the patellofemoral joint loading and patellofemoral joint pain.

A systematic review regarding the intervention program of PFPs (35) has reported that neuromuscular training program could improve knee kinematic in the frontal plane during functional task. Several studies used neuromuscular training program relieved symptom severity in persons with PFPs. (36-40) Previous study (39) investigated the alteration of the vastus lateralis and vastus medialis muscles activity after neuromuscular rehabilitation program. This study found that this neuromuscular retraining could alter the activation of the vastus lateralis and vastus medialis muscles. Furthermore, Noehren et al, (2011) (38) and Willy et al, (2012) (40) have reported that the neuromuscular training by using visual feedback from visual 3D monitor and mirror in PFPs persons during running on the treadmill could alter efficiently abnormal lower extremity kinematics such as decreased contralateral pelvic drop and hip adduction and also transfer to another task. This neuromuscular training could improve functional capacity and reduce pain in long-term more than hip strengthening exercise. (40)

Previous researches, (41, 42) both cross-sectional studies determined the effect of the corrected dynamic knee valgus on lower extremity kinematics in PFPs persons who exhibited the excessive dynamic knee valgus and pain during single leg squat. They found that the correction of dynamic knee valgus could reduce femoral adduction, internal rotation and pain in PFPs patient.

The laser guidance technique provided the visual sensory feedback which applied the laser beam to guide the normal movement pattern by pointed laser on the specific target. Previous study (43) compared the effects of cranio-cervical flexion and cervical proprioception training on neuromuscular control in patients with chronic neck pain. This study used the visual feedback from the laser attached to the head for cervical proprioception training. This finding indicated that the proprioceptive training by using laser guidance may have positive effects on the neuromuscular function of the deep cervical flexor muscle.

Abnormal kinematics of lower extremities is a contributing factor to develop the PFPs. Therefore, applying the laser guidance technique to relearn the new movement skill may be effective in persons with abnormal lower extremity kinematics. The objective of this research was to investigate the effect of neuromuscular training by using the laser guidance technique on alteration of lower extremity kinematics in persons with PFPs.

Research questions

Does the neuromuscular retraining by laser guidance alter hip and knee kinematics, reduce pain severity and improve functional ability in individual with patellofemoral pain syndrome?

Objective of the Study

1. To compare contralateral pelvic drop, hip adduction, hip internal rotation and dynamic knee abduction alteration between LASER group and the conventional physical therapy group, and between pre-post-intervention.
2. To compare pain severity reduction between LASER group and the conventional physical therapy group, and between pre-post-intervention.
3. To compare functional ability improvement between LASER group and the conventional physical therapy group, and between pre-post-intervention.

Research Hypotheses

1. There were significant differences in the contralateral pelvic drop, hip adduction, hip internal rotation and dynamic knee abduction angle between LASER group and the conventional physical therapy group and between pre-post-intervention.
2. There were significant differences in pain severity reduction between LASER group and the conventional physical therapy group and between pre-post-intervention.
3. There were significant differences in functional ability improvement between LASER group and the conventional physical therapy group and between pre-post-intervention.

Clinical Implication

The laser guidance technique is an external cue to enhance intrinsic feedback for neuromuscular retraining. The clinicians can apply this neuromuscular retraining protocol in individual with PFPs to alter abnormal lower extremity kinematics, reduce the pain severity and improve functional ability.

Key word

Neuromuscular training, Laser guidance, Hip and knee kinematics alteration, patellofemoral pain

Conceptual framework

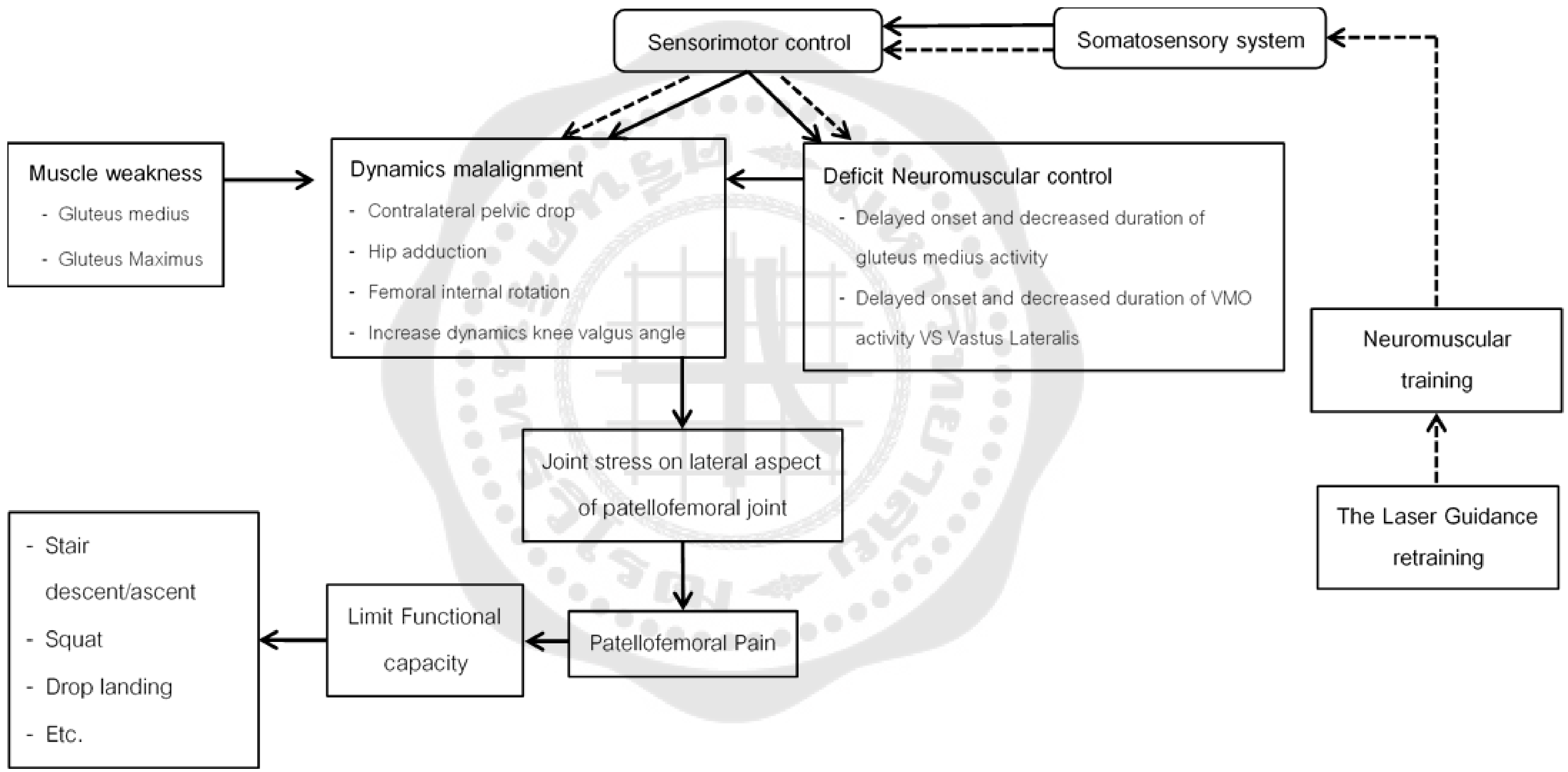

Figure 1 Conceptual framework

Chapter II
Review

Characteristic of patellofemoral pain syndrome

Definition

Patellofemoral pain syndrome (PFPs) or anterior knee pain syndrome is the most common chronic injuries in musculoskeletal system. Especially, PFPs is most population disorder on the lower limb, which reported 331 of 2002 runners with injuries. (1) The incidence rate of the PFPs persons was found 22 persons per years, and female more risk 2.23 times than male. (2) Sign and symptom of patellofemoral pain syndrome are pain at peripatellar and retropatellar during at least 2 of 6 functional activities i.e. prolong sitting (Sensitivity 72%, Specificity 57%), squatting (90%, 82%), stair ascent/descent (75%, 43%), jogging/running, hopping/jumping and/or kneeling (8 4%, 50%). (3-5)

Etiology

Patellofemoral pain syndrome developed via patella tracking on the femoral trochlea and increased force across the patellofemoral joint especially during weight bearing, eventually when this load exceeded to the joint toleration that contributed to articular failure and source of anterior knee pain. (11, 44, 45) The loading condition on the articular surface resulted from multifactorial combination of trunk and lower extremities such as lateral trunk lean, hip adduction and internal rotation, muscle activation/performance or any soft tissue. Currently, several previous studies have proved the etiologies of the patellofemoral pain syndrome, and it was controversial to clarify the cause of this problem.

The factors contributed to PFPs such as patellar malalignment/maltracking or lower extremity malalignment were grouped into 3 categories e.g. proximal factors, distal factors and local factors.

Proximal factors were focused on the abnormal kinematics of trunk, pelvis and hip. PFPs patients have shown lateral trunk lean with contralateral pelvic drop during single leg squat. (6, 7) Distal factors were emphasized on foot and ankle. Even though rear foot eversion kinematics contributed to PFPs was not clarified, previous studies have found similarly irregular kinematic mechanism in the presence of greater rear-foot eversion, navicular drop and tibial internal rotation during gait and jump-landing in PFPs persons. (4, 46, 47) The rear-foot eversion may associate with hip adduction. (46) Local factors were focused on the alteration of patellofemoral joint mechanics. Some studies have reported increased dynamic quadriceps angle (Q-angle) or knee abduction during functional tasks in PFPs subjects (6, 7, 48) that increased load to the joint and contributed to joint pain. (11, 44, 45)

Confounding factor

1.3.1 Age

PFPs is found frequently in adolescents and young active adults (1) because they have the exercises and fitness activities more than the other age groups (49) which lead to the increased patellofemoral joint stress and contribute to PFPs. (1, 2, 18, 50, 51) Most PFPs aged less than 49 years. (17, 37, 38, 40, 52)

1.3.2 Gender

PFPs is a common disorder on the lower limb. The 207 of 331 individuals with PFPs is females. (1) Female are 2.23 times more risk to PFPs than male. (2) An incidence rate of females and males were found 33 and 15/1000 person-years, respectively. (2) Odd ratios for female is 2.159 (95%CI = 1.334 to 3.493) whereas and male is 1.901 (95%CI = 1.153 to 3.135). These odd ratios indicated that the prevalence of PFPs in female is higher than male. (1)

Females were exhibited greater hip adduction, hip internal rotation, knee abduction and Q-angle when compared to males. (7, 53) The gender difference affected to the abnormal lower extremity kinematics, which contributed to PFPs (11-15)

1.3.3 Daily activities

Heavy activities, exercises or high impact sports is a cause of PFPs. (1, 2, 18, 50, 51) Athletic population was reported that the incidence rate in PFPs was greater than 25%. (18) In 2002, Taunton et al reported the number of runners with injuries. They found that there were PFPs 331 persons in lower limb injuries 2002 persons, which PFPs was the most common injury of lower extremities injuries. (1)

Additionally, the incidence risk and rate after basketball season showed 9.66 per 100 athletes and 1.09 per 1000 athletics exposure, respectively. (51) Additionally, the incidence rate of the PFPs persons in military training was found 22 persons per years. (2) These physical activities (i.e. running, jumping/hopping, stair ascending/descending or prolong sitting) led to elevate the patellofemoral joint loading that resulted in the increased patellofemoral joint stress. (1, 2, 18, 50, 51)

Anatomy and Kinesiology (54, 55)

Gluteus medius

Gluteus medius are on the lateral aspect of the ilium between the iliac crest and dorsal of posterior gluteal line and ventral of anterior gluteal line. It is also on more anterior and deeper than gluteus maximus. It places in oblique line through the ridge on lateral surface of the greater trochanter of the femur. The action of gluteus medius is the abduction of hip joint. The anterior fiber of this muscle acts the hip internal rotation whereas the posterior fiber acts the hip external rotation until hip flexion 45 degrees, then change to hip internal rotation beyond 45 degree of hip flexion. (56) Gluteus medius act in hip medial rotation during standing and hip extension with hip medial rotation during stance phase of gait cycle. Gluteus medius plays an important role to prevent the contralateral pelvic dropping during single limb stance.

Gluteus maximus

Gluteus maximus is on the outer surface of ilium behind posterior gluteal line and posterior surface of the lower part of the sacrum, side of the coccyx. It connects from aponeurosis of gluteal and erector spinae and sacrotuberous ligament. In portion of distal superficial fiber and proximal portion. Gluteus maximus muscle belly are across through the iliotibial tract of fascia lata; as in part of deep fiber, and the muscle belly are into the gluteal tuberosity of femur. Gluteus maximus main action are the hip extension and external rotation. At 45 degrees of hip flexion, anterior and superior fibers act for hip internal rotation, posterior and inferior fiber maintain the function of hip external rotation, and hip abduction action by upper fiber. The gluteus maximus muscle plays an important role for controlling posture to maintain upright position.(56)

Abnormal kinematics of the lower extremity

Patellofemoral pain syndrome results from the multifactorial factors. Abnormal kinematics is defined as the abnormal physiological movement pattern of trunk, pelvic and lower extremities during dynamics tasks that may result in patella maltracking on the femoral trochlea lead to patellofemoral joint pain syndrome or any anterior knee pain.

Abnormal patellofemoral joint kinematics (Local factors)

The painful knee in PFPs subjects presented greater iliotibial band (ITB) tightness than the non-painful knee in PFPs subjects and control subjects. (57) The distal part of ITB is connected to the lateral retinaculum of patella. It is possible that ITB tightness may pull laterally the patella and result in the patella lateral tilt and displacement. Moreover, Femoral internal rotation during single leg squat accompany with lateral patella tilt and displacement may promote to increased pressure on the patellofemoral joint. (13, 14)

Dynamics quadriceps angle (Q-angle) with quadriceps musculature moment is similar to knee abduction during weight-bearing lead to greater 45 percent of peak contact pressure. (11) Also, abnormal kinematics of patella or patella maltracking as lateral tilt and dislocation is commonly underlying impairment for developing patellofemoral pain because patella malalignment on femoral trochlea has contributed to increased patellofemoral joint stress, which lead to the injury of cartilage between the patella and femoral trochlea. (11, 12, 14, 58-61)

Lower extremity abnormal kinematics (Global Factors)

Contralateral pelvic drop / Hip adduction / Hip internal rotation / Knee valgus

Hip muscle weakness is a predisposing factor to lower extremity kinematics alteration during functional task, and then develop to patellofemoral pain. Hip abductor, hip external rotator or gluteus medius act to stabilize the pelvic obliquity, hip abduction and hip/femoral external rotation during standing, running, single leg stance, single leg squat, or other weight-bearing activities. PFPs persons have shown hip abductor and hip external rotator muscle weakness (16, 17) especially, in isometric and eccentric strengths. (7, 8, 18) The hip muscles of the affected limb side was weaker than those muscles of the unaffected side in unilateral PFPs. (19) Moreover, PFPs persons showed less peak torque of standing pelvic drop muscle in isometric testing, eccentric of isokinetic testing and less isotonic endurance when compare to healthy persons. (8) From systematics review reported the strong and moderate evidences in hip abductor and hip external rotator muscle weakness in PFPs persons. (62) Additionally, in vivo assessments of electromyography (EMG) activity reported lower gluteus medius muscle activation during single leg squat, (7) and also delay onset timing and shorter duration activation in stair ascending/descending task and running. (28, 29, 63, 64)

The deficit of hip muscle strength in parts of isometric, eccentric contraction or endurance and poor gluteus medius EMG activity may affect to act eccentrically to control hip movement that develop to faulty movement pattern during weight bearing task or repetitive task. In the task of single leg squat, persons with PFPs have exhibited greater contralateral pelvic drop, hip adduction and hip internal rotation especially in female with PFPs. (6, 7) In these cases, it is possible that these abnormal kinematics relate to the hip muscle problem because dynamic malalignments were found accompany with hip muscle weakness and irregular muscle EMG activation. (6, 7) Moreover, increased peak hip adduction was exhibit during stair ascent (peak hip adduction> 10.6°; sensitivity = 67%, specificity = 77%). (65, 66) Increased peak hip internal rotation was found after developing PFPs in the task of jump landing. (4) During running task, PFPs persons have shown the greater hip internal rotation and hip adduction (8, 9) that was strongly significant correlation to less hip abductor muscle strength. (17)

From the previous mention regarding to local factor, abnormal lower extremity kinematics in proximal factor are contributor to local factor. The abnormal pattern of pelvic and hip, contralateral pelvic drop contributed to hip adduction, that hip adduction related to knee valgus (r=.755, P=.001) during weight bearing activity. (67) Additionally, hip adduction, may associate with increased dynamics knee abduction during any activities. (67, 68) This hip adduction may affect to shifting the ground reaction force (GRF) vector to lateral knee joint center that the GRF shifting lead to produce knee abduction moment in PFPs patients (51, 69) and also increase load on the knee joint (70) that could increase the lateral forces acting on the patella. (14) Peak dynamics knee abduction during single leg squat was found in PFPs subjects, (6, 7) which lead to increase pressure on the cartilage of lateral facet of patella to femoral trachea. (11)

In addition, PFPs patient were found greater lateral patella tilt and displacement with greater femur internal rotation during weight bearing knee flexion. (15) Femoral internal rotation kinematic during unilateral squat is femoral trochlea rotation underneath a stable patella (result of anchored by quadriceps contraction tension), which is a primary contributor to lateral patella tilt and displacement on trochlea groove. (12-15) These abnormal patellofemoral kinematics led to increased the patellofemoral contact pressure on the lateral facet of patella, that contributed to patellofemoral pain. (11-15)

Consequently, this abnormal kinematics during daily activities (e.g. stair descending/ascending, squatting, running etc.) is a factor to produce patella maltracking on femoral trochlea with increased forces across patellofemoral joint that contribute to the patellofemoral joint pain.

Strengthening exercise in PFPs

From above mentioned, the assumption of hip muscle weakness may influence to abnormal lower extremity kinematics and develop to patellofemoral pain syndrome. Therefore, several studies have investigated the effectiveness of strengthening exercise on pain severity and functional activity in PFPs persons. (22-24, 27) The strengthening exercise program in previous studies included quadriceps, gluteus medius and gluteus maximus, hip abductor and lateral rotator muscle strengthening. (22-24, 27) These studies have reported the duration of strengthening exercise programs for 3 – 12 weeks. However, most studies spent 8-12 weeks for strengthening exercise program to exhibit outcome. Although, many studies have shown the effectiveness of strengthening exercise on pain severity and self-report functional ability, some studies exhibited–no change or difference in pain severity and functional ability between exercise group and control group, (21, 24, 25) and also no alteration of abnormal kinematics and muscle activities that were the contributing factors to develop the PFPs. (20, 22, 23)

However, the neuromuscular training exercises (36-40) have shown the effective exercise program to reduce pain severity, improve functional capacity and improve dynamics malalignment that was an important factor to develop the PFPs. These results also found that the outcomes could maintain the improvement though 1 month and 3 months after intervention. (36, 38, 40) The exercise spent only 2 weeks for duration of retraining program (38, 40) that was shorter than the duration of strengthening exercise. (20-27)

Furthermore, most studies investigated the effect of strengthening or other exercise program, but only few studies demonstrated the effect of neuromuscular exercise on pain relief in PFPs persons.

Neuromuscular control

Sensorimotor control (33, 71)

The sensorimotor system is integrated by the sensory, motor, and central nervous system to control static or dynamic alignment joint kinematics during functional activities by processing signal information from receptors through CNS to motor. (Figure 2)

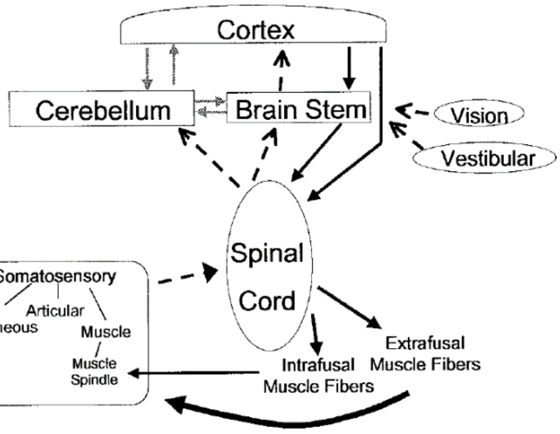

Figure 2 The sensorimotor system

Source: Riemann BL, Lephart SM. (2002). The sensorimotor system, part I: the physiologic basis of functional joint stability (33)

The peripheral mechanoreceptors or proprioceptors (e.g. muscle spindle, golgi tendon organ, tendon, ligament, fascia and joint), visual and vestibular sensory information are the input signals afferent to the spinal cord, through the associated areas as brain stem and cerebellum, then the signals ascend to the cortex for procession. The efferent signals from motor control level descend to congregate the alpha and gamma motor neurons at spinal cord, this new signals stimulate to intrafusal and extrafusal muscle fiber contraction pattern. (Figure 2)

Proprioception in sensorimotor control system is an important role for feedback and feed-forward motor control. For feedback motor control, activated or inhibited muscle reactivation by stimulating or inhibiting alpha motor neuron is the result of previous task. In feed-forward motor control are used for prediction or planning for preparatory to activate or inhibit muscle activation. These principles have suggested that abnormal proprioception in patient with patellofemoral pain syndrome (31, 32) may disturb the sensorimotor function. For example, the deficit of alpha motor neuron (72) for feedback or feed-forward is possible to stimulate deficient muscle activation or muscle activation pattern control that are important to body part movement.

Neuromuscular adaptation in PFPs

Proprioception in PFPs

Previous studies (31, 32) measured the proprioception at 15° to 60° knee flexion in PFPs persons compared to normal volunteers. They found that PFPs persons was significantly greater errors of knee joint proprioception (or less accurate and steady in knee joint) than normal subjects. They also found that the errors of knee joint proprioception in symptomatic sides was greater than those in asymptomatic sides. Therefore, this finding suggested that proprioceptive deficiency may result from the disturbance of sensorimotor control to control joint stability, balance, posture and movement. However, it is still unclear whether joint injury or structural damage causes to the proprioceptive deterioration.

Muscle activity in PFPs

Many studies investigated the differences in onset time and duration time of gluteus medius during functional activities between subjects with and without PFPs. For vastus medialis and vastus lateralis, muscle activity of these muscles remains unclear. A systematic review (73) regarding electromyography to observe neuromuscular control of the VMO and VL, they concluded that these EMG outcomes was not reliable to consider the onset time of VMO and VL muscle activation in patellofemoral pain syndrome. Furthermore, the delay onset timing and shorter duration EMG activity of gluteus medius muscle during stair ambulation were found in subjects with anterior knee pain or PFPs. (28) The onset timing and duration of EMG activity of gluteus medius muscle was more delay and shorter than adductor longus (29) that may be possible to increase hip adduction in PFPs during single leg squat. Also, moderate to strong evidence about gluteus medius muscle activity in the systematics review (30) was supported. These studies indicated that change in neuromuscular control may influence to abnormal kinematics e.g. hip kinematics in frontal and transverse plane, which was a main contributing factor to patellofemoral damage.

Neuromuscular training

Motor learning

Adam's Close-loop feedback theory *(Jack A. Adams, 1971)* (34)

Neuromuscular training engenders the relearning to alter voluntary movement by facilitating the signal from intrinsic and extrinsic sensory feedback e.g. visual, vestibular, verbal and proprioception etc., then the various sensory receptors send the afferent information to the control center. In Adam's Close-loop feedback theory proposes two memory types. First, *the memory trace* uses to select and initiate movement from past memory in initiate response. Then, *perceptual trace* uses to determine a proper movement by comparing to any sensory feedback. New movement is adjusted from previous feedback of movement when it error, and then the movement will stop at a perfect match. This theory indicate that the accuracy movement practice (by repeated the identical movement to greater correctness of movement) influences to the perceptual trace more than the specific movement practice.

Type of feedback

1. Intrinsic feedback (74)

1.1 Visual feedback: e.g. mirror movement retraining and monitor movement retraining etc. Observe own dynamics malalignment, adjust to the proper kinematics.

1.2 Audition feedback: e.g. verbal feedback, alarm sound or practitioner command etc. Listen practitioner describe the own error of movement and adjust to the correctness.

1.3 Tactile feedback: e.g. rough ground, soft floor or practitioner tapping on the trainee muscle belly. Mechanoreceptors in the skin response provide the sensory information to CNS, play an important role as movement accuracy, consistency, timing, movement force adjustment and estimate movement (improve movement that is performed by proprioception feedback) by tactile feedback

1.4 Proprioception feedback: as perception of trunk, position, limb movement direction, limb location and velocity etc.; This feedback plays an important role to change muscle length and velocity, change in muscle tension or force and joint receptor for movement accuracy, timing of the onset of motor command and coordination control. Be aware the joint, adjust to accurate joint kinematic.

1.5 Forces and Smell feedback

2. Extrinsic feedback

2.1 *Knowledge of result (KR):* Practitioner evaluated immediately outcome of practicable of movement to facilitate the learner to be aware the correct or incorrect movement.

2.2 Knowledge of performance (KP): (74) At the perceptual trace develop abnormal movement to better accuracy skill movement. Practitioners give the specific external feedback information (feedback form external source) by using verbal feedback. They give more information (more than KR) about the characteristic of movement that adjust abnormal kinematics to correct the proper movement of performer. There are various types, as follow.

- Selecting the skill component for KP: Practitioner analyzes the characteristic of movement, and then prioritizes the most critical and other for perform the proper skill of movement.

- Descriptive KP: Practitioner give a verbal feedback by described the error movement that performer did.

- Prescriptive KP: Practitioner give a verbal feedback by described the error and command to adjust the correct movement.

This theory suggests that the accuracy movement practice (by repeated the identical movement to greater correctness of movement) influence to the perceptual trace more than the specific movement practice. Accordingly, this theory is applied to update the control center for adjustment in the proper kinematics, eventually when the perceptual trace develops to strong skill, the proper movement progresses to automatically produce a new skill movement.

Schema Theory (Schmidt, 1972 of motor learning) (75)

This theory emphasizes on *open-loop control process* and *generalized motor program*. Motor program is not the specific movement but the motor program learn general rules of the movement pattern. This theory benefit to apply to various task in another environment.

Motor learning in this theory include two rules; 1.) *General motor program theory*: this program brings previous motor learning to create spatial and temporal movement pattern, 2,) *Motor response schema:* to response for proper movement pattern in any situation. Memory storage in the Schema theory a) *the initial movement conduction* such as during starting position, b) *response specification* of the movement pattern such as direction, velocity, force etc. c) *sensory consequences* of the movement e.g. looked, sound, tactile, d) *Knowledge of result*.

Accordingly, the new skill of movement pattern can influence ~~to~~ another new skill of movement and can transfer to new tasks.

To summarize, in both theories of motor learning indicate that neuromuscular training is an important role for generating new motor responses to control the last planed movement and plan afterwards movement. Alteration of abnormal lower extremity kinematics may affect decreased patella maltracking and patellofemoral joint stress that can recover the injury of patellofemoral joint and subsequently prevent the injury.

Factors to be influence to motor learning

From the previous study showed that female presented greater contributing factor to spatial alignment than male. There were also the differences in throwing accuracy during throwing task between genders. (76) This study indicated that there are differences in learning mechanism between the male and female.

The different motor ability related to age, motor deficit e.g. movement agility, coordination and balance was found in the older persons, they decreased manual asymmetries performance movement. (77)

Furthermore, many factors influence to individual difference of motor control and motor learning in any task. Ability, emotion, motivation, arousal, attention, memory or past experiences are under the personal control, but inherited ability, body type or cultural background are uncontrollable factors. (78) Consequently, our study will match paired the factors between group to control bias.

Neuromuscular training in PFPs

Currently, there are several management techniques for PFPs such as; strengthening exercise, soft tissue mobilization, stretching exercise. Several studies have suggested the effectiveness of neuromuscular training on pain relief in PFPs. (36-40) Previous studies, (38, 40) presented the effectiveness of neuromuscular training on kinematics alteration, improving severity of injury and integration into a clinical practice. In addition, Willy RW, (2012), (40) discussed that the neuromuscular training could be more effective to pain relief, improve functional movement and short duration for intervention period than strengthening exercise. In addition, this study investigated the effect of neuromuscular training program on PFPs management to apply in the clinical practice.

Noehren B et al, (2010) (38) studied the effect of real-time gait retraining on altered hip mechanics and pain relief during running and single leg squat in PFPs persons. PFPs subjects obtained visual feedback during running on treadmill by observing hip mechanics on the monitor of motion analysis system at real-time.

Willy RW et al, (2012) (40) examined the mirror gait retraining technique to alter abnormal kinematics and educe pain during running, single leg squat and stair descent in female runners with PFPs. Subjects received visual feedback during running on treadmill by observing pelvic, hip and knee movement on full length of mirror placed in front of them and verbal feedback from practitioner to adjust hip and knee mechanics.

Both neuromuscular training programs in persons with PFPs showed significantly improved joint kinematics and decreased pain and maintained these outcomes for the long term up to 1 and 3 months after the end of intervention.

Furthermore, the effect of neuromuscular training could transfer the corrected joint kinematics from running task to single leg squat and step-down task.

In case of excessive dynamic knee valgus during squat task, recent cross-sectional study as Salsich GB et al, (2012) and Graci V et al, (2015) (41, 42) determined the effect of corrected multi joint of lower extremity kinematics on hip and knee movement during single leg squat in PFPs persons. These findings reported the decreased femoral adduction/internal rotation and pain by correcting properly dynamics knee valgus.

The single leg squat task is underlying factor to aggravate symptom of PFPs and high sensitivity for testing (90%). (5, 79) Therefore, this abnormal lower extremity kinematics is an important factor to consider for PFPs management. It is possible that this study can apply the sensory feedback in neuromuscular training to improve the faulty kinematic that may lead to pain relief during the task.

Previous studies, (80, 81) reported the effectiveness of neuromuscular training program with visual and verbal feedback in squat tasks (e.g. squat, step down-up etc.) to alter properly kinematic alignments as decreased hip adduction ,femoral internal rotation and knee abduction. These researches applied the protocol of neuromuscular training intervention as Table 1.

Table 1 Neuromuscular training in PFPs of recently studies

Authors	Intervention	Feedback	Training task	Sessions/week	Weeks	Follow up
Noehren B, 2010	Motion monitor gait-retraining	- Visual feedback: 3D Motion analysis monitor - Verbal feedback: practitioner	Run	4	2	1 month
Willy RW, 2012	Mirror gait retraining	- Visual feedback: full length mirror - Verbal feedback: practitioner	Run	4	2	1 month 3 months
Olson TJ, 2011	Mirror retraining	- Visual feedback: full length mirror - Verbal feedback: practitioner	Squats	3	4	-
Wouters I, 2012	Mirror retraining	- Visual feedback: full length mirror - Verbal feedback: practitioner	Squats	3	4	-

The laser guidance

Many studies demonstrated the effect of sensory feedback from external environment to correct lower extremities movement especially visual feedback (from the monitor of motion analysis system or the mirror) and verbal feedback. (38, 40)

The laser guidance is innovative equipment by using the guide from laser beam to correct the abnormal lower extremity kinematics. There are few evidences to support the effect of laser guidance to control joint movement. Recently study (82) applied the laser guidance for cervical proprioception training. This finding indicated that the proprioceptive training by using laser guidance may have positive effects on the neuromuscular function of the deep cervical flexor muscle.

This finding suggested that the laser guidance technique in neuromuscular control may be effective to correct lower extremity movement in our study. The laser guidance technique provided the visual sensory feedback for learner by determining a specific point on the target to guide the learner to perform correctly the movement e.g. to keep contralateral pelvic drop, to decrease hip adduction, hip internal rotation and knee abduction.

Instrumentation

Three-direction motion analysis system

Three-dimensional motion analysis system was used to examine the abnormal joint kinematics pattern such a contralateral pelvic drop, hip adduction, hip or femoral internal rotation and knee abduction or knee valgus. (6-8, 17, 46, 67) Recent researches of Noehren B et al, (2010) (38) and Willy RW et al, (2012) (40) studied the effect of neuromusclar training on joint kinematics in persons with PFPs. They used *three-dimensional (3D) motion analysis system* to investigate the alteration of lower extremities kinematic value between before and after training and long term follow up.

Our study used the VICON motion analysis system (VICON T-series, Oxford Metrics Ltd, UK) as *a gold standard* device to assess joint kinematics. Intraclass correlation coefficients (ICC) of the VICON motion analysis system was between 0.84 to 0.97 that was an excellent reliability. (83)

10-centimeter Visual Analog Scale

Many researches (36-40) studied effect of neuromuscular training on pain relief. They used visual analog scale (VAS) to evaluate the pain severity outcome after management. The minimum clinically important difference of the VAS is 2 of 10 centimeter scale in PFPs persons. (84) Test-retest reliability of visual analog scale was good, $ICC_{3,1}$ was at 0.76. (84)

The Kujala Anterior knee pain scale (AKPS)

The anterior knee pain scale (AKPS) is a questionnaire discovered by Kujara et al, (1993), (85) which used to evaluate pain severity and functional ability of persons with anterior knee pain syndrome, including patellofemoral pain syndrome. It has 13-item questionnaire as limp, limitation during weight support, walking, ascent-descent stair, squatting, running, jumping, Prolonged sitting with the knees flexed, pain, swelling, abnormal painful kneecap (patellar) movements (subluxations), atrophy of thigh and flexion deficiency. This questionnaire has 0 to 100 score ranges, 100 score; it means no functional capacity limitation and no symptom. The questionnaire are high internal consistency (α Coef=0.91) (86) and high reliability ($ICC_{2,1}$=0.95). (87) The minimal clinical important difference (MCID) of the AKPS in PFPs persons was 10 of 100 score change. (84) Apivatgaroon et al, (2016), (88) translated AKPS in Thai version and test reliability and internal consistency. They reported the excellent test–retest reliability (intra-class correlation coefficient 3,1) of 0.908 ($p<0.001$; 95% CI [0.842–0.947])) and strong the internal consistency (0.952 ($p<0.001$)).

Summary

Patellofemoral pain syndrome (Anterior knee pain) is common knee injury which the causes of PFPs are multifactorial. Recent study found that persons with PFPs exhibited hip abductor muscle weakness, the deficit of muscle activation, the delay onset and short duration (e.g. gluteus medius and gluteus maximus) and abnormal kinematics during weight-bearing activity (e.g. contralateral pelvic drop, hip adduction, hip internal rotation and increase knee valgus) which led to increased patellofemoral contact pressure. Several researches showed the treatment technique to relieve pain severity and improve functional capacity. The previous studies revealed the effectiveness of neuromuscular training on pain and joint kinematics in PFPs patient. However, the research design of these studies was only the quasi-experimental study. In addition, the previous studies used the mirror or monitor of visual 3d as a visual feedback that may be not convenient to move anywhere for training. Consequently, the laser guidance technique may be an effective visual feedback in neuromuscular training to correct hip and knee kinematics pattern and relieve pain.

Chapter III
Research Methodology

Research Design

This study was a randomized, assessor-blinded, controlled trial which was registered in Thai Clinical Trials Registry (TCTR). The study identification number for this study protocol was TCTR20190309001.

Setting

Data collection were set at Faculty of Physical Therapy, Srinakharinwirot University, Ongkharak campus.

Participants

Twenty participants with patellofemoral pain syndrome (PFPs), aged 18-49 years, diagnosed by licensed physical therapist who has experienced in PFPs, participated in this study. They were assigned randomly into 1 of 2 groups, laser guidance retraining group (LASER group; n= 10) or conventional physical therapy group (Control group); n= 10). Simple random sampling was used to allocate in each group after baseline investigation. The PFPs persons were blinded to group allocation by ensuring that they were unaware of the intervention of the other group. The inclusion criteria for persons with PFPs were pain at the anterior part of knee for at least 2 months. (36, 38) There was pain at peripatellar or retropatellar which was aggravated by at least 2 in 6 activities (i.e. prolong sitting, squatting, stair ascent/descent, jogging/running, hopping/jumping and/or kneeling). (3-5) The pain level presented at least 3 cm. (identified by 10 centimeters of Visual Analog Scale; 10-cm. VAS) during of single leg squat. They could perform single leg squat as much as possible at least 60° knee flexion. All participants exhibited observable excessive hip adduction or dynamics knee valgus during a descent phase of maximum single leg squat depth. (41, 42, 89)

The participants were excluded if they showed signs or symptoms of any of the following: an insidious onset of symptom related to trauma (e.g. knee menisci, ligament, synovial plica and bursa); (4) a history of lower extremities surgery; severe pain during squat training; a history of neurological or cardiopulmonary disorder that risks to exacerbate during investigation or training; BMI exceeded 29.9 kg/m^2. (90, 91)

For the discontinuation criteria, the participants had to stopped investigation or training if they reported provocative pain (i.e. 10-cm. VAS was equal or greater than 2 of 10-cm.) (84) or other symptoms that impeded the protocol training.

This study had been approved by Certificate of Approval Number of Srinakharinwirot University, Thailand is SWUEC/E-487/2561. (Appendix A) All participants were informed about the objectives of study, study procedure and signed the informed consent form prior to participation.

Sample size

A sample size was calculated by GPower 3.1.9.2 program (Figure 3). The effect size was based on the study of Willy RW (2012) (40) that was a quasi-experiment design which compared the alteration between pre and post intervention of hip kinematics variables. Effect size (f) was set at *0.68.* Two-tailed, an alpha level and power was set at 0.05 and 0.8, respectively. Total sample size calculation was 19 participants. However, the study design in this study was a randomized controlled trial to compared kinematics, pain severity and functional ability between groups. Allowing 20% dropout, 24 individuals with PFPs be were recruited for this study. Twelve participants per group were determined.

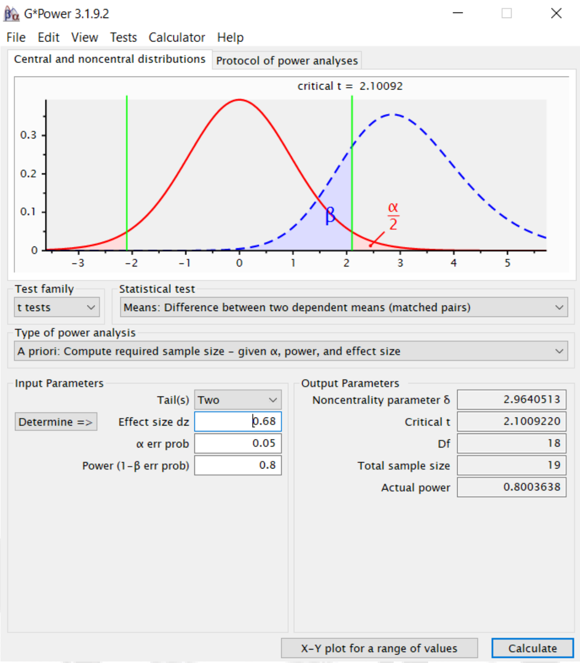

Figure 3 Sample size calculation by GPower 3.1.9.2 program

Variables and Instrumentation

Kinematics data

Three-Dimensional, lower extremity kinematic data e.g. contralateral pelvic drop (CPD), hip adduction (HADD), hip internal rotation (HIR) and knee abduction (KABD) (6, 7, 36, 40-42) were collected by using 10-camera (sampling frequency at 100 Hz) motion analysis system (VICON T-series, Oxford Metrics Ltd, UK). The marker set used for this study was the plug-in-gait lower body model. (92) The participants wore the short pant and did not wear shoes or socks. Sixteen reflective markers (14-mm spheres) were placed over the following body landmarks: left and right anterior superior iliac spine (LASI & RASI), left and right posterior superior iliac spine (LPSI & RPSI), left and right lateral femoral epicondyles (LKNE & RKNE), over the lower 1/3 of lateral surface of the thigh (below the swing of the hand) of left and right thigh (LTHI & RTHI), over the lower 1/3 of left and right shank (LTIB & RTIB), left and right lateral malleolus (LANK & RANK), over the 2nd metatarsal head of left and right foot (LTOE & RTOE) and left and right calcaneus at the same height above the toe marker (LHEE & RHEE). (93) (Figure 4 and 5) (93)

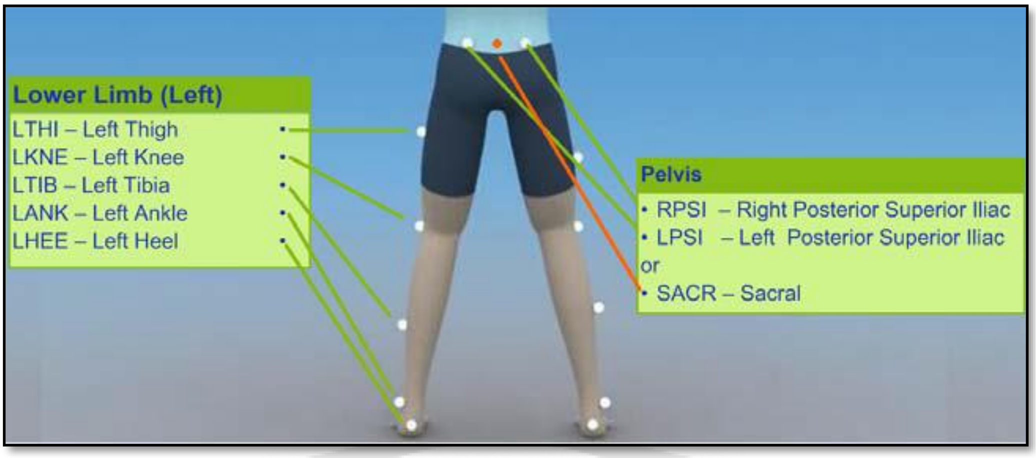

Figure 4 Lower Body Marker Placement back view

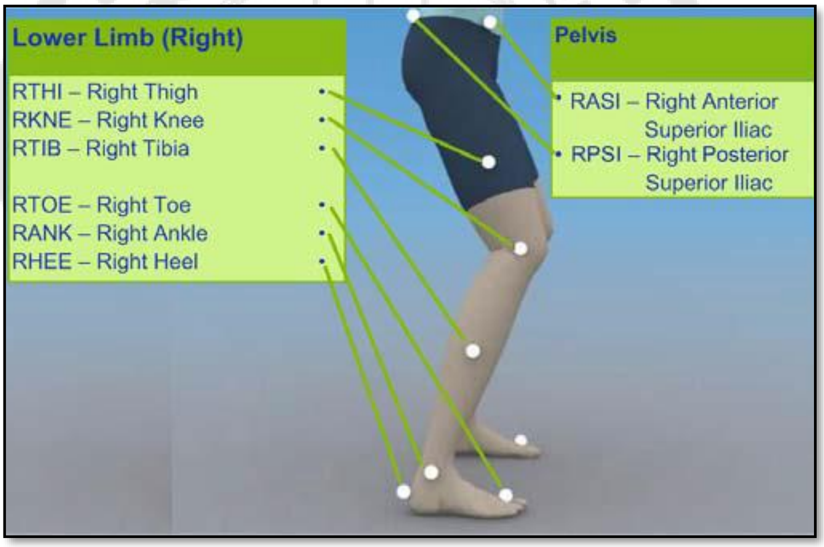

Figure 5 Lower Body Marker Placement side view

Source: Plug-in-Gait model Marker Placement

Pain severity evaluation

The Visual Analog Scale (10-cm. VAS) was a tool for self-reported of pain assessment. It was used to evaluate pain severity during single leg squat. (41, 42, 84)

Functional ability evaluation

Functional capacity was evaluated by the Anterior Knee Pain Scale (AKPS) (Appendix E). (88) The AKPS is self-report for 13-item questionnaires as limb, limitation during weight support, walking, ascent-descent stair, squatting, running, jumping, prolonged sitting with the knees flexed, pain, swelling, abnormal painful kneecap (patellar) movements (subluxations), and atrophy of thigh and flexion deficiency. The AKPS is scored from a minimum score of 0 to a maximum score of 100 points. Lower scores indicate greater pain and disability.

Procedures

Participants reported the questionnaire about their demographic, characteristics of pain, history of treatment and injury for screening to recruit the participants in the study (Appendix B). For participants with bilateral pain, the most painful side was defined as the treatment side which the lowest symptomatic leg side had to be less than 3 of 10 cm. VAS or did not limit the daily activities (Appendix C). (1, 8, 10, 15, 16) The dominant leg side was defined as preferred the leg to kick a ball. (13) The participants were recruited following the criteria (Appendix C): characteristics of anterior knee pain, criteria of pain (pain on functional activities), pain scale by 10-cm. VAS (Appendix D) and pain duration. To evaluate functional ability improvement, the participants reported the subjective responses to specific activities and symptoms by using the AKPS. (Appendix E)

Before the kinematics data collection, the anthropometric data of each participant (e.g. Inter anterior superior iliac spine (ASIS) distance, lower limb length (ASIS to Medial malleolus), knee width (lateral-medial femoral epicondyles distance) and ankle width (medial to lateral malleolus distance) was measured.

Then, a standing calibration trial was conducted to define the segment coordination system. Prior to testing, the participants received the opportunity to practice the squat at least 60° knee flexion until they felt comfortable with their performance.

Instruction for single leg squat, the participants stood on the involved limb and lifted the uninvolved foot up approximately 90° of knee flexion (behind the body). They started from initial single leg stance and performed single-leg squat as much as possible at least 60° knee flexion. Then, they returned to the starting single leg stance. Five trials of single leg squat were required at 2 second for a descent phase and 2 second for an ascent phase, (7, 9) paced with a metronome. A 1-minute rest was allowed between trials. (36)

Hip and knee kinematics, 10-cm. VAS during single leg squat and the AKPS were measured at baseline (before the intervention program) and after 3rd week of the intervention program. (Figure 11) Assessor was blinded to the intervention groups of participants.

Intervention protocol

Trainer or therapist of each group did not involve between LASER group (Trainer) and the conventional physical therapy group (Therapist). Both the trainer and the therapist have physical therapy license.

Participants in both groups obtained a leaflet about the cause of patellofemoral pain syndrome. (Appendix G)

Training/Treatment

Prior to training program, subjects were given the stretching program of gluteus medius, gluteus maximus, iliotibial band, quadriceps, hamstring and gastrocnemius for 3 repetitions of 30 seconds each. (94)

The laser guidance group

Participants completed the intervention program in 12 sessions (80, 81) for 3 weeks and 4 sessions per week. (38, 40) This program was modified from the previous neuromuscular training protocol. (38, 40-42, 80, 81) They were instructed to correct properly the dynamic alignment i.e. reduced hip adduction, hip internal rotation and knee valgus during the squats by applying the laser guidance as a visual feedback. (34, 74) The squat tasks in this study were progressed from bilateral weight bearing to partial weight bearing on one leg to unilateral weight bearing, which composed of Sq1. *'double leg squat'* task, Sq2. *'double leg squat with partial weight bearing'* task (squat with uninvolved side on a bosu ball), and Sq3. *'single leg squat*' task, respectively. (Figure 6)

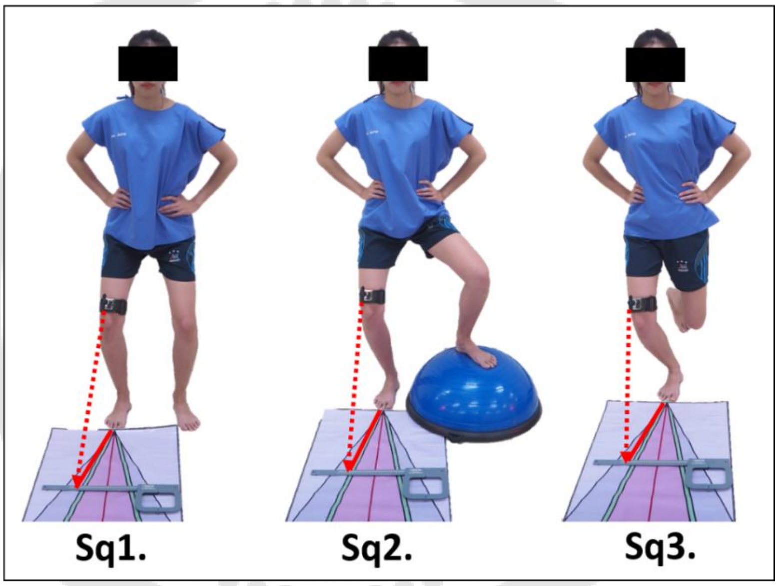

Figure 6 The squats task e.g. Sq1 : Double leg squat task, Sq2 : Double leg squat with partial weight bearing task and Sq3 : Single leg squat task

The laser guidance kit included the laser pointer, the laser pointer base, the adjustable strap and the target plate. In the target plate, there were three lines; the middle line (AB line), and both 10-degree lines to diverge from AB line (AC line). (Figure 7 and 8)

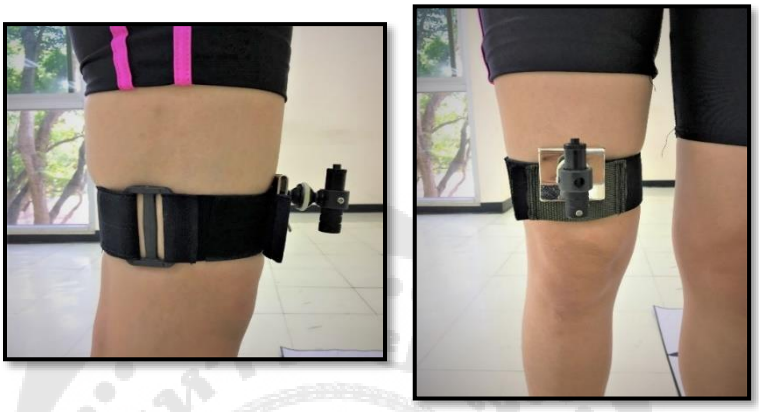

Figure 7 The laser guidance kit

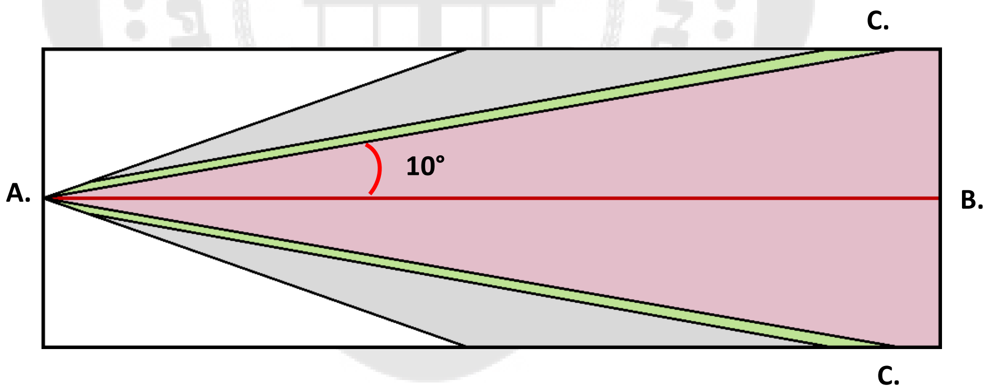

Figure 8 The target plate

Before training, the participant was strapped a belt with laser on the distal of thigh. The laser was adjusted to parallel and on middle of the laser pointer base. The middle of the laser pointer base was approximately on the middle of inter-epicondyle of femur on the belt. They performed double leg squat to 60 degrees of knee flexion in order to mark individual distance of the laser beam on the target plate.

During the squat training, the participants were instructed to stand with their trunk upright and hands on waist and bend their involved knee approximately 60 degrees (individual distance of the laser beam on the target plate). The foot of involved limb was placed on point A of the target plate. The preferred foot position of each participant was in the neutral or toe out position which the individual foot position was placed as the starting position throughout the intervention program. The participants attempted to correct the knee kinematics during descent and ascent phases of the squat tasks. To correct the knee dynamic alignment, trainer instructed all participants to *'keep your knee out of the middle of your foot'* (41, 42) and visual cue to *'control the beam of laser on or out of the 10-degree line (Green area) until to the individual distance of the laser beam on the target plate' that 'will not move their knee forward over the toes during the squat tasks'*. (Figure 9)

Protocols of the laser guidance retraining were determined as 5-10 repetitions of a set with 1 minute rest between sets, (81) 3 sets of each trial with 5-10 minutes rest between trials, (41) 4 trials of a session and 4 sessions for a week. (38, 40) The total protocol completed in 12 sessions for 3 weeks (80, 81) (Appendix F).

After the instruction of the squats task, the participants began the neuromuscular training program, and received the additional instruction from the trainer after performing the task if they did not complete properly the movement task. Trainer advised the additional instruction in the first sessions of each stage of protocol.

The intensity of protocol training gradually increased the repetition of squat at first 4 sessions (Appendix F). For the progression of motor learning, the visual cue from laser gradually was withdrawn in order to facilitate the internal cue learning within four progressive stages of 3 weeks (Appendix F). (38, 40)

All participants followed the four stages of training to gradually withdraw sensory feedback (laser cue). In case of individual performance progression, the participants were progressed to next stage if they could complete all repetitions of the session (i.e. they could control the beam of laser on green area with laser cue or performed properly knee out of the middle of foot during squat tasks without laser cue).

First stage or first week (session 1-4): In each session, the participants performed double leg squat in the 1st and 2nd trial, performed double leg squat with partial weight bearing in the 3rd trial and performed single leg squat in the 4th trial (session 1 to 2: 5 repetitions/set, session 3: 8 repetitions/set and session 4: 10 repetitions/set). They obtained the laser cue throughout the first stage and received the instruction only the 1st session (after the end of each set). The additional instruction was *"Before squatting, please stand steadily on one leg (in case of double leg squat with partial weight bearing and single leg squat), contract belly and buttock muscles, slowly descend squat and attempt to correct the knee by controlling the beam of laser toward on 10° green area or over"*. At the end of each trial, trainer asked all participants about the training as *"Do you have pain during performing the tasks?"* or *"What is the reason that you cannot accomplish the tasks?"* Then, trainer suggested them how to complete the tasks easier.

Second stage in second week (session 5-8): In each session, the participants performed double leg squat in 1st trial, double leg squat with partial weight bearing in 2nd and 3rd trial and single leg squat in 4th trial. In this stage, they obtained the laser cue only in 1st and 2nd set of each trial, and attempted to perform properly the squat tasks without the laser cue (trainer instructed them to correct the knee out of the middle of foot) in 3rd set. They received the instruction only in 5th session. In the squat task without the laser cue in 3rd set, instruction were prescribed that *"Before squatting, please stand steadily on one leg (in case of double leg squat with partial weight bearing and single leg squat), contract belly and buttock muscles, slowly descend squat, perceive your knee movement and attempt to control the knee out of the middle of your foot"*.

Third stage in third week (session 9-10): In each session, the participant performed double leg squat in 1st trial, double leg squat with partial weight bearing in 2nd trial and single leg squat in 3rd and 4th trial. They obtained the laser cue only in 1st set of each trial and attempted to performed properly the squat tasks without the laser cue in 2nd and 3rd set. They received the instruction only in 9th session.

Fourth stage in third week (session 11-12): In each session, the participants performed the same protocol as a third stage. The laser cue was completely withdrawn throughout the protocol. They attempted to perform properly the squat tasks without the laser cue in 2^{nd} and 3^{rd} set. They received the instruction only in 11^{th} session.

In squat training, if the participants reported pain scale (10-cm. VAS) equal or greater than 2 cm. (84) or other symptoms that restricted the training, the trainer suggested them to decrease the depth of squat until they could perform as much as they felt comfortable. And if they still had pain at the same scale, the squat task had to move backward to the easier task (such as single leg squat go back to double leg squat with partial weight bearing and then go back to double leg squat). The participants could discontinue the intervention if their pain had no change after decreasing the progression of training.

During intervention period, the participants were not permitted to do functional activities as jogging/running, hopping/jumping that aggravated their symptoms. They had to avoid any daily activities as prolong sitting, squatting, stair ascent/descent, and/or kneeling that aggravated symptoms. They attempted to correct properly the multi-joint movement in daily activities.

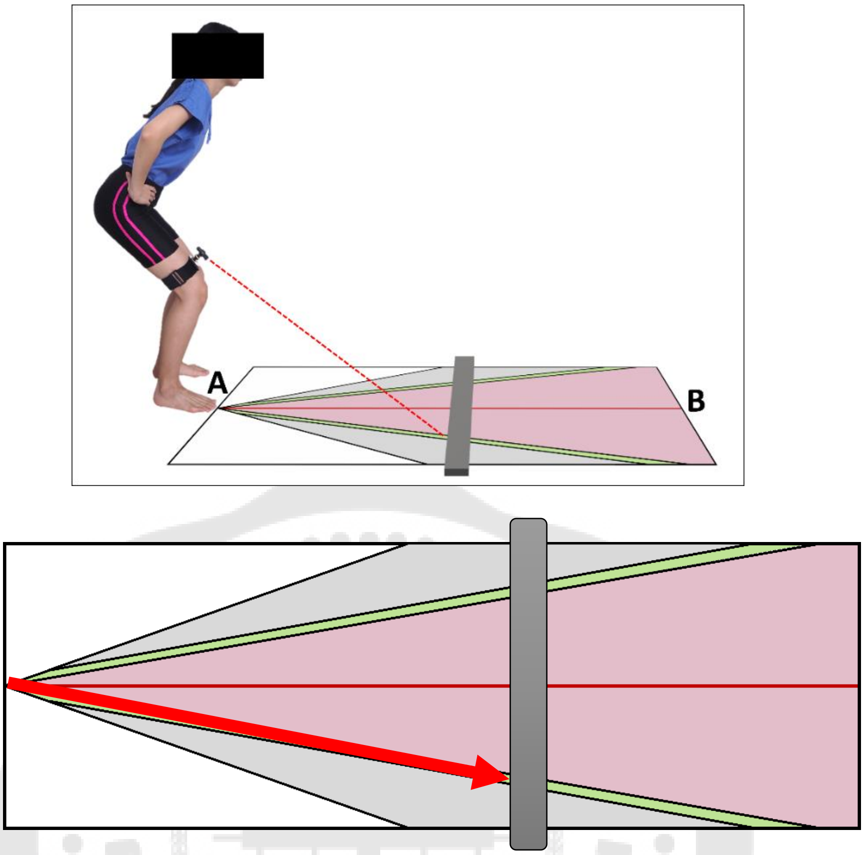

Figure 9 Neuromuscular training, using the laser guidance

The conventional physical therapy group

Persons in this group obtained any conservative treatment (95, 96) in 4 sessions for a week, the total treatment visits completed in 12 sessions for 3 weeks (i.e. ultrasound therapy, short wave diathermy, patella joint mobilization, hip strengthening exercise (cram shell exercise, squatting with elastic band and lateral walking with elastic band), self-massage by foam roller, stretching exercise, patella kinesio-taping, hot-pack).

Data analysis

The kinematic data were processed by VICON Nexus 2.6.1 and VICON Polygon software 4.3.3 program. The kinematic variables were the angles of CPD, HADD, HIR and KABD. The angles of each kinematic were defined as the peak knee flexion time point (PKFT) (the dashed line in figure 10) (41, 42) that increased the knee extensor moment and contributed to increased patellofemoral joint stress. (11) Each angle was averaged from five trials of single leg squat testing. (36)

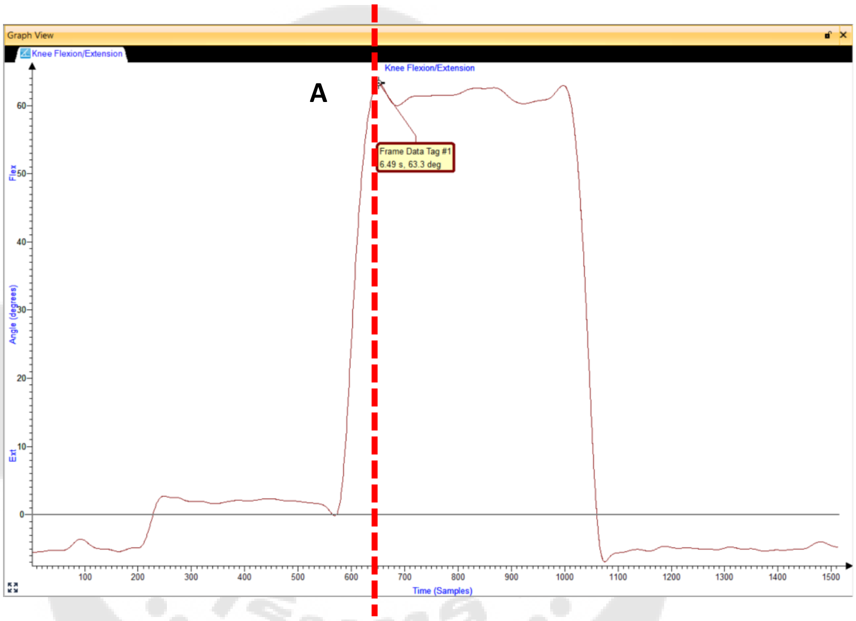

Figure 10 The peak knee flexion time point

Statistical Analysis

The normal distribution of all variables was analyzed by Shapiro-Wilk test. Paired samples t tests was used to compare the data between baseline and post-intervention in both groups. Independent samples test was used to compare the differences of change value between LASER group and control group.

CONSORT Flow Chart for summarize process of the study

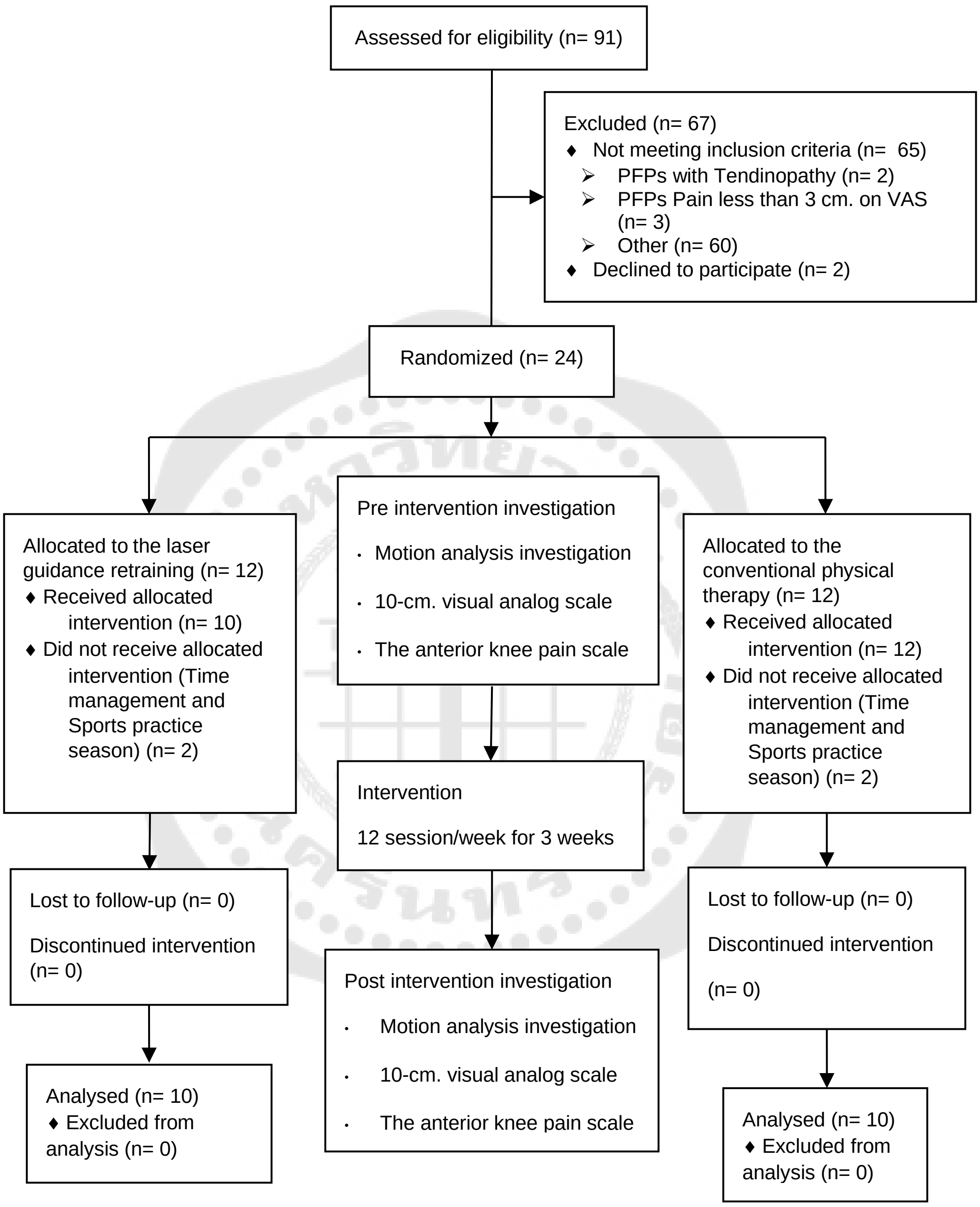

Figure 11 CONSORT Flow Chart for summarize process of the study

PFPs, Patellofemoral pain syndrome; VAS, 10 cm. Visual Analog Scale

Chapter IV
Result

The objective of this research was to investigate the effect of neuromuscular training by using the laser guidance technique in persons with patellofemoral pain syndrome on the alteration of lower extremity kinematics (e.g. contralateral pelvic drop, hip adduction, hip internal rotation and knee abduction). Additionally, symptom severity and functional ability improvement has been determined.

Demographic characteristics

Twenty-four persons with PFPs were recruited in this study. Two persons in LASER group and two persons in control group were not allocated the intervention after recruitment. Both LASER group (n=10) and control group (n=10) completed their intervention. The demographic characteristics of 20 participants were shown as in Table 2.

Table 2 Baseline demographic and clinical characteristics of LASER and Control group

Outcome measure	LASER group (n=10)	Control group (n=10)	*p-value*
Age (years)	24.00±4.88	28.30±9.50	0.224
Gender (Male : Female)	1 : 9	3 : 7	-
Body mass index (kg/m^2)	20.45 ±3.16	20.78±2.81	0.808
Symptom duration (months)	27.50 ±18.72	27.60±18.56	0.991
Pain severity (10-cm. VAS)	4.46±1.01	4.26±0.94	0.652
The anterior knee pain scale	76.9±8.23	77.3±8.92	0.918

Table 2 (Continued)

Outcome measure	LASER group (n=10)	Control group (n=10)	*p-value*
Area of pain (number of paticipants)			
Retropatellar	7	8	-
Peripatellar	7	3	-
PFPs side (number of paticipants)			
Only Left	3	1	-
Only Right	3	2	-
Both sides	4	7	-
Treatment side (Left: Right)	5 : 5	5 : 5	-
Functional activities aggravated symptom (number of paticipants)			
Prolong sitting	10	10	
Squatting	9	10	
Stair ascent/descent	9	9	
Jogging/running	6	6	
Hopping/jumping	3	7	
Kneeling	7	2	

Intra-tester reliability and SEM

The intra-rater reliability ($ICC_{3,1}$) of the marker replacement was measured in 10 healthy persons, a week period distance between 2 times of measurement for each person. Intraclass Correlation Coefficient model 3, 1 ($ICC_{3,1}$) use to statistical calculation, that the peak knee flexion angle was 0.856, the hip adduction angle was 0.740. Standard Error of measurement (SEM) of the peak knee flexion angle was 2.546, the hip adduction angle was 2.187. (Table 3)

Table 3 Intra-tester reliability ($ICC_{3,1}$) and SEM for the marker replacement of motion analysis system investigation in healthy persons

Variables	$ICC_{3,1}$	95% Confidence Interval Lower - Upper Bound	Variables
the peak knee flexion angle	0.856	0.483 - 0.958	2.546
the hip adduction angle	0.740	0.250 - 0.929	2.187

Kinematic data

Kinematic data (i.e., contralateral pelvic drop (CPD), hip adduction (HADD), hip internal rotation (HIR) and knee abduction (KABD) angles) were compared between LASER group and control group by using differences in change score between pre- and post- intervention in each group.

Between group difference, there was only statistically significant difference in HADD angle between LASER group and control group. HADD angle in LASER group was significantly decrease greater than control group (-7.40±5.61 and 2.38±5.57, respectively; p=0.001). However, there were not significantly differences in the CPD, KABD and HIR angles. The differences in change score of CPD and the KABD in LASER group tended to be greater than those in control group (CPD: LASER=3.96±4.31, control=0.71±2.37; p=0.082 and KABD: LASER=9.96±24.40 control=-6.42±17.02;

p=0.099). And HIR of both groups showed was not statistically significant difference (LASER=3.81±27.95, control=-4.12±16.05; p=0.446). (Table 4, Figure 12)

Within group difference, only LASER group represented statistically a significant decrease HADD after the laser guidance training (pre=11.92±7.38 and post=4.52±4.68; p=0.002), while control group remained unchanged after the conventional physical therapy intervention (pre=-14.27±9.37 and post=-16.65±8.00; p=0.209). After post-intervention in each group indicated that the LASER group did not change significantly in their CPD, HIR and KABD angle (CPD: pre=0.71±4.98 and post=2.88±3.48; p=0.145, HIR: pre=-10.07±27.39 and post=-6.25±12.69; p= 0.676 and KABD: pre=-8.01±22.72 and post=1.95±14.23; p=0.229). Similarly, control group did not change significantly in CPD, HIR and KABD angle after conventional treatment. (CPD: pre=-2.65±3.85and post=-2.62±4.07; p=0.968, HIR pre=-4.29±14.87 and post=-8.41±16.45; p= 0.438 and KABD: pre=1.35±15.92and post=-5.07±13.92; p=0.263) (Table 4, Figure 13)

Table 4 Lower extremity kinematic data between LASER group and control group and between pre-post intervention during single leg squat task

	Within group differences in pre-post intervention					Between group differences in change score			
	Pre-Intervention	Post-Intervention	95% Confident interval		*p-value*	Pre-Post Intervention Change score	95% Confident interval		*p-value*
			Lower	Upper			Lower	Upper	
CPD (-)									
LASER group	0.71±4.98	2.88±3.48	-0.91	5.26	0.145	3.96±4.31	-1.12	5.41	0.082
Control group	-2.65±3.85	-2.62±4.07	-1.66	1.72	0.968	0.71±2.37			
HADD (+)									
LASER group	11.92±7.38	4.52±4.68	-11.41	-3.39	0.002*	-7.40±5.61	-15.03	-4.53	0.001**
Control group	14.27±9.37	16.65±8.00	-1.60	6.36	0.209	2.38±5.57			
HIR (+)									
LASER group	-10.07±27.39	-6.25±12.69	-16.18	23.82	0.676	3.81±27.95	-13.48	29.35	0.446
Control group	-4.29±14.87	-8.41±16.45	-15.60	7.36	0.438	-4.12±16.05			
KABD (-)									
LASER group	-8.01±22.72	1.95±14.23	-7.50	27.41	0.229	9.96±24.40	-3.38	36.14	0.099
Control group	1.35±15.92	-5.07±13.92	-18.60	5.76	0.263	-6.42±17.02			

Table 4 (Continue)

NOTE Contralateral Pelvic Drop (CPD), Hip adduction (HADD) Hip internal rotation (HIR) and Knee abduction (KABD)

Comparison pre and post intervention within group.

* indicated Significant difference at p-value < 0.05 by Paired-samples T tests

$ indicated Significant difference at p-value < 0.05 by Wilcoxon signed-rank test

Comparison the pre and post intervention change between both groups.

** indicated Significant difference at p-value < 0.05 by Independent-samples T test

✧ indicated Significant difference at p-value < 0.05 by Mann Whitney U test

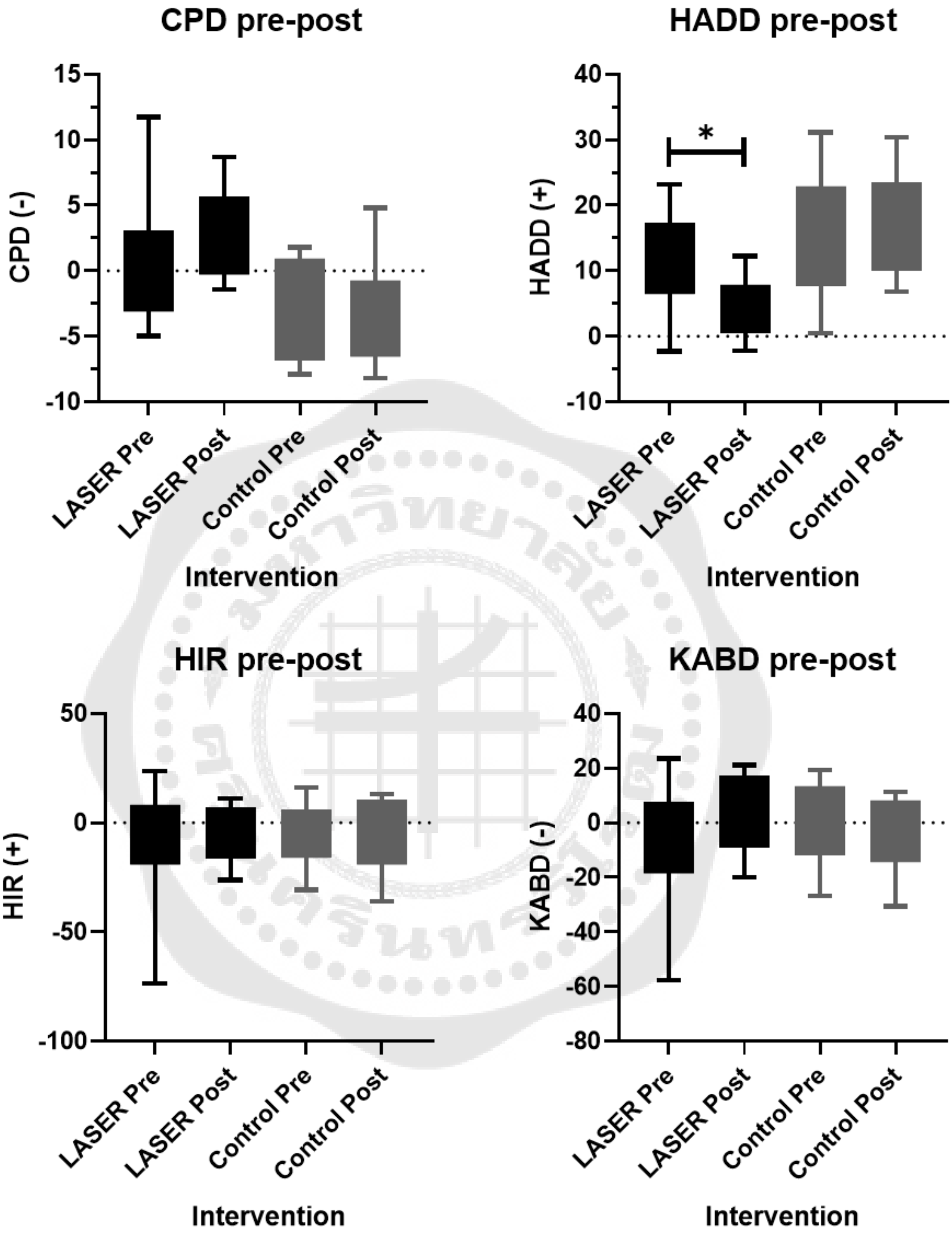

Figure 12 Within group kinematics data.

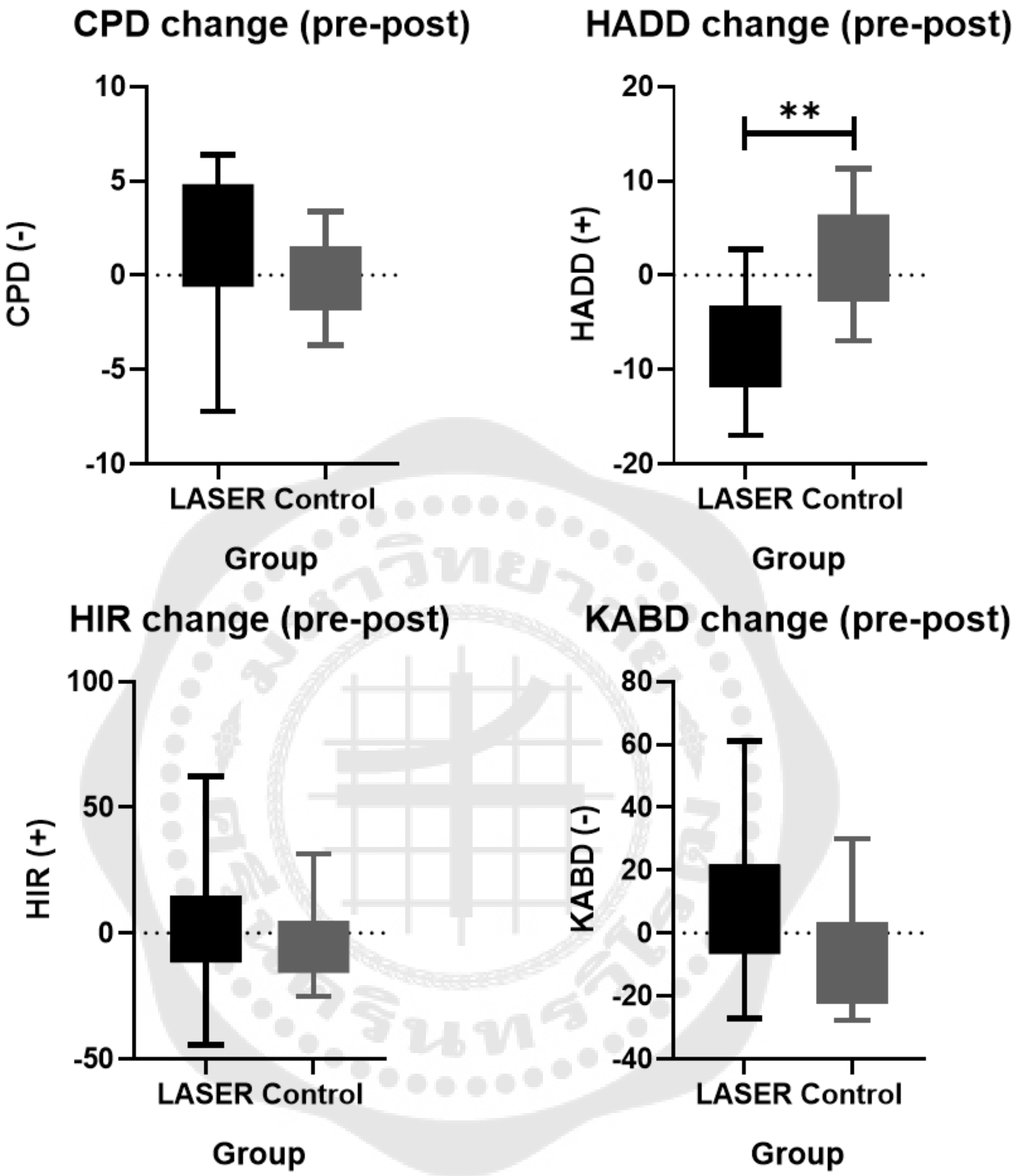

Figure 13 Between group difference in change score of kinematics data.

Pain severity data

The 10-cm. Visual Analog Scale (10-cm. VAS) was used to compare pain score between LASER group and control group by considering the differences in change score and between pre- and post- intervention within group.

At baseline (pre-intervention), this study represented no significant differences in pain severity between group (p=0.652). Between group difference, there was no statistically significant difference between LASER group and control group (-3.93±1.59 and -2.42±2.27, respectively; p=0.102). Within group difference, both LASER group and control group decreased significantly in pain score after intervention. (LASER: pre=4.46±1.01 and post=0.53±0.83; p=0.005 and control: pre=4.26±0.94 and post=1.84±1.93; p=0.022). (Table 5)

Functional ability

The Kujala Anterior Knee Pain score (AKPS) was used to compare the functional ability between LASER group and control group by considering the differences in change score and between pre- and post- intervention within group.

At baseline (pre-intervention), this study showed no significant differences in functional ability between LASER group and control group (p=0.918). Between group differences, there was not statistically significant difference in functional ability between LASER and control group (10.4±5.78 and 5.3±11.84, respectively; p=0.243). (Table 5)

Within group difference, only in LASER group that there was significantly increased functional ability after intervention when compared to before intervention (pre=76.9±8.23 and post=87.3±5.25; p=0.0001), whereas there was not significantly difference in functional ability between pre- and post-intervention in the control group (pre=77.3±8.92 and post=82.0±9.96; p=0.191) as in Table 5

Table 5 Symptom severity data (10-cm. VAS) during single leg squat task and Functional ability data (AKPS) between LASER group and control group

	Within group differences in pre-post intervention					Between group differences in change score			
	Pre-Intervention	Post-Intervention	95% Confident interval		*p-value*	Pre-Post Intervention Change score	95% Confident interval		*p-value*
			Lower	Upper			Lower	Upper	
10-cm. VAS									
LASER group	4.46±1.01	0.53±0.83	-5.13	-2.70	0.005$	-3.93±1.59	-3.35	0.33	0.102
Control group	4.26±0.94	1.84±1.93	-4.25	-0.85	0.022$	-2.42±2.27			
AKPS									
LASER group	76.9±8.23	87.3±5.25	6.27	14.53	0.0001*	10.4±5.78	-3.90	14.10	0.243
Control group	77.3±8.92	82.0±9.96	-3.17	13.77	0.191	5.3±11.84			

NOTE

Comparison pre and post intervention within group.

* indicate Significant difference at p-value < 0.05 by Paired-samples T tests

$ indicate Significant difference at p-value < 0.05 by Wilcoxon signed-rank test

Comparison the pre and post intervention change between both groups.

** indicate Significant difference at p-value < 0.05 by Independent-samples T test

✧ indicate Significant difference at p-value < 0.05 by Mann Whitney U test

Chapter V
Summary Discussion and Suggestion

The current study investigated the movement skill relearning after the neuromuscular training by using laser guidance technique during squats task. We hypothesized that the contralateral pelvic drop (CPD), hip adduction (HADD), hip internal rotation (HIR) and knee abduction (KABD) in LASER group would decrease when compared to control group. Moreover, LASER group would also reduce pain severity and improve functional ability.

Regarding the lower extremity kinematics, LASER group showed only a significant decrease in hip adduction when compared to control group (LASER= -7.40±5.61 and control=2.38±5.57; p=0.001). Additionally, after training in LASER group, there was a significant decrease in HADD angle during single leg squat task as compared to before training (-7 .4 0 ±5 .6 1 , p=0.002). Although HADD at baseline of LASER group in the current study showed greater than HADD angle of healthy persons in the other study (LASER pre-retraining=11.92±7.38 and healthy=8.6±7.2), HADD after the retraining in LASER group represented less than HADD in healthy persons (LASER post-retraining=4.52±4.68 and healthy=8.6±7.2). (97)

According to the previous studies, Noehren et al, (2010) (38) and Willy RW et al, (2012) (40) investigated the effect of neuromuscular training by using visual feedback from visual 3D monitor and mirror in PFPs persons on the lower extremity kinematics during running on the treadmill. These studies found that there were significantly decreased contralateral pelvic drop and hip adduction after neuromuscular training. Due to the subjects were instructed to abduct their thigh by using visual feedback. (38, 40)

Refer to Adams Closed-loop feedback theory (*Jack A. Adams, 1971*) (34), the current study used the laser pointer that was the external feedback or augmented feedback to engender the relearning to correct abnormal lower extremity kinematics (e.g. decreased hip adduction). The laser pointer attached the thigh of participants was a visual feedback (i.e. sensory feedback) by using a laser beam to guide the abduction of femur during squat tasks ('double leg squat' task, 'double leg squat with partial weight-bearing' task and 'single-leg squat' task,). In Adam's Close-loop feedback theory, the sensory receptors sent the information from sensory feedback afferent to the control center for generating the relearning. In accordance with the sensory processing signal information from receptors integrated through CNS to motor system. (33, 71) First, the memory trace was used to select and initiate the hip abduction during the squat movement from the last memory of squat task in initiated response. Afterward, the perceptual trace was used to determine hip muscle control to abduct thigh during squat movement by guidance with sensory feedback (i.e. the current study used visual feedback from the laser beam and proprioceptive feedback from muscle and joint movement). (71) Finally, the new movement skill was an ongoing adjusted action. (34) This theory suggested that the practice to correct LE kinematics was updated in the control center to generate the new movement skill.

CPD angle in the current study was not a significant difference between pre- and post-training in LASER group. Contrary to previous studies CPD angle decreased after the visual 3D monitor or mirror retraining program. (38, 40) Due to the previous studies, subjects were instructed to raise contralateral pelvic by observing the quality of movement in the visual 3D monitor or mirror whereas the participants in current study were only instructed to abduct thigh. (38, 40) And our study did not exhibit CPD at baseline of LASER group. These results suggested that visual feedback was the importance in neuromuscular training for relearning a new movement skill. Likewise, several studies showed that the sensory feedback stimulation in motor relearning program was effective program in both PFPs and healthy persons to alter the new movement skill of pelvic, hip and knee joint. (36, 80, 81, 98) However, the result of HIR in the current study was similar to previous studies that there was no alteration in HIR after the retraining. (38, 40) Due to the subjects in the current study and the previous studies did not exhibit excessive hip internal rotation at baseline which PFPs usually showed HIR angle. (38, 40-42) Moreover, HIR was the small range of motion in transverse plane during weight bearing. It may be difficult to detect the change in this angle. In addition, the KABD in the current study did not change significantly after LASER retraining. Consist with the previous studies, (41, 42) they studied the immediate effect of movement pattern modification on lower extremity kinematics during single leg squat. They found that there was not significant difference in the KABD, although the HADD decrease after corrected LE kinematics. (41, 42)

The most important goals of persons with PFPs were the reduction of pain severity (10-cm. VAS) and the improvement of functional ability (AKPS). The current study found that there was no significant difference in pain score between groups (p=0.102). LASER group and control group reduced pain score to 3.93 and 2.42 of 10-cm. VAS, which the pain reduction was approximately 88% and 57%, respectively. Both groups decreased pain preponderant 2 cm. that was more than the minimal clinically important difference (MCID). (84) It indicated that the NM training in LASER group and conventional physical therapy in control group could relieve pain after intervention. According to the studies of Noehren B et al, 2011 and Willy RW et al, 2012, (38, 40) the neuromuscular (NM) training from visual 3D monitor and mirror feedback for PFPs person could reduce pain score approximately 86% and 90.5%, respectively and maintain the pain relief up to a month and three months after completed intervention. Furthermore, the pain reduction after NM training was greater than pain reduction after strengthening program that was approximately at 41.3 to 87.5%. (20, 22-24, 26, 27)

The current study also found that there was no significant difference in functional ability between groups (p=0.243). It denoted that both LASER and control group improved the functional ability. However, LASER group exhibited increased AKPS score to 10.4 of 100 as 13.52% after training, which greater than MCID of AKPS (i.e. more than 10 scores), (84) whereas AKPS in control group increased 5.3 of 100 as 6.86% after intervention. Increased AKPS score in control group did not statistically and clinically improve the functional ability. (84) Moreover, 9 of 10 participants in LASER group exhibited the increased AKPS score, while only 6 of 10 in control group showed the increased AKPS score. The improved items of AKPS questionnaire in LASER group were walking, stair ambulation, running and prolong sitting items. The current study used the squat tasks for neuromuscular training, especially the single leg squat which aggravated symptom in persons with PFPs. The single leg squat was unilateral weight bearing that was similar to activity in AKPS questionnaire as walking, weight bearing stair ambulation, running and hopping/jumping. Therefore, It is possible that the items regarding weight bearing activities may be improved in LASER group.

The results represented only the alteration of hip joint in frontal plane (i.e. reduced hip adduction and no change in HIR angle). In addition, the current study did not investigate the segment of femoral internal rotation which was a contributing factor in PFPs. The investigation to detect the segmental angle in transverse plane may be essential analysis in the further study.

Reduced pain severity in LASER group may result from reduced HADD. HADD angle measurement was an indirect measure of ITB length test. According to previous study, (57) the persons with PFPs exhibited ITB tightness. Due to the ITB tightness is a cause of PFPs, the distal part of ITB attaches to lateral retinaculum of the patella, that may pull laterally the patella on trochlear of femur and result in decreased the patellofemoral joint contact area, increased patellofemoral joint stress and contribute to PFPs. (57, 99, 100) Consequently, decreasing in the hip adduction during single leg squat in the current study may reduce ITB tension which may decrease pulling the patella to lateral translation (57, 99, 100) and reduce the patellofemoral joint compression. (11)

From the previous studies concerning the effect of hip strengthening exercise program on pain, function and biomechanics, Earl and Hoch, (2011) (22) and Ferber et al, (2011), (23) found that the strengthening exercise program could reduce pain symptom, improve functional ability and increase muscle strength, but could not correct the lower extremity biomechanics. Due to the insufficient neuromuscular control in PFPs persons (28-32) that resulted in abnormal lower extremity kinematics as a contributing factor to PFPs. Therefore, training with strengthening program may be inadequate to promote the normal lower extremity kinematics and result in recurrent pain symptoms.

Furthermore, the duration of strengthening program was approximately 3 to 12 weeks (20-27) that was longer than the NM training program.

Limitations and Suggestion

First, the current study did not investigate the segmental angle of femur because the limitation of model used to collect and analyze the data. Second, this study did not investigate gluteal muscle activity to confirm the improvement of neuromuscular control. Due to neuromuscular control in functional activities must process the signal information from receptors through CNS to muscle for controlling movement. The further study should also examine the gluteal muscle activity during movement. Third, the current study investigated the effect of neuromuscular training on hip and knee kinematics, pain and functional ability only after training. Finally, the current study did not investigate the other tasks in daily activities aggravated pain severity and resulted in the abnormal kinematics. The further study should be followed up the long-term effect of the neuromuscular training on all outcomes whether can maintain the normal kinematics, pain reduction and functional ability improvement. Furthermore, it should be investigated the effect of this protocol NM training on kinematics whether can transfer the NM control to the other tasks.

Clinical implication

The laser guidance is an external cue to enhance intrinsic feedback for neuromuscular training. Additionally, the laser guidance kit is a compact portable tool, easy to use and inexpensive. The clinicians can apply this neuromuscular training protocol by using laser guidance kit in an individual with PFPs to alter the abnormal lower extremity kinematic, reduce the severity of the pain symptom and improve functional ability.

Summary

The neuromuscular retraining using the laser guidance technique was effective protocol to reduce hip adduction, pain severity and improve functional ability.

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Appendix

Appendix A

เอกสารรับรองจริยธรรมวิจัยในมนุษย์

MF-04-version-2.0
วันที่ 18 ต.ค. 61

หนังสือรับรองจริยธรรมการวิจัยของข้อเสนอการวิจัย
เอกสารข้อมูลคำอธิบายสำหรับผู้เข้าร่วมการวิจัยและใบยินยอม
หมายเลขข้อเสนอการวิจัย SWUEC- 487/2561E

ข้อเสนอการวิจัยนี้และเอกสารประกอบของข้อเสนอการวิจัยตามรายการแสดงด้านล่าง ได้รับการพิจารณาจากคณะกรรมการจริยธรรมสำหรับพิจารณาโครงการวิจัยที่ทำในมนุษย์ มหาวิทยาลัยศรีนครินทรวิโรฒแล้ว คณะกรรมการฯ มีความเห็นว่าข้อเสนอการวิจัยที่จะดำเนินการมีความสอดคล้องกับหลักจริยธรรมสากล ตลอดจนกฎหมาย ข้อบังคับและข้อกำหนดภายในประเทศ จึงเห็นสมควรให้ดำเนินการวิจัยตามข้อเสนอการวิจัยนี้ได้

ชื่อโครงการวิจัยเรื่อง: ผลของการฝึกโดยใช้แสงเลเซอร์เป็นตัวนำทางต่อการเปลี่ยนแปลงการเคลื่อนไหวของข้อสะโพกและข้อเข่าในผู้ป่วยที่มีอาการปวดเข่าทางด้านหน้า: การทดลองแบบสุ่มมีกลุ่มควบคุม

ชื่อผู้วิจัยหลัก: นายธนภัทร วิทยาวราพงศ์

สังกัด: คณะกายภาพบำบัด

เอกสารที่รับรอง:
1. แบบเสนอโครงการวิจัย
2. โครงการวิจัย
3. เอกสารชี้แจงผู้เข้าร่วมการวิจัย
4. หนังสือให้ความยินยอมเข้าร่วมโครงการวิจัย

เอกสารที่พิจารณาทบทวน

1. แบบเสนอโครงการวิจัย	ฉบับที่ 1 วัน/เดือน/ปี 21 ก.พ. 2562
2. โครงร่างการวิจัย	ฉบับที่ 1 วัน/เดือน/ปี 21 ก.พ. 2562
3. เอกสารชี้แจงผู้เข้าร่วมการวิจัย	ฉบับที่ 1 วัน/เดือน/ปี 21 ก.พ. 2562
4. หนังสือให้ความยินยอมเข้าร่วมโครงการวิจัย	ฉบับที่ 1 วัน/เดือน/ปี 21 ก.พ. 2562

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หมายเลขรับรอง : SWUEC/E-487/2561
วันที่ให้การรับรอง : 21/02/2562
วันหมดอายุใบรับรอง : 21/02/2563

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Appendix B

แบบสอบถามคัดกรองข้อมูลอาสาสมัครเพื่อเข้าร่วมงานวิจัย

คณะกายภาพบำบัด มหาวิทยาลัยศรีนครินทรวิโรฒ

คำชี้แจง

เรื่อง ผลของการฝึกโดยใช้แสงเลเซอร์เป็นตัวนำทางต่อการเปลี่ยนแปลงการเคลื่อนไหวของข้อสะโพกและข้อเข่าในผู้ป่วยที่มีอาการปวดเข่าทางด้านหน้า

วัตถุประสงค์

1. เพื่อเปรียบเทียบผลของการเปลี่ยนแปลงการเคลื่อนไหวของการตกลงของเชิงกรานฝั่งตรงข้ามเข่าข้างบาดเจ็บ การหุบเข้าและการหมุนเข้าด้านในของข้อต่อข้อสะโพก และการกางออกข้องเข่าหลังการรักษา
2. เพื่อเปรียบเทียบผลของความรุนแรงของอาการเจ็บหลังการรักษา
3. เพื่อเปรียบเทียบความสามารถในการทำกิจวัตรประจำวันต่างๆ หลังการรักษา

คำอธิบาย : กรุณากรอกข้อมูลและทำเครื่องหมาย ✓ ลงในช่องว่าง ☐ ที่กำหนดให้ โดยให้ข้อมูลตามจริงมากที่สุด (ข้อมูลดังกล่าวจะไม่ถูกเผยแพร่แต่ประการใด)

Subject No. .... วันที่กรอกข้อมูล ..../........./.......... เวลา...........

1. ข้อมูลส่วนตัวและข้อมูลติดต่อ

 1.1 อายุ...................ปี เพศ ☐ ชาย ☐ หญิง

 1.2 ส่วนสูง...........เซนติเมตร น้ำหนัก...........กิโลกรัม BMI.........กก./ม^2(ไม่ต้องระบุ)

 1.3 เบอร์โทรศัพท์............................. LINE/E-mail…………………..……….……..

2. ข้อมูลเพื่อคัดกรองเข้าร่วมงานวิจัย

 2.1 ท่านมีอาการปวดเข่าด้านหน้าหรือบริเวณลูกสะบ้าหรือไม่

 ☐ มี ☐ ไม่มี

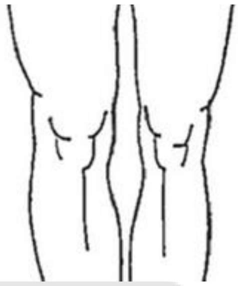
 2.2 ขาข้างที่มีอาการ

- ☐ ซ้าย ☐ ขวา (หรือ)
- ☐ มีอาการสองข้าง; ระบุขาข้างที่มีอาการมากที่สุด ☐ ซ้าย ☐ ขวา (หรือ)
- ☐ หากอาการเท่ากันสองข้าง; ระบุขาข้างที่ถนัด ☐ ซ้าย ☐ ขวา

2.3 ท่านมีอาการปวดบริเวณใดของเข่าด้านหน้า(ระบุตำแหน่งในภาพข้างล่าง)

☐ รอบ ๆ กระดูกสะบ้า

☐ ใต้ต่อกระดูกสะบ้า



2.4 ท่านมีอาการปวดในกิจกรรมใดต่อไปนี้

☐ นั่งนานๆ ☐ ยืนย่อเข่า ☐ ขึ้น-ลงบันได ☐ วิ่ง

☐ กระโดด ☐ ท่ายืนเข่า

☐ อื่นๆ โปรด

ระบุ:……………………………………………………………………………………

กิจกรรมที่มีอาการเจ็บมากที่สุด ระบุ:…………………………………………………

2.5 ระดับความเจ็บ

ระดับความเจ็บมากที่สุดในสัปดาห์ที่ผ่านมา

0 |————————————————| 10

ระดับความเจ็บขณะพักในสัปดาห์ที่ผ่านมา

0 |————————————————| 10

ระดับความเจ็บในท่ายืนย่อเข่าลงบนขาข้างเดียว

0 |————————————————| 10

2.6 ท่านมีอาการปวดมาเป็นระยะเวลานานเท่าไหร่

……….ปี ....เดือน ....สัปดาห์ ....วัน

2.7 ท่านเคยให้รักษาตนเองหรือเคยได้รับการรักษาอาการดังกล่าวมาก่อนหรือไม่ และครั้งล่าสุดที่รับการรักษาผ่านมานานเท่าไหร่

☐ เคย ☐ ไม่เคย; ☐ ด้วยตนเอง ☐ ด้วยบุคลากรทางการแพทย์อื่น

การรักษา...

ระยะเวลาที่รับการรักษา ....ปี ....เดือน ....สัปดาห์ ....วัน

ครั้งล่าสุด ผ่านมานานแค่ไหน ....ปี ....เดือน ....สัปดาห์ ....วัน

3. ข้อมูลสุขภาพ

3.1 ปัจจุบันลักษณะกิจกรรมหลักที่ท่านทำในชีวิตประจำวันเป็นอย่างไร

☐ ระดับน้อย (นั่งโต๊ะเป็นส่วนใหญ่ เช่น เรียนหนังสือ/ทำงานนั่งโต๊ะ)

☐ ระดับปานกลาง (นั่งเป็นครั้งคราว)

☐ ระดับค่อนข้างมาก (เดินบ่อยครั้ง)

☐ ระดับมาก (ทำงานหนัก เช่น ยืน-เดินนาน, ใช้กำลัง, ออกกำลังกาย)

3.2 ปกติท่านออกกำลังกายหรือไม่ ลักษณะการออกกำลังกายหรือกีฬาเป็นอย่างไร

☐ นักกีฬา ☐ ออกกำลังกาย ☐ ไม่ออกกำลังกาย

ระบุ (ตอบได้มากกว่า 1) ....

☐ มากกว่า 2 วัน/สัปดาห์ ☐ น้อยกว่าหรือเท่ากับ 2 วัน/สัปดาห์

3.3 ท่านออกกำลังกายครั้งล่าสุดมานานแค่ไหน

☐ ไม่เกิน 1 สัปดาห์ที่ผ่านมา

☐ เกิน 1 สัปดาห์ ถึง 1 เดือน

☐ เกิน 1 เดือน ระบุจำนวน..........เดือน

3.4 หากไม่ได้ออกกำลังกาย ท่านเว้นการออกกำลังกายเนื่องจากสาเหตุใด

☐ เนื่องจากอาการบาดเจ็บ บริเวณ...............................

☐ ปัจจัยอื่น ระบุ...........................

3.5 ประวัติอุบัติเหตุ/ได้รับการบาดเจ็บ

☐ เคยประสบอุบัติเหตุ/ได้รับการบาดเจ็บ ลักษณะบริเวณ…………….………….

☐ ไม่เคย

3.6 ประวัติการรักษาอาการบาดเจ็บดังกล่าว (หาก<u>ไม่เคย</u>ในข้อ 3.5 ไม่ต้องตอบ)

ระบุ...

☐ ไม่เกิน 6 เดือน ☐ เกิน 6 เดือน ระบุ...........เดือน

☐ เกิน 12 เดือน ระบุ.......... เดือน..........ปี

3.7 ประวัติการผ่าตัด

☐ เคยมีประวัติ บริเวณ.......................ได้รับการผ่าตัดเมื่อใด......................

☐ ไม่เคยมีประวัติ

3.8 ประวัติกระดูกหัก

☐ เคยมีประวัติ บริเวณ.......................ได้รับการผ่าตัดเมื่อใด......................

☐ ไม่เคยมีประวัติ

3.9 ท่านมีโรคประจำตัวเกี่ยวกับหัวใจและหลอดเลือด หรือโรคทางระบบประสาทหรือไม่

☐ หัวใจและหลอดเลือด

☐ โรคทางระบบประสาท การบาดเจ็บที่ส่งผลต่อเส้นประสาท ทำให้เกิดอาการชา อ่อนแรง หรือสูญเสียการทรงตัว บริเวณ...

☐ ไม่มี

3.10 โรคประจำตัว

☐ มี ระบุ

....

☐ ไม่มี

Appendix C

แบบบันทึกการตรวจประเมินอาสาสมัครผู้เข้าร่วมงานวิจัย

Subject No. ………………..

Investigation No. ……………………

วันที่กรอกข้อมูล ..../........./..........   เวลา............

Dx. Patellofemoral pain syndrome ☐ positive   ☐ negative

1. Group

   1.1 ☐ Laser guidance group   ☐ Conventional physical therapy group

2. Patellofemoral pain syndrome assessment

   2.1 Anterior knee pain during functional activities

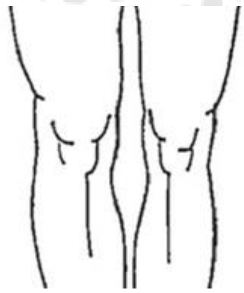
   ☐ Yes   ☐ No

   ☐ Peripatellar knee pain   ☐ Retropatellar knee pain

   2.2 Involved side

   ☐ Left   ☐ Right; or most pain at ☐ Left   ☐ Right

   2.3 Pain area



   2.4 Functional activities relate pain

   ☐ Prolong sitting   ☐ Squat   ☐ Stair ambulation

   ☐ Jogging/Running   ☐ Hopping/Jumping   ☐ Kneeling

   ☐ More than 2/6   ☐ Less than 2/6

2.5 Pain scale

☐ During aggravate pain………………(of 10)

☐ During resting………………(of 10)

☐ During single leg squat………………(of 10)

Duration of symptom

☐ at least 2 months ☐ less than 2 months

……….years ....months ....weeks ....days

2.6 Treatment history

☐ No ☐ less than 12 months ago ☐ more than 12 months ago

Treatment..

Treatment duration …….years ....months ....weeks ....days

Last time ……….years ....months ....weeks ....days

3. Observable excessive hip adduction or dynamics knee valgus during

☐ Excessive hip adduction ☐ Excessive dynamics knee valgus

☐ Not found

4. Other

3.1 Pain relates to trauma

☐ Yes ☐ No

☐ Knee menisci ☐ Ligament

☐ Synovial plica ☐ Bursa

3.2 Lower extremity surgery history

☐ Yes ☐ No

3.3 Injury or pain limit during double leg squat training

☐ Yes ☐ No

3.4 Neurological or cardiorespiratory disorder

☐ Yes ☐ No

3.5 Discontinuation

☐ Yes ☐ No; Cause ☐ pain greater than 1.3/10 ☐ Other...........

Appendix D

แบบประเมินระดับความเจ็บ 10-cm. Visual analog scale

ในท่าทางยืนย่อเข่าลงบนขาข้างเดียว (Single leg squat)

Subject No. …………….........**วันที่เก็บข้อมูล** ....

Score ……….. of 10

ไม่เจ็บ |———————————————| **เจ็บมากที่สุด**

Appendix E

แบบประเมินอาการปวดข้อกระดูกสะบ้าตามแบบ Kujala ฉบับภาษาไทย*

		คะแนน
1	**การเดินกะเผลก**	
	ก.) ไม่มี	5
	ข.) เล็กน้อยหรือเป็นบางครั้ง	3
	ค.) ตลอดเวลา	0
2	**การลงน้ำหนัก**	
	ก.) ลงน้ำหนักได้เต็มที่โดยไม่เจ็บปวด	5
	ข.) มีอาการเจ็บปวด	3
	ค.) ไม่สามารถลงน้ำหนักได้	0
3	**การเดิน**	
	ก.) เดินได้ไม่จากัด	5
	ข.) เดินได้มากกว่า 2 กิโลเมตร	3
	ค.) เดินได้ 1 ถึง 2 กิโลเมตร	2
	ง.) ไม่สามารถเดินได้	0
4	**การขึ้น-ลงบันได**	
	ก.) ไม่มีความลำบาก	10
	ข.) เจ็บปวดเล็กน้อยเมื่อลงบันได	8
	ค.) เจ็บปวดทั้งขึ้นและลงบันได	5
	ง.) ไม่สามารถขึ้น-ลงบันไดได้	0
5	**การนั่งยอง**	
	ก.) ไม่มีความล่าบาก	
	ข.) เจ็บปวดเมื่อนังยองซ้ำๆ	4
	ค.) เจ็บปวดเมื่อนั่งยองทุกครั้ง	3
	ง.) นั่งยองได้หากลงน้ำาหนักแค่บางส่วน	2
	จ.) ไม่สามารถนั่งยองได้	0
6	**การวิ่ง**	
	ก.) ไม่มีความลำบาก	10
	ข.) เจ็บปวดหลังจากวิ่งมากกว่า 2 กิโลเมตร	8
	ค.) เจ็บปวดเล็กน้อยตั้งแต่เริ่มวิ่ง	6
	ง.) เจ็บปวดรุนแรง	3
	จ.) ไม่สามารถวิ่งได้	0
7	**การกระโดด**	
	ก.) ไม่มีความลำบาก	10
	ข.) มีความลำบากเล็กน้อย	7
	ค.) เจ็บปวดตลอดเวลาที่กระโดด	2
	ง.) ไม่สามารถกระโดดได้	0

		คะแนน
8	**การนั่งงอเข่าเป็นเวลานาน**	
	ก.) ไม่มีความลำบาก	10
	ข.) เจ็บปวดเมื่อ นั่งงอเข่าเป็นเวลานานหลังออก กำลังกาย	8
	ค.) เจ็บปวดตลอดเวลาที่นั่งงอเข่าเป็นเวลานาน	6
	ง.) ความเจ็บปวดทำให้ต้องยืดขาเป็นบางครั้ง	4
	จ.) ไม่สามารถนั่งงอเข่าเป็นเวลานาน	0
9	**ความเจ็บปวด**	
	ก.) ไม่มี	10
	ข.) เล็กน้อยและเป็นบางครั้ง	8
	ค.) รบกวนการนอนหลับ	6
	ง.) รุนแรงเป็นบางครั้ง	3
	จ.) รุนแรงและตลอดเวลา	0
10	**อาการบวม**	
	ก.) ไม่มี	10
	ข.) มีอาการหลังจากออกแรงมาก	8
	ค.) มีอาการหลังการทำกิจวัตรประจำวัน	6
	ง.) มีอาการทุกเย็น	4
	จ.) มีอาการตลอดเวลา	0
11	**มีการเคลื่อนที่ผิดปกติของกระดูกสะบ้าร่วมกับมีอาการปวด(มีการเคลื่อนหลุดบางส่วน)**	
	ก.) ไม่มี	10
	ข.) เป็นบางครั้งในการเล่นกีฬา	6
	ค.) เป็นบางครั้งในการทำกิจวัตรประจำวัน	4
	ง.) มีการเคลื่อนหลุดที่มีการบันทึกไว้ชัดเจนอย่างน้อย 1 ครั้ง	2
	จ.) มีการเคลื่อนหลุดมากกว่า 2 ครั้ง	0
12	**การลีบฝ่อของต้นขา**	
	ก.) ไม่มี	5
	ข.) เล็กน้อย	3
	ค.) รุนแรง	0
13	**ความบกพร่องในการงอเข่า**	
	ก.) ไม่มี	5
	ข.) เล็กน้อย	3
	ค.) รุนแรง	0

(*คะแนนสูงสุด= 100) ***คะแนนรวม*** = ...

Subject No. ....วันที่เก็บข้อมูล ....

Source: Apivatgaroon A, Angthong C, Sanguanjit P, Chernchujit B. The validity and reliability of the Thai version of the Kujala score for persons with patellofemoral pain syndrome. Disabil Rehabil [Internet]. 2016;8288(January):1–4.

Appendix F

Table 1 The laser guidance retraining protocol of LASER group

Weeks	Sessions	Description	Feedback and withdrawal
1 (Stage 1)	1 2	DLS 5 reps/set, 3 sets/trial for 2 trials DLSP 5 reps/set, 3 sets/trial for 1 trial SLS 5 reps/set, 3 sets/trial for 1 trial	▪ Laser guidance throughout the protocol ▪ Instruction (only 1st session)
	3	DLS 8 reps/set, 3 sets/trial for 2 trials DLSP 8 reps/set, 3 sets/trial for 1 trial SLS 8 reps/set, 3 sets/trial for 1 trial	
	4	DLS 10 reps/set, 3 sets/trial for 2 trials DLSP 10 reps/set, 3 sets/trial for 1 trial SLS 10 reps/set, 3 sets/trial for 1 trial	
2 (Stage 2)	5 - 8	DLS 10 reps/set, 3 sets/trial for 1 trial DLSP 10 reps/set, 3 sets/trial for 2 trials SLS 10 reps/set, 3 sets/trial for 1 trial	▪ Laser guidance: only 1st & 2nd sets of each trial ▪ Instruction (only 5th session)
3 (Stage 3)	9 10	DLS 10 reps/set, 3 sets/trial for 1 trial DLSP 10 reps/set, 3 sets/trial for 1 trial SLS 10 reps/set, 3 sets/trial for 2 trials	▪ Laser guidance: only 1st set of each trial ▪ Instruction (only 9th session)
(Stage 4)	11 12	DLS 10 reps/set, 3 sets/trial for 1 trial DLSP 10 reps/set, 3 sets/trial for 1 trial SLS 10 reps/set, 3 sets/trial for 2 trials	▪ Removal the laser guidance ▪ Instruction only at the end of each trial (only 11th session)

Appendix G

The leaflet about Patellofemoral pain syndrome

ข้อควรปฏิบัติขณะเข้าร่วมโครงการวิจัย

ขอความกรุณา..งดปฏิบัติ

- งดกิจกรรมที่มีการลงน้ำหนักหรือแรงกระแทกต่อรยางค์ขามากๆ เช่น วิ่ง กระโดด ฯลฯ
- งดกีฬาประเภทที่มีการวิ่ง กระโดด หรืออื่นๆ ที่เกิดการลงน้ำหนักหรือแรงกระแทกต่อรยางค์ขามากๆ เช่น ฟุตบอล บาสเกตบอล วอลเลย์บอล แบดมินตัน เทนนิส ฯลฯ
- งดกิจกรรมที่ใช้แรงถีบรยางค์ขาหรือมีการยืนย่อเข่ามากๆ เช่น เล่นชักเย่อ ปีนเขา การออกกำลังขาโดยใช้ Seated leg press
- ไม่รับการรักษาอาการปวดเข่าด้วยวิธีอื่นใด เว้นแต่เป็นการบาดเจ็บจากอุบัติเหตุหรือด้วยสาเหตุอื่นจากที่เป็นอยู่เดิม (กรุณาแจ้งให้ผู้วิจัยทราบ)

ขอความกรุณา..ระวัง/เลี่ยง ในการปฏิบัติ

- ระวัง/เลี่ยงกิจกรรมที่ต้องมีการย่อเข่าพร้อมกับลงน้ำหนักรยางค์ขา แม้จะไม่มีแรงกระแทกในการลงน้ำหนักมากนัก เช่น ท่ายืนย่อเข่า เดินขึ้น-ลงบันได โดยปรับท่าทางการเคลื่อนไหวรยางค์ขาให้เหมาะสม เพื่อลดอาการเจ็บขณะทำท่าทางนั้นๆ
- ระวัง/เลี่ยงท่าที่ต้องมีการงอเข่ามากๆ เป็นเวลานาน เช่น นั่งงอเข่า นั่งพับเพียบ นั่งขัดสมาธิ นั่งยอง โดยการเปลี่ยนอิริยาบถอย่างสม่ำเสมอ เมื่ออยู่ท่าเดิมเป็นเวลานานหรือมีอาการปวด

เอกสารฉบับนี้ เป็นส่วนหนึ่งของโครงการวิจัยนิสิตปริญญาโท คณะกายภาพบำบัด มหาวิทยาลัยศรีนครินทรวิโรฒ

ที่ปรึกษา ผศ.ดร.ชิงฎา ชินกุลประเสริฐ

เรียบเรียงและจัดทำโดย ธนภัทร วิทยาวราพงศ์

หากมีปัญหาหรือต้องการปรึกษา กรุณาติดต่อ

ธนภัทร วิทยาวราพงศ์ หัวหน้าโครงการวิจัย

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ปวดเข่า
บริเวณผิวสะบ้า

กลุ่มอาการปวดเข่าบริเวณผิวสะบ้า
or Patellofemoral pain syndrome

อาการ ปวดเข่า...จะมีความรู้สึกปวดที่ข้อเข่าด้านหน้าบริเวณระหว่างกระดูกต้นขากับรอบ ๆ และ/หรือ ใต้ต่อลูกสะบ้า โดยอาการมักจะเกิดขึ้นในท่าทางหรือกิจวัตรที่มีการงอเข่าร่วมกับการลงน้ำหนักที่รยางค์ขา

ท่าทาง/กิจวัตรที่กระตุ้นอาการ

- นั่งงอเข่าเป็นเวลานาน นั่งยอง พับเพียบ ขัดสมาธิ
- ยืนย่อเข่า (Squat)
- เดินขึ้น-ลงบันได หรือ ที่ลาดชัน
- วิ่ง หรือแม้แต่การวิ่งเหยาะๆ
- จังหวะลงจากการกระโดด หรือกระโดดลงจากที่สูง
- การยืนเข่า หรือ เดินเข่า
- ท่าทางที่ต้องออกแรงเกร็งกล้ามเนื้อต้นขาด้าน

สาเหตุและปัจจัยเสริม

Patellofemoral pain syndrome
มักพบในนักกีฬาที่ต้องมีการวิ่ง กระโดด หรือกิจกรรมที่มีการงอเข่าร่วมกับการลงน้ำหนักมากๆ ติดต่อกันเป็นเวลานาน เช่น วิ่ง บาสเกตบอล ดังนั้นจึงมักพบปัญหานี้ในกลุ่มวัยรุ่น และวัยผู้ใหญ่ตอนต้นมากกว่าวัยอื่นๆ โดยเฉพาะในกลุ่มคนที่มีกิจกรรมในชีวิตประจำวันที่หนัก ออกกำลังกาย หรือเล่นกีฬาหนักๆ เป็นประจำ มักพบในเพศหญิงมากกว่าเพศชาย เนื่องจากลักษณะการเคลื่อนไหวของรยางค์ขาที่ผิดปกติไปในเพศหญิง โดยมีปัจจัยที่เป็นสาเหตุดังนี้..

1. แรงกดอัดระหว่างผิวสะบ้าต่อผิวข้อของกระดูกต้นขา

จากความผิดปกติในการเคลื่อนไหวของสะบ้าไปบนผิวข้อต่อของกระดูกต้นขาขณะทำกิจวัตรที่มีการลงน้ำหนักขาและงอเข่าไปพร้อมกัน ทำให้เกิดแรงดึงอย่างสูงจากกล้ามเนื้อเหยียดเข่า (Quadriceps) ไปที่สะบ้า ทำให้เพิ่มแรงกดอัดระหว่างผิวข้อ มากขึ้น จนเกิดการเสื่อมและอักเสบที่ผิวสะบ้า ซึ่งนำมาสู่อาการปวด

2. ความผิดปกติในการเคลื่อนไหวรยางค์ขา

การเคลื่อนไหวของรยางค์ขาที่ผิดปกติ ได้แก่ 1) การหุบเข้าและหมุนเข้าของต้นขาร่วมกับการกางออกของข้อเข่าขณะเคลื่อนไหว 2) การบิดออกของเท้าทำให้เกิดการหมุนเข้าของกระดูกหน้าแข้งขณะทำกิจวัตรที่มีการลงน้ำหนักและงอเข่าพร้อมกัน จะนำไปสู่ปัญหาดังข้อ 1.

3. สมรรถนะในการออกแรงและควบคุมการทำงานของกล้ามเนื้อกางและหมุนข้อสะโพกออกด้านนอกผิดปกติ

จากการที่กล้ามเนื้อสะโพกทำงานอย่างไม่มีประสิทธิภาพ ส่งผลทำให้การเคลื่อนไหวรยางค์ขาผิดปกติ ดังข้อ 2

การรักษาทางกายภาพบำบัด

1. การรักษาด้วยความเย็นเพื่อลดการอักเสบ เช่น ประคบเย็น
2. การออกกำลังกายเพื่อเพิ่มความแข็งแรงกล้ามเนื้อ
3. การออกกำลังกายเพื่อเพิ่มความยืดหยุ่นของกล้ามเนื้อ
4. เทปยึดทางกายภาพบำบัด, อุปกรณ์พยุงเข่า
5. การรักษาด้วยไฟฟ้าคลื่นความถี่สูงและปานกลาง

การปฏิบัติตัวเพื่อลดความรุนแรงของอาการ

จากที่กล่าวมาข้างต้น เป็นไปได้ว่าปัจจัยหลักที่ส่งผลให้เกิดอาการปวดเข่าบริเวณผิวสะบ้า คือ การเคลื่อนไหวที่ผิดปกติของรยางค์ขา ฉะนั้นในกิจวัตรต่างๆ จึงควรปรับเปลี่ยนท่าทางการเคลื่อนไหวของรยางค์ขาให้เหมาะสม โดยเฉพาะในกิจวัตรที่มี *การลงน้ำหนักร่วมกับการงอเข่า*

- เลี่ยงท่านั่งที่งอเข่ามากๆ และเป็นเวลานาน เช่น นั่งยอง ขัดสมาธิ พยายามปรับนั่งเก้าอี้ หรือนั่งเหยียดขา
- เลี่ยงท่ายืนย่อเข่าบ่อยๆ หรือเป็นเวลานานๆ หากต้องยืนย่อเข่า ให้พยายามกางเข่าทั้งสองข้างออกจากกัน และหาที่ค้ำยันเพื่อลดการทำงานของกล้ามเนื้อเหยียดเข่า และลดแรงกดอัดที่สะบ้า
- ในขณะขึ้น-ลงบันได วิ่ง หรือจังหวะที่ลงจากการกระโดด พยายามปรับรยางค์ขาให้เหมาะสม คือ กางเข่าทั้งสองข้างออกจากกัน หมุนต้นขาและปลายเท้าออกด้านนอก

List of Abbreviations

Table 2 List of Abbreviations

PFPs	Patellofemoral pain syndrome	CPD	Contralateral pelvic drop
LASER group	The laser guidance retraining group	HADD	Hip adduction
Control group	The conventional physical therapy group	HIR	Hip internal rotation
ITB	Iliotibial band	KABD	Knee abduction
Q-angle	Dynamics quadriceps-angle	Trainer	Trainer for the laser guidance retraining group
EMG	Electromyography	Therapist	Therapist for the conventional physical therapy group
GRF	Ground reaction force	AB line	The middle line of the target plate
CNS	Central nervous system	AC line	The 10-degree lines of the target plate
VM	Vastus medialis	PKFT	The peak knee flexion time point
VL	Vastus lateralis	Pre	Pre intervention
KR	Knowledge of result	Post	Post intervention
KP	Knowledge of performance	LE	Lower extremity
3D	Three Dimensional	NM training	Neuromuscular training
ICC	Intraclass correlation coefficients	DLS	Double leg squat
MCID	Minimal clinical important difference	DLSP	Double leg squat with partial weight bearing
BMI	Body mass index	SLS	Single leg squat
10-cm. VAS	10-centimeter visual analog scale	reps	repetitions
AKPS	The Anterior knee pain scale		

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