COMPARISON OF SACROILIAC JOINT MOVEMENT BETWEEN PRIMIGRAVIDA AND NON PREGNANT WOMEN

PUTHIPONG THOWMANEE

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Puthipong Thowmanee

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การเปรียบเทียบการเคลื่อนไหวของข้อต่อกระดูกเชิงกรานระหว่างสตรีตั้งครรภ์และสตรีไม่ตั้งครรภ์ (COMPARISON OF SACROILIAC JOINT MOVEMENT BETWEEN PRIMIGRAVIDA AND NON PREGNANT WOMEN)

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บทคัดย่อ

การศึกษาครั้งนี้มีจุดประสงค์เพื่อเปรียบเทียบการเคลื่อนไหวของข้อต่อกระดูกเชิงกรานระหว่างสตรีตั้งครรภ์และสตรีไม่ตั้งครรภ์โดยบันทึกภาพ marker ที่ตำแหน่ง PSIS ในสตรีไทยที่ตั้งครรภ์ท้องแรกอายุครรภ์ระหว่าง 28-30 สัปดาห์และสตรีไทยสุขภาพดีช่วงอายุเดียวกัน ระหว่าง 20-35 ปี กลุ่มละ 30 คน, โดยบันทึกภาพของข้อต่อกระดูกเชิงกรานขณะยืนตรงและขณะงอข้อสะโพกและข้อเข่าที่มุม 90 องศา (modified Gillet test) ในแต่ละข้างของทั้ง 2 กลุ่ม โดยใช้กล้องดิจิตอล

ผลการศึกษาพบว่า การเคลื่อนไหวของข้อต่อกระดูกเชิงกรานในกลุ่มสตรีตั้งครรภ์ มีค่ามากกว่ากลุ่มสตรีไม่ตั้งครรภ์อย่างมีนัยสำคัญทางสถิติในทั้ง 2 ข้าง ($p<0.01$) โดยการเคลื่อนไหวของข้อต่อกระดูกเชิงกรานในกลุ่มสตรีตั้งครรภ์ด้านซ้ายและขวามีค่าเท่ากับ 3.69±1.49 มม.และ3.95±1.72 มม. ตามลำดับ และ การเคลื่อนไหวของข้อต่อกระดูกเชิงกรานในกลุ่มสตรีไม่ตั้งครรภ์ด้านซ้ายและขวามีค่าเท่ากับ 2.16±1.01มม.และ2.08±1.19 มม. ตามลำดับ นอกจากนี้การเคลื่อนไหวของข้อต่อกระดูกเชิงกรานในกลุ่มสตรีตั้งครรภ์ที่มีและไม่มีอาการปวดบริเวณหลังและเชิงกราน ไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ

การศึกษาครั้งนี้ทำให้ทราบข้อมูลของการเคลื่อนไหวของข้อต่อกระดูกเชิงกรานในสตรีไทยที่ตั้งครรภ์ท้องแรกที่มีอายุครรภ์ 28-30 สัปดาห์และสตรีที่ไม่ตั้งครรภ์ในช่วงอายุเดียวกัน ข้อมูลที่ได้จากการศึกษานี้แสดงให้เห็นว่าสตรีที่ตั้งครรภ์มีการเคลื่อนไหวของข้อต่อกระดูกเชิงกรานมากกว่าสตรีที่ไม่ตั้งครรภ์ถึงเกือบ 2 เท่า ซึ่งอาจนำไปสู่อาการปวดหรือความผิดปกติของข้อต่อได้ภายหลังการคลอดบุตร ดังนั้นนอกจากการแนะนำท่าทางในสตรีตั้งครรภ์แล้ว นักกายภาพบำบัดควรแนะนำการออกกำลังกายเพื่อเพิ่มความมั่นคงของกระดูกสันหลังส่วนเอวและเชิงกรานเพื่อป้องกันความผิดปกติที่อาจเกิดขึ้นได้ในภายหลัง นอกจากนี้การศึกษาครั้งนี้ยังนำเสนอวิธีการวัดการเคลื่อนไหวของข้อต่อกระดูกเชิงกรานที่สามารถนำไปประยุกต์ใช้ในทางคลินิกได้

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COMPARISON OF SACROILIAC JOINT MOVEMENT BETWEEN PRIMIGRAVIDA AND NON PREGNANT WOMEN

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M.Sc. (PHYSIOTHERAPY)

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ABSTRACT

The aim of this study was to compare the change of sacroiliac joint displacement between primigravida women in third trimester and healthy female subjects by detecting posterior superior iliac spine on the modified Gillet test. Thai pregnant women aged between 20 and 35 years at 28-30 weeks gestation and Thai healthy non pregnant women at the same age range participated in this study. Each group consisted of 30 subjects. The displacement of sacroiliac joint was recorded by digital camera from erect standing position to 90º flexion of hip and knee in each side of both groups.

The results showed that sacroiliac joint displacements of the primigravida women were significantly greater than those of the non pregnant women for both sides ($p<0.01$). The sacroiliac joint displacements of pregnant women for left and right sides were 3.69±1.49 mm and 3.95±1.72 mm respectively. The sacroiliac joint displacements of non pregnant women for left and right were 2.16±1.01 mm and 2.08±1.19 mm respectively. Moreover, there was no significant difference in either left or right sacroiliac joint displacement between pregnant women with and without lumbopelvic pain.

In conclusion, this study provides information on the sacroiliac joint displacements of primigravida women in third trimester and non pregnant women at the same age range. This study indicates that primigravida women in the third trimester have an almost two times greater sacroiliac displacement than the non pregnant women. This can lead to pain and sacroiliac joint dysfunction after delivery. Therefore, physical therapists should recommend lumbopelvic stabilization exercises for post partum period in order to prevent a further dysfunction. In addition, this study also provides quantitative measurement of sacroiliac joint displacement that can be applied in clinics.

KEY WORDS: SACROILIAC JOINT MEASUREMENT / PREGNANCY / SACROILIAC JOINT MOVEMENT

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LIST OF ABBREVIATIONS

BMI	Body mass index
Ht.	Height
Wt.	Weight
LLD	Leg length discrepancy
ASLR	Active straight leg raising test
PSIS	Posterior superior iliac spine

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CHAPTER I

INTRODUCTION

During pregnancy there are many physiological changes in various systems. The changes of musculoskeletal system during pregnancy can be resulted from hormonal change that could cause pain, disabilities and instability of sacroiliac joints (49-52).

Many studies analyzed movement of the sacroiliac joint by using several methods such as radiostereometric analysis, a computerized system for the exact radiographic localization of landmarks in human body (27), the invasive technique using Kirchner wires in ilium and sacrum bone in healthy subjects detected by cameras (26,28). The three dimensional analysis system that used coordinate system to analyze movement of ilium and Doppler imaging that used transmissions of vibration through sacroiliac joint to measure joint stiffness (36,50). Although these methods were highly accurate to analyze movement of sacroiliac joint but they were difficult and more expensive to be applied in clinical use (35,36,39,40).

The movement of sacroiliac joint between ilium and sacrum can be detected in the frontal plane. The displacement of the posterior superior iliac spine during hip flexion in standing indicates the sacroiliac joint movement known as Gillet test (43,44). Using digital camera is one of the feasible instruments and effective to detect the movement in two dimensions.

This study therefore aimed to study the movement of sacroiliac joint in the frontal plane in primigravida and healthy female subjects to determine the displacement of sacroiliac joint by using the digital camera.

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Purposes of the Study

General Objective

To study the movement of sacroiliac joint in the primigravida in third trimester and healthy female subjects.

Specific Objective

1. To compare the change of sacroiliac joint displacement between the pregnant and healthy female subjects.
2. To compare the change of sacroiliac joint displacement between the pregnant female subjects with and without pain.

Parameter

The displacement of posterior superior iliac spine from standing position to the 90 degrees of hip flexion for left and right sides.

Hypotheses of the Study

There were significantly greater movements of the sacroiliac joint of the pregnant female subjects than those of non pregnant female subjects. There were no significant differences in sacroiliac joint displacements between the pregnant female subjects with and without pain.

Limitation of the Study

This study does not consider for concentration of relaxin that causes joint laxity.

Advantage of the Study

This study provides the objective measurement of sacroiliac joint combined with the modified Gillet test. The finding of this study would be useful in planning the physical therapy program in prevention of low back pain in pregnant women.

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CHAPTER II
LITERATURE REVIEW

2.1 Biomechanics of Sacroiliac Joints

Sacroiliac joint could be protected against dislocation from the mechanic of form and force closure.

2.1.1 Form closure

Form closure meaned that the stable position with closely fitting joint surfaces, where no extra force were needed to maintain the state of the system. The sacroiliac joints were protected from compressive forces, bending moments and shear forces in three ways. Firstly, due to its wedge-shape the sacrum was stabilized by the innominates. Secondly, the articular cartilages were not smooth. Thirdly, by studying in embalmed specimens, the presenced of cartilage covered bones extensions protruding into the joint so call ridge and grooves, that resisted gliding.

Furthermore sacroiliac joint surfaces could be protected against shearing by contouring of arch that mechanism depended on the connection between two ends. The sacrum, firmly entrapped between the innominates and suspended from ilium, carried the weight of spine. The sacroiliac joints were essentially non-weight bearing joints. Increasing in weight loading would increase the tension on the posterior ligaments and caused the sacrum to ride more deeply between the innominates (1, 2).

2.1.2 Force closure

Force closure meaned that the mechanism of compression of the sacroiliac joints due to extra forces to keep equilibrium. During walking, mobility as well as stability in the pelvis must be optimal. The ligament and muscle forces were needed to provide compression of sacroiliac joint. Especially during unilateral loading of the legs this system had to become active. Force closure could be generated by the structures which fibers's direction perpendicular to the sacroiliac joint. Chamberlain observed

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that the strong ligaments over the sacroiliac joint were in the direction that fibers were tightened when innominates rotated posteriorly and loosened when the innominates rotatateted anteriorly. In the normal standing posture, the line of gravity fell posterior to the center of the acetabula, so most of the weight of the trunk was transmitted through the posterior pelvic and caused posterior rotation force that caused pelvis rotated downward posteriorly around the acetabula that created automatic pelvic tilt without any support of anterior pelvis from the abdominal muscles (2-4).

2.1.2.1 Ligaments

Both interosseus and short dorsal sacroiliac ligaments that originated from the sacrum and attach to the ilium close to the joint surfaces. During nutation of the sacrum the tension in these ligaments increased, leading to more friction at joint surfaces and hence more stability of the sacroiliac joints.Nutation of the sacrum occured during loading situations, supine to sitting or supine to standing (5).

-The sacrotuberous ligament

The sacrotuberous ligament originated from the dorsal side of the sacrum and attached to the ischial tuberosity. Its tension could stabilize the sacroiliac joints in four ways. Firstly, increasing tension in this ligament by applying tension to the long head of biceps femoris muscles caused tilting backwards of the ilium due to traction on ischial tuberosity. Secondly, the tension of the sacrotuberous ligament could be influenced by increased tension of gluteus maximus and piriformis muscles because of the anatomical connection. Thirdly, the thoracolumbar fascia could increase the tension of this ligament due to the anatomical connection. Finally, during nutation caused increasing tension in the sacrotuberous ligament (6).

-The longdorsal ligament

The longdorsal ligament originated from the dorsal surface of the sacrum at the level of S2-S4 and attached to the posterior superior iliac spine (PSIS). The tension of this ligament could be increased during increment loading of the ipsilateral sacrotuberous ligament. The tension of the longdorsal ligament could be decreased by traction to the gluteus maximus muscle (7)**.**

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In 2003, Pool-Goudzwaard et al studied the influence of the iliolumbar ligament on sacroiliac joint stability in 12 human specimens. An incremental moment was applied to the sacroiliac joint to induce rotation in the sagittal plane. After the assessment of the relationship between rotation angle and moment in the intact situation, specific parts of the iliolumbar ligaments were transected. The results showed that Sacroiliac joint mobility in the sagittal plane was significantly increased after a total cut of both iliolumbar ligaments. This increase was in particular due to the transection of a specific part of the iliolumbar ligament, the ventral band (8).

2.1.2.2 Musculature

Several muscles were supposed to contribute to force closure of the sacroiliac joint. Transverse oriented pelvic muscles such as internal oblique, transverse abdominis,piriformis and pelvic floor contributed to sacroiliac joint stability.

In 2002, Richardson et al studied effect of transverse abdominis muscle in reducing sacroiliac joint laxity in healthy subjects by using Doppler Imaging of Vibration (DIV) methods. The results showed that the values of sacroiliac joint laxity significantly decreased (9).

In 2004, Cowan et al studied the effect of transverse abdominis, obliquus internus, obliquus externus and rectus abdominis. The researchers used EMG to investigate these muscles activation during Active Straight Leg Raising (ASLR) test in subjects manifested of long-standing groin pain and compared with asymptomatic subjects. The results showed that the long-standing groin pain subjects had delay onset of transverse abdominis contraction. However, there were no difference between groups for the onset of activity of obliquus internus, obliquus externus and rectus abdominis (10).

In 2004, Stuge et al evaluated specific stabilizing exercises for patients with pelvic girdle pain after pregnancy that focused with pain intensity, disability and quality of life. The researchers used randomized clinically controlled study into exercise group that received physical therapy which focused on specific stabilizing

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exercises and control group that received individualized physical therapy program without specific stabilizing exercises and follow up for 1 year. The results showed that the specific stabilizing exercise group showed statistically and clinically significant lower pain intensity, lower disability and higher quality of life compared with the control group (11).

In 2005, Mills et al studied effect of training program for improved lumbopelvic stability at 10-week period on athletes by randomized-controlled study. The researchers randomed subjects into three groups: 1) treatment group received specific exercises of transverse abdominic,multifidus and priformis. 2) Pseudo treatment group received training of global abdominal muscles,rectus abdominis and external oblique.3)control group. The exercises were evaluated by pressure biofeedback. The results showed that the athletic performanced was improved in treatment group and pseudo treatment group. Furthermore, the agility and lower limb power were increased in treatment group (12).

In 2006, Snijders et al studied addressed piriformis muscle and related pelvic structures in cross-legged sitting in healthy subjects in standing, normal sitting and cross-legged sitting, and were used to simulate these postures on embalmed pelvises and measure piriformis muscle elongation.This study found that cross-legged sitting resulted in a relative elongation of the piriformis muscle of 11.7% compared to normal sitting and even 21.4% compared to standing. Application of piriformis muscle force resulted in inward deformation of the pelvic ring and compression of the sacroiliac joints and the dorsal side of the pubic symphysis (13).

2.2 Factors Influencing Sacroiliac Joint Movement

2.2.1 Leg length difference

Many researchers have noted postural changes in individuals with leg length inequality. Some of these changes include lateral tilting of the pelvis in the frontal plane, pelvic torsion in the sagittal plane, and lumbar scoliosis. Leg-length discrepancies can be classified as mild (< 3 cm), moderate (> 3 but < 6 cm), or severe (> 6 cm) (14).

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In 1993, Cumming et al investigated effect of various degrees of imposed leg length difference on symmetry of the innominate bones in healthy subjects by motion analysis system. The leg length was determined by clinical and radiographic procedures. The results revealed that posterior innominate bone rotation occurred on the sides of lengthened limb and anterior rotation innominate occurred on the shorter limb. The amount of pelvic obliquity increased linearly with leg length difference from 2/8 to 7/8 inches (15).

In 2000, Walsh et al investigated leg length discrepancy and gait kinematics alteration by three-dimensional gait analysis systems. The 7 normal subjects were fitted with raises of varying heights to one lower limb and then analyzed in static and dynamic. The results showed that pelvic obliquity was used to compensate for small degrees of leg length discrepancy up to 2.2 cm, particularly in static standing. With larger degrees of discrepancy, the subjects developed flexion of the knee of the longer leg. Compensatory mechanisms during walking were more complex and included a combination of kinematic changes at the pelvis, knee and ankle (16).

In 2000, Rebecca et al studied the modified leg length, using relative iliac crest height as a criterion, was associated with alterations in pelvic torsion or trunk mobility in young healthy adults with no problems in the lumbosacral region. They used the inclinometer to measure left innominate inclination. The results showed that the innominate contralateral to the lift became more anteriorly rotated than the ipsilateral innominate and lateral flexion of the trunk increased toward the side of the lift. These effects can be associated with clinical leg length inequality. A lateral pelvic tilt of 1.2° could signal the suitability of more extensive examination for possible lower limb asymmetry (17).

In 2005, Defrin et al studied the effect of LLD correction on LBP patients with an LLD of 10mm that corrected with shoe insertion and measured by ultrasonographic and telescopic rule that equipped with a 2-way spirit level to ensure accurate horizontal and vertical alignment. The results showed that shoe inserts

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significantly reduced both pain intensity and disability. A moderate positive correlation was found between LLD and the degree of pain relief after wearing shoe inserts (18).

2.2.2 Pelvic asymmetry

Pelvic asymmetry refers to asymmetric positioning of landmarks on the two sides of the pelvis. The cause of pelvic asymmetry may be structural or functional. In the clinical setting, pelvic asymmetry may be associated with the presence of true leg length discrepancy (LLD). This could lead to false diagnosis or inaccurate measurement of LLD or itself be independently associated with back pain.

In 1998, Kingma et al studied asymmetric torques develop during increasing asymmetry in lifting movements and investigated the degree of pelvic twist in these lifting tasks by video-based motion recording system. The results showed that the peak pelvic twist increased with lifting asymmetry (19).

In 1998, Cibulka et al investigated the pattern of hip ROM in patients with low back pain and determined the sacroiliac joint dysfunction by the pattern of hip ROM compared with those with unspecified low back pain and classified into a left or right posteriorly tilted innominate groups by goniometric measurements. The results showed that the patients with low back pain but without evidence of sacroiliac joint dysfunction had significantly greater external hip rotation than internal rotation bilaterally, whereas those with evidence of sacroiliac joint dysfunction had significantly more external hip rotation than internal rotation unilaterally, specifically on the side of the posterior innominate (20).

In 2006, Egan et al studied the effect of pelvic asymmetry on trunk kinematics during sitting. Pelvic asymmetry was measured in 54 patients with unilateral nonspecific LBP and 59 control subjects. They used motion-analysis system to test the range and symmetry of lateral flexion and axial rotation in sitting and standing positions. The researchers found significant between pelvic asymmetry and asymmetric trunk motion performed in sitting, differences between the LBP and

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control groups in patterns of trunk motion performed in a sitting posture, and differences between kinematics of motions performed in sitting and standing postures (21).

2.2.3 Pelvifemoral rhythm

In 1997, Smidt et al studied sacroiliac kinematics and hip position in fresh cadavers to determine the three-dimensional motion at the left and right sacroiliac joints by placing radiopaque markers at the sacrum and each innominate bone and using computed tomography scans at 3-mm intervals. The results showed that the largest amount of sacroiliac motion occurred in the sagittal plane (7° on left and 8° on the right, with a range of 3° to 17°) and the translation of the posterior superior iliac spines with respect to the sacrum ranged from 4 to 8 mm. This motion tended to occur in all directions (22).

In 2000, Sturesson et al studied the sacroiliac joint motion during the standing hip flexion test that reflected movement in the sacroiliac joints and whether the increased load of one sacroiliac joint also reduces the mobility of the other sacroiliac joint by using a radiostereometric analysis in 22 patients with sacroiliac pain. The results showed that the movements of the sacroiliac joint around the three axes were very small. The innominates rotated a mean of 0.2° posteriorly. However, in some patients they rotated anteriorly. The mean rotation of the helical axis was 0.6°. In all cases, the translations were very small (mean, 0.3 mm) (23).

In 2002, Murray et al studied pelvifemoral rhythm during unilateral hip flexion in standing by two-dimensional sagittal plane analysis that captured by video in 14 subjects performed standing with unilateral hip flexion with and without a 4.53 kg at ankle. The results showed that pelvic rotation contributed 18.1% of the change in hip flexion angle and occurred throughout the movement (24).

In 2003, Dewberry et al studied the ratio of pelvic to femoral motion during suspended bilateral hip flexion in 14 subjects by video analysis. The ratios of pelvic to femoral motion were calculated from hamstring length in SLR, and knee position

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(flexed and extended) on the ratio was determined. The results revealed that the mean pelvifemoral ratio ranged from 0.131 to 0.355, depending on hamstring length and knee position, pelvic rotation was between 13.1–35.5% of the hip flexion. Furthermore, the largest pelvic contribution occurred during hip flexion with the knee in the extended position among subjects with shorter hamstrings (25).

2.3 Objective Measurement of Sacroiliac Joints

2.3.1 Direct measurement

In 1995, Jacob and Kissling studied three dimensional movement of sacroiliac joint by stereophotogrammetry technic in healthy subjects between 20 and 50 years of age. The instruments composed of two cameras and 3D K-wires markers were inserted to the sacroiliac joint's bony landmarks. Then the subjects performed flexion and one-legged stance in each side. The results showed that the motion occurred in horizontal, frontal and sagittal planes respectively. The average values for total rotation and translation were 1.7 degrees and 0.7 mm respectively (26).

In 2000, Sturesson et al used Radio Stereometric Analysis (RSA) method to investigate sacroiliac joint movement during performing reciprocal straddle position and standing hip flexion. This method, the subjects were inserted 4 tantalum ball with diameter of 0.8 mm and a mass of 0.004 grams into bony landmarks under local anesthesia using fluoroscopy. Then 14 days later the RSA was performed in a special room. The RSA calculations were performed by computer programs (27).

In 2004, Snijders et al studied lumbopelvic kinematics when trunk move too slouch, the transition from lumbar lordosis to lumbar kyphosis by the combination with backward rotation of the pelvis, in unembalmed human body. With needles 1.5 mm in diameter were inserted into spinous process of L1, PSIS and median crest of S1.Then the movement were filmed with three cameras (28).

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2.3.2 Indirect measurement

2.3.2.1 Photogrammetric methods

In 1999, Lee et al studied the effect of seated workstation that designed for pregnant subjects with 2D motion analysis system (29).

In 2002, Gillerd et al studied effect of pregnancy on the kinematics of the trunk segments during seated and standing in various postures with 3D motion analysis system with 8 mm video cameras that positioned around the subject so that each marker was clearly seen (30).

In 2002, Tully et al studied lumbo-pelvic and hip coordination during standing with fully unilateral hip flexion in 22 healthy young adults and 22 healthy children by using two dimensional computer-aided video analysis with six spherical reflective markers 2.5 cm in diameter with a 4-cm black base were attached over the thoracolumbar spine, pelvis, and lateral aspect of the right thigh. The results showed that on the average, every 3° of hip motion was accompanied by 1° of lumbar motion. Throughout the upward movement, the relative contribution of hip movement decreased while that of the lumbar spine increased (31).

In 2003, Vogt et al studied innominate bone motion during ambulation on treadmill with 3D motion analysis system. The researchers used plate mounted markers over S1, ASIS and PSIS. Rotation of pelvic movements was recorded by 3D ultrasonic measurement devices (32).

In 2006, Al-Eisa et al studied pelvic asymmetry that related to trunk kinematics on sitting. The researchers used 3D motion analysis system to study trunk kinematic, 8 mm skin markers were placed at ASIS, PSIS. Then used anthropometric measuring frame to obtain width and height of PSIS. For studying trunk kinematic, 13 reflective markers were applied on the spinous process of thoracic, lumbar and sacral segment (33).

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2.3.2.2 Joint laxity measurement

In 1995, Buyruk et al used Color Doppler imaging to measure sacroiliac joint stiffness on embalmed human pelvises with three conditions; no intervention, artificially fixed (screws through each SI joint) and removed and the anterior and interosseous ligaments. The results revealed that this method showed high reproducibility and significant differences among conditions (34).

In 1999, Bjorklund et al investigated symphyseal laxity and pelvic pain in pregnancy with ultrasonographic assessment in supine position. The subjects were asked to elevate a stretched leg 45 degrees that resulted traction on the ipsilateral pelvic. The results showed that the median symphyseal width at 12, 35 weeks of pregnancy and at 5 months postpartum was 3.5 mm, 4.6 mm and 2.8 mm respectively (35).

In 2001, Damen et al studied the association between pregnancy-related pelvic pain and sacroiliac joint laxity in pregnant women during third trimester. The researchers used Doppler imaging of vibrations (DIV) that done in prone position with relaxed muscles. Then the transducer was positioned across the sacroiliac region and intensity of vibration was measured on both sides of the sacroiliac joint. With this procedure small difference between threshold units of the sacrum and ilium indicated stiff joint (<2 TU), large difference between threshold units of the sacrum and ilium (> 5 TU) indicated joint laxity (36).

2.3.2.3 Non-invasive measurement

In 1988, Alviso et al used depth calipers to measure pelvic tilt in standing. The researchers examined intertester reliability of instrument and found that the intertester reliability was high (ICC 0.95 for pelvic tilt in standing, ICC 0.88 for the anterior pelvic tilt ROM and ICC 0.93 for posterior pelvic tilt ROM.)(37).

In 1999, Furburger and Riddle investigated reliable derived of measurement of handheld calipers and inclinometer to measure the various angle of inclination of

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pelvic bone. The results indicated that the ICC was 0.27, SEM was 5.4 degrees. The researchers concluded that measurement of sacroiliac joint alignment were unreliable (38).

In 2000, Granata and Sanford studied lumbopelvic coordination during lifting. The researchers used electromagnetic sensors placed on the skin over T10 and S1 to record motion of the pelvis and lumbar spine flexion, then converted into Eigenvector models of lumbo-pelvic coordination (39).

In 2003, Jackson et al studied lumbopelvic morphology that related with spondylolisthesis by radiographic method. The researchers used pelvic radius technic to measure pelvic lordosis angle (40).

In 2003, Sprigle et al used pelvic goniometer that designed to measure the pelvic tilt and hip flexion angle in seated posture. These instruments comprised two components: pelvic band for placement at iliac spine and thigh bar aligned to femur. The goniometer grid and inclinometer were integrated into the connection between the components to measure pelvic tilt and hip flexion angles. Validation of this instrument was done with radiographically (41).

2.4 Mobility Test of Sacroiliac Joint Dysfunction

Sacroiliac joint dysfunction could be symptomatic or asymptomatic. Mechanical tests for the SIJ may be divided into two categories :(1) palpation tests for hypermobility, hypomobility, and positional faults and (2) pain provocation tests (42). The Gillet test that performed with one thumb was placed over the second sacrum tubercle and the other thumb directly placed under the inferior slope of the posterior superior iliac spine (PSIS) on the side to be tested. The subject stood with his feet approximately 12 inches apart. Then the subject was asked to flex the knee and hip bringing the thigh to the abdomen. In normal joint, the ilium rotated posteriorly on the sacrum and the PSIS was believed to rotated postero-inferiorly with respected to the second sacral tubercle (43).

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In 1999, Meijne et al investigated intraexaminer and interexaminer reliability of Gillet test. Thirtyeight subjects were examined in the first test procedure, and at least 4 days later 37 subjects were examined again. The subjects were subdivided into symptomatic and asymptomatic groups on the basis of certain criteria. The results showed that the mean Cohen's kappa did not exceed the value of 0.081. Only the percentage agreement of the symptomatic group did exceed the minimum level of 80%. When kappa was positive, the prevalence adjust biased kappa was markedly higher than kappa; when kappa was negative, the prevalence-adjusted bias-adjusted kappa was only slightly higher than kappa. Only small differences were found between kappa and bias adjusted kappa (44).

2.5 Sacroiliac Joint during Pregnancy

Sacroiliac joints are synovial joints with strong ligaments, posterior and interrosseus ligaments connected the sacrum to the ilium. Panjabi proposed conceptual model of sacroiliac joint stability that the zone of motion, neutral zone, which small range of displacement near the joint's neutral position where minimal resistance of the osteo-ligamentous structures and high flexibility and laxity (45). Physiological changes during pregnancy caused ligamentous laxity (46).

In 1997, Albert et al studied the level of circulating relaxin and pelvic pain in 455 women with pelvic pain and 455 normal pregnants by strictly defined type of pelvic pain into five subgroups. The results showed that no significant difference in serum relaxin level and pelvic pain between two groups (47).

In 1999 Larsen et al studied prevalence, predisposing factors and duration of symptom-giving pelvic girdle relaxation (PGR) from antenatal to postpartum period for 227 women. PGR was defined as condition occurred during pregnancy or delivery and characterized by disabling pain located to sacroiliac joint or pubic symphysis area. This prospective study showed that prevalence two months postpartum was 5%, six months postpartum was 4% and twelve months postpartum was 2% and the incidence during pregnancy was 14% (48).

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In 1999, Dongen et al studied the correlation between joint hypermobility and peripartum pelvic pain (PPPP) in 509 African women by Breighton score and group of PPPP tests. The researcher found that 4.9% of pregnants were hypermobile and no correlation of joint hypermobility and incidence of PPPP (49).

In 2000, Bjorklund et al investigated the association between symphyseal distension, relaxin levels and pelvic pain during pregnancy to postpartum period with ultrasonography. The results revealed that pelvic pain was associated with increasing of symphyseal distension. Furthermore at third trimester symphyseal width was 4.5-7.4 mm. However serum relaxin levels were not associated with symphyseal distension (50).

In 2001, William et al studied the association between maternal hormones, estradiol, and laxity of joint in the third trimester of pregnancy with knee arthrometry. The results showed that level of estradiol during third trimester correlated with increased knee laxity (51).

In 2003, Monarch et al studied the relation between joint laxity and maternal hormone during pregnancy through postpartum period in 46 women. The researchers found that joint laxity during pregnancy did not correlate with maternal hormones; estradiol, progesterone and relaxin (52).

2.5.1 Musculoskeletal changes during pregnancy

During pregnancy it was necessary for women to adapt posture to compensate changing center of gravity of the body from growth of fetus. These changes involved sacroiliac and spinal structures included muscles and joints. Abdominal muscles were stretched from growth of fetus caused decreasing ability to stabilize pelvis and spine and the load could be transfered to paraspinal muscles and joints caused strain from hyperlordosis of lumbar spine (53).

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Ostgaard in 1993 revealed that increasing of lumbar lordosis as pregnancy progress associated with back pain (54).

Similar to the study of Pilompol that used motion analysis system to study postural changes of pregnancy in full term primiparas during standing and sitting position. The results revealed some posture variables were changed as pregnancy progressed particularly in final period of pregnancy. In standing position increase lumbar lordosis, anterior pelvic tilt, knee flexion but decrease in hip flexion, asymmetry of head, knee, ankle between left and right sides were found. In sitting position increase posterior pelvic tilt but decrease hip flexion. The asymmetry of head and pelvic inclination between left and right sides were found (55).

Sihvonen studied back pain by using EMG to detect back muscle activity and found that back pain associated with increasing of body weight from first to third trimester (56).

Chantopas used flexible ruler to study spinal curvature and association between spinal curvature change and back pain. The study revealed no association between spinal curvature changes and back pain (57).

In addition postural change could involve other aspect of the musculoskeletal system when pregnants performed activity during the day. Paul studied load on hip joint during standing from first to third trimester of pregnancy and found that reactive force on hip joint increased 2.8 times (58).

Gillerd studied effects of various positions of pregnants from pregnancy to postbirth and found that as pregnancy progressed the movement of thoracolumbar segment decreased in standing with forward flexion and sitting with rotation. Furthermore, as pregnancy progressed, the growth of fetus caused abdominal muscles became less effective to maintain posture and stabilize pelvis because the size of fetus and uterus stretched muscles. Gillerd used 3D-photographic method studied change

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and function of abdominal muscles, especially rectus abdominis reduced their function to 50% from normal (59).

2.5.2 Pelvic pain during pregnancy

During pregnancy period, women had many changes in body systems. Pelvic pain and back pain were commonly found in musculoskeletal problems. Several studies tried to define back pain and pelvic pain in pregnant women.

In 1997, Ostgaard et al studied back pain and posterior pelvic pain as one condition by questionnaire and visual analog scale for six years (60). Whereas study of Sturesson tried to differ back pain and pelvic pain by using pain drawing to determine pain pattern during pregnancy (61).

In 1999, Larsen et al studied pain characteristic and clinical finding of PGR in women with disabling pelvic pain and found that pain was described as shooting pain which increased by physical activities. Pain remained for longer time during the day and caused decrease daily activity about 25-75%. In addition, women with PGR had muscular tenderness on paravertebral muscles and gluteal areas (48).

In 2001, Albert et al defined pain related pelvic region into five subgroups depended on pain characteistic and pain location. The researchers studied during pregnancy and prolong to 24 months after delivery. The results revealed that pelvic pain could persist in 8.5 % (62).

In 2001, Mens et al used active straight leg raise test (ASLR), to determine posterior pelvic pain after pregnancy (PPPP) and assessed validity of ASLR. This test determined PPPP as severity scale compared with pain provocation tests included pelvic torsion, sacral trust, tenderness of long dorsal sacroiliac ligament and lumbar pressure. The results revealed that ASLR associated with pain severity scale (63).

In 2002, Wu et al studied gait in pelvic girdle pain (PPP) pregnant which emphasis on coordination between transverse plane of trunk and pelvic rotation by

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treadmill and 2D video cameras system. The study showed that the pregnant with PPP could not walk more than 0.83 m/s and walking velocity was significantly reduced when compared to non-pregnant female but the coordination of trunk and pelvic did not differ significantly (64).

In 2006, Gutke et al studied the prevalence of lumbopelvic pain in pregnant women with questionnaire and VAS for two years. They reported that pelvic pain affected women during early pregnancy. The prevalence of lumbopelvic pain was 62% during the 12-18 weeks of pregnancy (65).

Summary of Research Problem

From literature review, an increase in the sacroiliac joint displacement during pregnancy has been widely accepted and could lead to pelvic or back pain as well as further sacroiliac joint dysfunction after delivery. A quantitative and non harmful measurement is of important to determine the sacroiliac joint displacement in pregnant women. Therefore, this study attempted to study the sacroiliac movement during pregnancy by using non invasive technique, reliable and feasible into clinical use.

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CHAPTER III

MATERIALS AND METHODS

3.1 Subjects

Subjects were primigravida recruited from the antenatal care unit of the Department of Obsthetrics and Gynecology, Faculty of Medicine Siriraj Hospital, Mahidol University. Subjects were between 20 and 35 years old. At the time of initial assessment, subject's gestational age was between 28-30 weeks.

Inclusion criteria for pregnant women

-Primigravida who were between 20 and 35 years old.

-The subjects intended to have delivery in Siriraj hospital.

-Leg length discrepancy was equal or less than 1 centimeter.

Inclusion criteria for non-pregnant women

-Healthy female who were between 20 and 35 years old.

-The subjects had no history about back pain or pelvic pain in the past 6 months prior to participate in the study.

-Leg length discrepancy was equal or less than 1 centimeter.

Exclusion criteria

-Subjects had a history of fracture, neoplasm, previous surgery of lumbar spine, lower extremity or abdominal surgery.

-Subjects had neurological signs such as asymmetry of Archilles tendon reflex or SLR test positive

-Deformities in the back such as scoliosis

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3.2 Instrumentations

3.2.1 Digital camera Fuji Finepix 5100

The digital camera 4.0 mega pixel was positioned 3 meters behind the subject.The digital camera was placed perpendicular to the frontal plane of the subject.

Figure 3.1 The digital camera.

3.2.2 Wooden platform

The wooden platform which its level could be adjusted to support the foot of subject when perform the modified Gillet test.

Figure 3.2 Adjustable foot platform and stability frame.

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3.2.3 The reference frame board

The reference frame board was placed in front of subject to adjust body alignment.

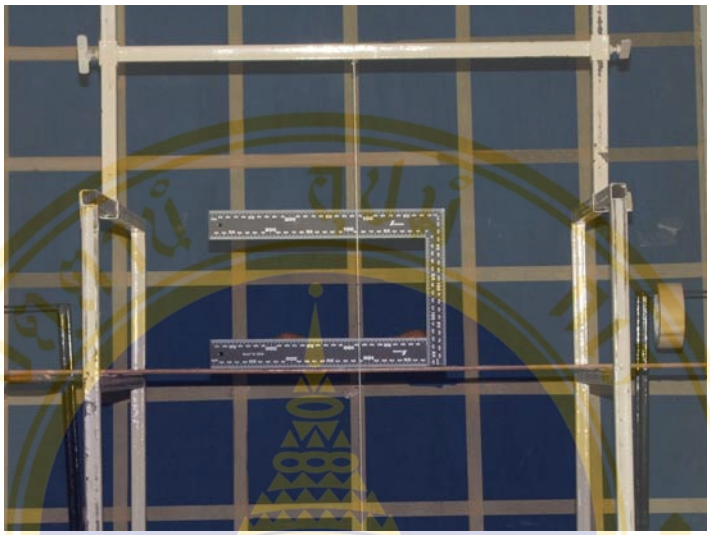

Figure 3.3 Reference frame board.

3.2.4 The circle tape marker

The circle tape marker with 0.8 centimeter diameter .

Figure 3.4 Circle tape markers.

3.2.5 Tape measurement

Plastic tape used to measure leg length discrepancy during standing.

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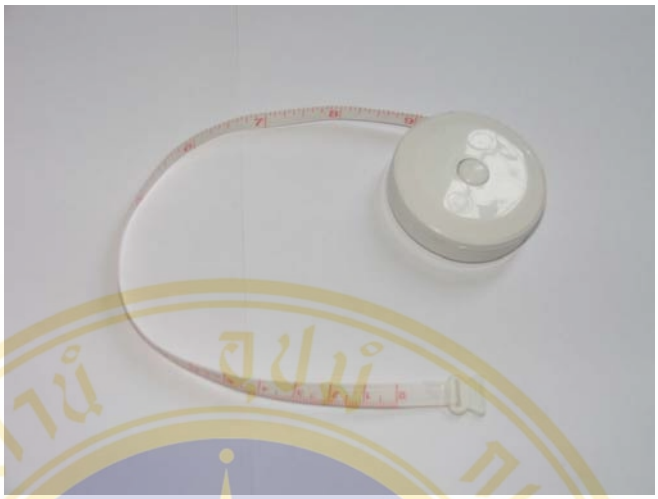

Figure 3.5 Tape measurement.

3.2.6 Paper sheets

Paper sheets were used to collect foot position of subjects that placed on foot platform.

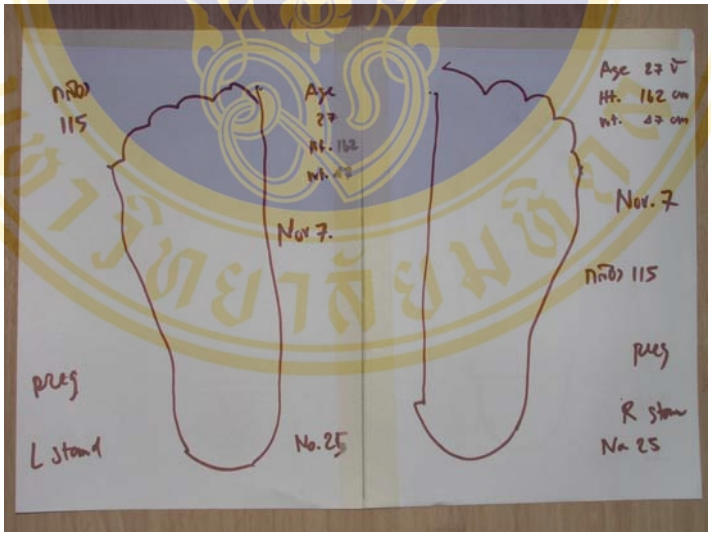

Figure 3.6 Paper sheets.

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3.2.7. The standard goniometer

The standard goniometer was used to measure hip and knee flexion angles.

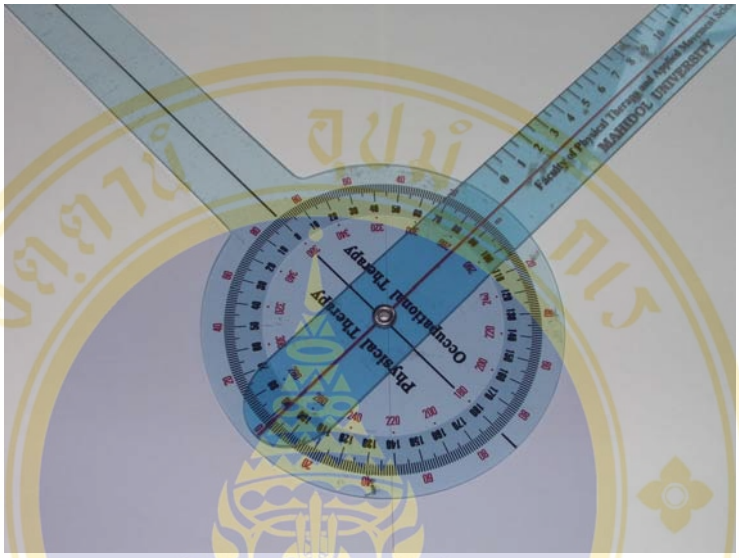

Figure 3.7 The standard goniometer.

3.3 Procedures

Prior to participation, subjects were asked to sign informed consent. Subjects were interviewed about their age, height, weight and medical history. The researcher measured the leg length of subjects in standing position. The two circle tape markers with 0.8 centimeters diameter were placed on left and right posterior superior iliac spine (PSIS). Then subjects stood with their feet approximately at shoulder width apart. The standard goniometer was used to measure angles of hip and knee flexion. Then subjects were asked to perform modified Gillet test one leg at the time by raising the leg to 90 degrees flexion of hip and knee. Subjects were then asked to place their foot on the wooden platform. The present study was approved by the Ethical Committee on Research Involving Human Subject, Faculty of Medicine Siriraj Hospital, Mahidol University.

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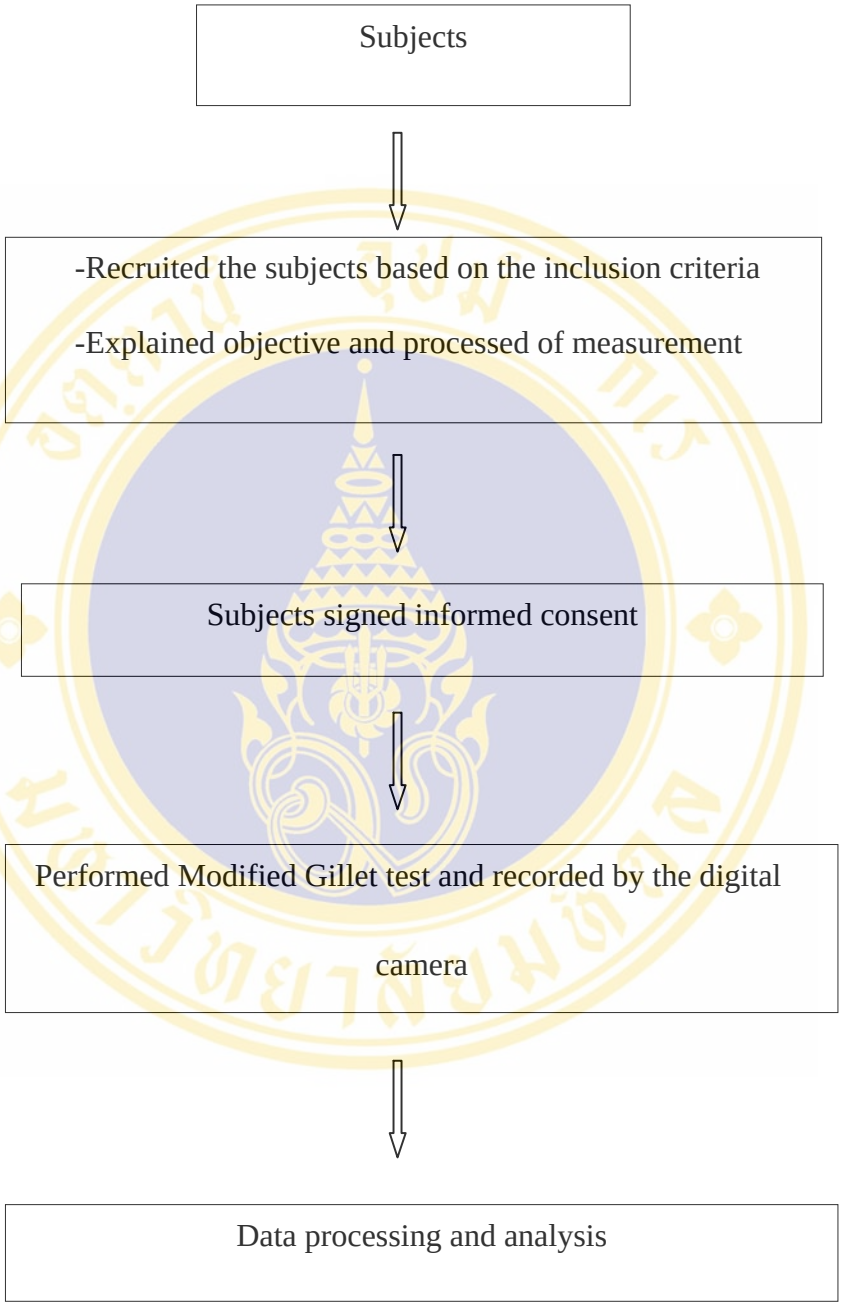

Figure 3.8 Flowchart of the experimental protocol.

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3.4 Research Setting

In this study, the digital camera was used to collect data. The distance from digital camera and subjects was fixed throughout the process and all markers were clearly seen. The height of digital camera was set at level of PSIS of each subject. The markers positions were recorded at the standing, 90 degrees of hip flexion and adjusted position of markers at 90 degrees of hip flexion.

3.5 Error Reduction

3.5.1. Accuracy of the posterior superior iliac spine palpation

Prior to the experiment, accuracy of the PSIS palpation of the researcher was tested in 30 subjects to determine that the researcher could identify location of these bony landmarks. A confirmation of PSIS position was palpated by qualified manipulative physical therapists (Roongtiwa Vachalathiti and Keerin Mekhora).

3.5.2. Reliability of digitization of center of markers.

Two circles tape markers were attached on skin over the center of tip of both PSIS. The digital camera was used to record these markers placed in 10 subjects, then the image were manually digitized by the researcher using Scion Image for Windows program in which each marker was repeatedly digitized one week apart. The intratester reliability tested by ICC (3, 1) for X and Y coordinates equal to 0.95 and 0.97 respectively (see Appendix D, Table D2).

3.6 Statistical Analysis

Statistical analysis was calculated by setting the p-value less than 0.05.

1. Kolmogorov Smirnov Goodness of Fit test was used to test for distribution of the data.

2. Unpaired t-test was used to compare the displacement of the sacroiliac joint between pregnant women and healthy subjects if the data were normal distributed.

3. Mann Witney U test was used to compare the displacement of the sacroiliac joint between pregnant women and healthy subjects if the data were not normal distributed.

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CHAPTER IV

RESULTS

4.1 Characteristics of Subjects

The present study investigated the movement of sacroiliac joint in the frontal plane by modified Gillet test of pregnant and non-pregnant subjects. The study consisted of 30 subjects in each group aged between 20 and 35 years. Mean values and standard deviations of age, height, weight and body mass index are shown in Table 4.1. All data of subjects were normal distribution and no significant differences were found between pregnant and non-pregnant groups ($p>0.05$).

Table 4.1 Mean values and standard deviations of characteristic of pregnant and non-pregnant groups

Characteristics of Subject	**Pregnant (N=30)**	**Non-pregnant (N=30)**	***p*-value[a]**
Age (years)	24.87 ± 4.4	25.2 ± 5.43	0.795
Height (cm.)	157.80 ± 4.94	158.47 ± 5.18	0.612
Weight (kg)	52.07 ± 8.40	48.97 ± 4.17	0.076
Body Mass Index (kg/m^2)	20.44 ± 2.96	19.76 ± 2.16	0.311

a ; *p*-value from unpaired t-test

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4.2 Comparison of Sacroiliac Joint Displacement between Pregnant and Non pregnant Women

The sacroiliac joints displacement during performing modified Gillet tests with hip flexion 90 degrees from standing in each side are presented in Table 4.2. There were significant difference between pregnant and non pregnant women ($p<0.01$).

Table 4.2 Mean values and standard deviations of sacroiliac joint displacement between pregnant and non pregnant women.

Parameter	Pregnant (N=30)	Non pregnant (N=30)	*p*-value[a]
Left sacroiliac displacement (mm)	3.69 ±1.49	2.16 ±1.01	0.001*
Right sacroiliac displacement (mm)	3.95±1.72	2.08 ±1.19	0.001*

*; significant difference at $p<0.05$

a ; *p*-value from unpaired t-test

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4.3 Comparison of Sacroiliac Joint Displacement between Pregnant Women with and without Lumbopelvic Pain

The sacroiliac joints displacement during perform modified Gillet tets with hip flexion 90 degrees from standing in each sides are presented in Table 4.3. The results showed no significant difference in both sides of sacroiliac joint displacement.

Table 4.3 Sacroiliac joint displacement in pregnant women with and without pain

Parameter	**Pregnant women with lumbopelvic pain (N=30)**	**Pregnant women without lumbopelvic pain (N=30)**	***p*-value[a]**
Left sacroiliac joint displacement (mm)	3.78±1.11	3.61±1.76	0.763
Right sacroiliac joint displacement (mm)	3.84±1.59	4.04±1.86	0.757

a ; p-value from unpaired t-test

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CHAPTER V

DISCUSSION

5.1 Characteristics of Subjects

Subject recruited in this study were Thai pregnant and non pregnant women aged 20-35 years with and without low back pain. The age, weight, height and body mass index of both groups were similar and no statistically significant difference were indicated between groups. These implied that age, weight, height and body mass index would not be the cause of differences of all parameters in this study.

5.2 Lumbopelvic Pain in Pregnancy

The present study revealed that the finding of lumbopelvic pain in pregnant women were 43.33% (13 out of 30). The finding was similar to the previous studies of Ostgaard (60) and Gutke (65) that used questionnaire to investigate lumbopelvic pain and found that pelvic girdle pain affected women with high impact during early stage of pregnancy than back pain alone. However, pregnant women with lumbopelvic pain in the present study were less affected to activity of daily living than the previous studies. Similar to study of Dumas et al that investigated the effect of exercise on pregnancy-related back pain in 65 pregnant women, which 27 were exercise group and 38 were controls, during pregnancy until 4 months postpartum period by questionnaire with 28 functional activities rating scales. The biomechanical factors that studied were weight, spinal curvature and joint laxity. They found that no significant differences in back pain and functional activities limitation reported by two groups. Furthermore these biomechanical factors were unable to explain the pain variation (68).

The previous studies (69-71) revealed that there were several factors influencing back and pelvic pain. In 1998, Turkut et al investigated the prevalence of back pain with prospective study after delivery through 6 months postpartum. They

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studied in 88 pregnant women with aged between 14-46 years that had back pain during pregnancy. The results showed that back pain before pregnancy was the dominant factor of back pain at postpartum period. Furthermore, the number of previous pregnancy and older age were other risk factors for back pain (69). Brynhildsen et al investigated the long term risk of low back pain among women with previous severe low back pain during pregnancy with questionnaire that regarding occupation, sick leave due to low back pain and oral contraceptions. The results showed that women with previous severe low back pain during pregnancy experienced the same symptoms in a later pregnancy and used more sick leave due to low back pain. Furthermore, heavy occupation increased risk of low back pain (70). Wang et al studied the prevalence of low back pain during pregnancy with questionnaire. They found that current back pain during pregnancy was predicted by younger age, proned to develop back pain, back pain during previous pregnancy. Furthermore, 30% of pregnant women were unable to perform activity daily living (71).

5.3 Sacroiliac Joint Displacement

The conceptual biomechanic of sacroiliac joint during one leg stance or asymmetric loading was that when subject is in standing position and lift one leg, the load transferred to the ipsilateral sacroiliac joint at least doubled muscles force and ligaments also prevent shear forces by means of compression to the specific loading situation (27). Therefore, the true sacroiliac joint displacement should be occurred on the hip flexion side.

The displacements of sacroiliac joint in this study were 3.69-3.95 mm. for pregnant group and 2.08-2.16 mm. of non-pregnant group. Smidt et al reported the translation of PSIS with respect to the sacrum in fresh cadavers ranged from 4 to 8 mm with the largest amount of sacroiliac joint motion occurred in the sagittal plane (22). Hungerford et al used motion analysis system to analyze movement of innominate bones from erect standing to each hip flexed to 90 degrees in angular and translation motion. They used reflective ball markers with 15 mm in diameter attached to innominate bone both sides and three armed triangular wand with a single marker 10 mm in diameter at the second sacral spinous process. The results showed that the

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innominate displacement in vertical were between 4-6.5 mm in the left side and 5-7.5 mm in the right side. They suggested that the detected movement included the skin movement and movement of muscles close to the placement of skin markers (72). When compared to the bones movement in the study of Kissling (26) that inserted three dimension k-wires into bony landmark of innominate bones and sacrum. During performed one-legged stance for each side, the displacement in each plane was between 0.45-0.62 mm. Similar to the study of Sturesson (27) that used radiostereometric analysis that tantalum ball markers were inserted into bony landmarks of sacroiliac joints during performed standing hip flexion test. The sacroiliac joint displacement from standing both feet to each hip maximally flexed was 0.3 mm in each side.

From comparing to the previous studies, the results of the present study were closely similar to the studies of Smidt et al and Hungerford et al. However, the displacements of sacroiliac joint were generally larger than the studies of Kissling and Sturesson. Furthermore, this study used standing with hip flexed to 90 degrees with support both feet of subjects instead of really one leg stance in the reason for safety and enhance stability of pregnant subjects during performed the modified Gillet test.

The sacroiliac joint displacement of pregnant women was greater than non pregnant women. This indicated that pregnant women proned to develop injury of sacroiliac joint. The previous studies of sacroiliac joint laxity suggested that the pelvic belt could reduce this effect (73-77). However, these studies suggested pelvic belt was effective when using in the postpartum period. Nilsson-Wikmar et al compared education, belts with different exercise programs in 3 groups the results showed no statistically significant differences among the groups at week 38 of pregnancy with respect to pain intensity and activities of daily living (73). Ostgaard et al investigated education and nonelastic pelvic belt support in different groups of pregnant women with posterior pelvic pain. They found that 83% of these women experienced reduced problems when wearing belt (74). Mens et al reported that pelvic belt was effective in the management of peripartum pelvic pain but was less effective during pregnancy than after delivery (75). Damen et al investigated positions and tensions of nonelastic

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pelvic belt that caused reducing sacroiliac joint laxity in healthy young women. They used DIV technique to investigate the effect of pelvic belt at the level of the symphysis with tensions of 50 N, 100 N. The results showed that the different tensions of pelvic belt had no significant influence on the amount of sacroiliac joint laxity. However, pelvic belt was more effective when applied below the anterior superior iliac spines (76). The similar of this effect was proved by Mens et al that investigated the effect of pelvic belt on sacroiliac joint laxity in pregnancy-related pelvic girdle pain subjects with DIV technique. They found that sacroiliac joint laxity decreased significantly during application of pelvic belt below the anterior superior iliac spines of the pelvis (77).

5.4 Clinical Implication

The present study was the first study in Thailand that provided quantitative measurement of sacroiliac joint displacement during performing modified Gillet test with photographic method in pregnancy. The method used was reliable and easy to apply in clinic. Moreover, using photographic technique is safe for pregnant women.

The findings of this study demonstrated that the displacements of sacroiliac joint in pregnant women were greater than those in non pregnant women. Furthermore, there were no significant differences in the displacement of sacroiliac joint between in pregnant women with and without lumbopelvic pain. This finding supported the study of Damen et al (36) that used Doppler imaging of vibration to investigate the association between sacroiliac laxity and pelvic pain during pregnancy. They found that sacroiliac laxity in pregnant women with and without pelvic pain was not significantly different. However, asymmetrical laxity of both sides of sacroiliac joint was correlated with pregnancy-related pelvic pain (PRPP). Damen et al investigated the association of the differences between left and right sacroiliac joint laxity and pelvic pain with DIV technique in 123 women from 36 weeks' gestation to 8 weeks' postpartum. They reported that pelvic pain during pregnancy was associated with high body weight during pregnancy and pelvic pain in previous pregnancy. The pelvic pain in 52.7% of subjects during pregnancy had disappeared at 8 weeks postpartum. The

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researchers suggested the asymmetric laxity of sacroiliac joint can be used in the prognosis of PRPP postpartum (78).

It seems that pregnant women had a greater laxity of sacroiliac joint from various physiological changes that could be induced to sacroiliac joint dysfunction. The finding of this study indicated that sacroiliac joint displacement in the third trimester were almost two times greater than non pregnant women. The women with laxity of sacroiliac joint prone to have injury. Therefore, apart from using the pelvic belt, lumbopelvic stabilization exercise should be recommended for pregnant women in order to prevent sacroiliac joint dysfunction after delivery.

For further study, it is interesting to investigate the effects of lumbopelvic stabilization exercise including transverse abdominis, internal oblique and pelvic floor muscles on sacroiliac joint displacement during postpartum period.

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CHAPTER VI

CONCLUSION

This study investigated the displacement of sacroiliac joint in the frontal plane by using the digital camera during performing modified Gillet test in pregnant and non pregnant women. Thirty subjects were in each group. The results showed significant difference of the sacroiliac joint displacement between pregnant and non pregnant groups in both sides of sacroiliac joints. Comparing between pregnant women with and without low back pain, no significant difference was indicated in either left or right side of sacroiliac joint displacement.

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APPENDIX

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APPENDIX A.1

PARTICPANT INFORMATION SHEET

เอกสารแนะนำสำหรับอาสาสมัคร

(Participant information sheet)

1.ขั้นตอนการวิจัย

1.ขั้นเตรียมการ

ผู้เข้าร่วมการวิจัยทุกคนจะได้รับการซักประวัติและตรวจร่างกายเพื่อประเมินอาการปวดบริเวณกระดูกเชิงกราน จากนั้นผู้วิจัยจะอธิบายขั้นตอนการวิจัยและให้ผู้เข้าร่วมวิจัยลงนามยินยอมเข้าร่วมการวิจัยและเปลี่ยนชุดที่เปิดเฉพาะบริเวณหลังส่วนล่าง สะโพก และบริเวณกระดูกเชิง กราน ที่ห้องสำหรับการเก็บข้อมูล

2. ขั้นตอนการทำการเก็บข้อมูล

ผู้วิจัยทำการชี้แจงวัตถุประสงค์ อธิบายขั้นตอนการทดสอบ ผลข้างเคียงที่อาจเกิดขึ้นและประโยชน์ที่ได้รับจากการวิจัยโดยผู้วิจัยจะบันทึกข้อมูลดังต่อไปนี้ในทุกครั้งที่ผู้เข้าร่วมวิจัยมาพบ ระดับความรุนแรงของอาการปวดในวันที่พบ ประเมินโดยใช้เส้นตรงบอกระดับความปวด

ผู้วิจัยเริ่มทำการศึกษา โดย ผู้วิจัย(ผู้เข้าร่วมวิจัยอยู่ในช่วงไตรมาสที่ 3 ขณะตั้งครรภ์) จะทำการบันทึกข้อมูลต่อไปนี้

1. ส่วนสูง น้ำหนัก อายุ อายุครรภ์ ดัชนีมวลกาย อาชีพ
2. ประวัติเกี่ยวกับการปวดหลังและกระดูกเชิงกราน
3. ความยาวขาทั้ง 2 ข้าง ในขณะยืนตรง
4. ระดับความรุนแรงของอาการปวด

บันทึกการเคลื่อนไหวของข้อต่อกระดูกเชิงกราน โดยใช้กล้องถ่ายภาพโดยผู้วิจัยจะติดเครื่องหมายที่ กระดูกเชิงกรานทั้ง 2 ด้าน หลังจากที่ผู้เข้าร่วมวิจัยได้เปลี่ยนชุดที่จัดเตรียมไว้เฉพาะ ที่ห้องสำหรับเก็บข้อมูลที่ ตึกศรีสังวาลย์ชั้น 7และทำการถ่ายภาพ โดยใช้กล้องถ่ายภาพ (การเดินทางจากตึกผู้ป่วยนอกมาที่ ตึกศรีสังวาลย์ชั้น 7 ใช้รถเข็นนั่งที่มีเจ้าหน้าที่มาส่ง) ในครั้งที่ 1 นี้ใช้ระยะเวลาทั้งสิ้นประมาณ 1 ชั่วโมงในการเก็บข้อมูล

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APPENDIX A.2

CONSENT FORM

แบบหนังสือที่อาสาสมัครหรือผู้ป่วยแสดงความสมัครใจ

เข้าร่วมการศึกษาวิจัย

เรื่อง ขอความร่วมมือในการศึกษาการวัดการเคลื่อนไหวของข้อต่อกระดูกเชิงกราน

เรียน สตรีมีครรภ์

เนื่องด้วยข้าพเจ้า นายพุฒิพงษ์ เถามณี นักศึกษาวิทยาศาสตรมหาบัณฑิตสาขากายภาพบำบัด โรงเรียนกายภาพบำบัด อยู่ในระหว่างการดำเนินงานวิจัยเพื่อเสนอเป็นวิทยานิพนธ์เรื่อง “การเปรียบเทียบการเคลื่อนไหวของข้อต่อกระดูกเชิงกรานในสตรีครรภ์แรกและสตรีปกติ” โดยคาดว่าการวิจัยครั้งนี้จะเป็นประโยชน์อย่างยิ่งต่อการวางแผนการรักษาทางกายภาพบำบัดในสตรีมีครรภ์ต่อไป การรวบรวมข้อมูลจะมีขั้นตอนดังนี้

1. ซักประวัติ ได้แก่ ชื่อ นามสกุล อายุ อาชีพ ส่วนสูง น้ำหนัก อายุครรภ์ประวัติที่เกี่ยวข้องกับอาการปวดหลังและบริเวณกระดูกเชิงกราน ขณะตั้งครรภ์และก่อนการตั้งครรภ์ เป็นต้น รวมทั้งบันทึกระดับความรุนแรงของอาการปวดโดยใช้แบบสอบถาม
2. วัดความยาวของขาในขณะยืนตรง และตรวจดูท่าทางของกระดูกสันหลังและขาทั้ง 2 ข้าง
3. วัดการเคลื่อนไหวของข้อต่อกระดูกเชิงกราน โดยใช้การบันทึกภาพด้วยกล้องถ่ายภาพ

ผลการศึกษาครั้งนี้จะเป็นประโยชน์อย่างยิ่ง โดยสามารถนำข้อมูลที่ได้จากการศึกษามาใช้เป็นแนวทางในการส่งเสริมสุขภาพแก่สตรีมีครรภ์ที่มีปัญหาปวดข้อต่อกระดูกเชิงกราน

การเก็บข้อมูลครั้งนี้ ไม่มีความเสี่ยงหรือผลเสียต่อสุขภาพของสตรีมีครรภ์แต่อย่างใด และผู้เข้าร่วมการวิจัยมีสิทธิที่จะขอยุติการวิจัยได้ทุกเมื่อ และหากผู้วิจัยมีข้อมูลเพิ่มเติมทั้งด้านประโยชน์และโทษที่เกี่ยวข้องกับการวิจัย จะแจ้งให้ข้าพเจ้าทราบอย่างรวดเร็วโดยไม่ปิดบัง

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จึงเรียนมาเพื่อขออนุญาตในการเก็บรวบรวมข้อมูลดังกล่าวและขอขอบคุณเป็นอย่างสูงในความร่วมมือมา ณ โอกาสนี้

ด้วยความนับถือ
นายพุฒิพงษ์ เถามณี
(ผู้ทำการวิจัย)

ข้าพเจ้า นาง.....
ได้รับทราบขั้นตอนในการเก็บรวบรวมข้อมูลเกี่ยวกับการทำวิจัยเรื่อง “การเปรียบเทียบการเคลื่อนไหวของข้อต่อกระดูกเชิงกรานในสตรีครรภ์แรกและสตรีปกติ” และได้ซักถามผู้วิจัยจนหมดข้อสงสัยโดยตลอดแล้ว และยินดีเข้าร่วมการศึกษาวิจัยครั้งนี้ จึงได้ลงลายมือชื่อไว้เป็นหลักฐานต่อหน้าพยาน

ลงชื่อ.....
(.....)
ผู้เข้าร่วมโครงการ

ลงชื่อ.....
(.....)
หัวหน้าโครงการ

ลงชื่อ.....
(.....)
พยาน

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APPENDIX B

MODIFIED OSWESTRY LOW BACK PAIN DISABILITY QUESTIONNAIRE

(ภาคภาษาไทย)

แบบสอบถามนี้ จัดทำเพื่อให้ผู้รักษาของท่านเข้าใจผลกระทบของอาการปวดหลังของท่านที่มีต่อชีวิตประจำวัน กรุราตอบคำถามทุกข้อ โดยการขีด √ ด้านหน้าข้อความเพียงข้อเดียวที่จะบอกสภาพของคุณวันนี้ได้ดีที่สุด เราทราบดีว่า ท่านอาจจะรู้สึกว่ามี 2 ข้อความในข้อนั้นที่ตรงกับสภาพของคุณ แต่**กรุณาขีดเครื่องหมายในที่ว่างด้านหน้าข้อความที่ใกล้เคียงกับสภาพในปัจจุบันของคุณมากที่สุดเพียงข้อเดียว**

ระดับความเจ็บปวด

- ☐ สามารถทนปวดได้โดยไม่ต้องใช้ยาแก้ปวด
- ☐ มีอาการปวดมาก แต่จัดการได้โดยไม่ต้องใช้ยาแก้ปวด
- ☐ ยาแก้ปวดทำให้หายปวดโดยสิ้นเชิง
- ☐ ยาแก้ปวดทำให้หายปวดได้ในระดับปานกลาง
- ☐ ยาแก้ปวดทำให้หายปวดได้เล็กน้อย
- ☐ ยาแก้ปวดไม่มีผลต่ออาการปวด

การดูแลตัวเอง (อาทิเช่น การทำความสะอาด, การแต่งตัว)

- ☐ ดูแลตัวเองได้ตามปกติ โดยไม่ทำให้อาการปวดเพิ่มขึ้น
- ☐ ดูแลตัวเองได้ตามปกติ แต่มันทำให้อาการปวดเพิ่มขึ้น
- ☐ ปฏิบัติได้ช้าๆ โดยมีอาการปวด และต้องระมัดระวัง
- ☐ ต้องการความช่วยเหลือ แต่ก็สามารถจัดการธุระส่วนตัวส่วนใหญ่ได้
- ☐ ต้องการความช่วยเหลือทุกวัน สำหรับธุระส่วนตัวเกือบทุกเรื่อง
- ☐ แต่งตัวไม่ได้เลย อาบน้ำด้วยความลำบาก และอยู่แต่ที่เตียงนอน

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การยกของ

- ☐ ยกของหนักได้โดยที่อาการปวดไม่เพิ่มขึ้น
- ☐ ยกของหนักได้ แต่มันทำให้อาการปวดเพิ่มขึ้น
- ☐ อาการปวดเป็นอุปสรรคในการยกของหนักขึ้นจากพื้น แต่ก็ยกได้ ถ้าของที่มีน้ำหนักมาก ถูกจัดวางให้สะดวกในการยก (เช่นของตั้งบนโต๊ะ)
- ☐ อาการปวดเป็นอุปสรรคในการยกของหนัก แต่ก็ยกได้ ถ้าของที่มีน้ำหนักไม่มากนัก ถูกจัดวางให้สะดวกในการยก
- ☐ ยกได้แต่ของที่เบามาก
- ☐ ไม่สามารถยกหรือถืออะไรได้เลย

การเดิน

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

การนั่ง

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

การยืน

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

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การนอน

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

การเข้าสังคม

- ☐ การใช้ชีวิตในสังคมเป็นปกติ และไม่ทำให้อาการปวดเพิ่มขึ้น
- ☐ การใช้ชีวิตในสังคมเป็นปกติ แต่มันเพิ่มระดับความเจ็บปวด
- ☐ อาการปวดเป็นอุปสรรคในการทำกิจกรรมที่ต้องออกแรงมาก (เช่น กีฬา, การเต้นรำ)
- ☐ อาการปวดเป็นอุปสรรคในการออกไปข้างนอกบ่อยๆ
- ☐ อาการปวดจำกัดการใช้ชีวิตในสังคม ให้อยู่แต่ในบ้าน
- ☐ แทบไม่มีการเข้าสังคม เนื่องจากอาการปวด

การเดินทาง

- ☐ เดินทางไปได้ทุกแห่งโดยอาการปวดไม่เพิ่มขึ้น
- ☐ เดินทางไปได้ทุกแห่ง แต่มันทำให้อาการปวดเพิ่มขึ้น
- ☐ อาการปวดจำกัดการเดินทางที่เกิน 2 ชั่วโมง
- ☐ อาการปวดจำกัดการเดินทางที่เกิน 1 ชั่วโมง
- ☐ อาการปวดจำกัดการเดินทาง โดยเดินทางได้ในระยะสั้นที่ไม่เกินครึ่งชั่วโมง
- ☐ อาการปวดเป็นอุปสรรคต่อการเดินทางทั้งหมด ยกเว้นการไปพบแพทย์ / นักกายภาพบำบัด หรือไปโรงพยาบาล

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การจ้างงาน / งานบ้าน

- ☐ งานบ้าน / กิจกรรมทางการงาน ไม่ทำให้เกิดอาการปวด
- ☐ งานบ้าน / กิจกรรมทางการงาน เพิ่มอาการปวด แต่สามารถทำงานที่ต้องการทำทั้งหมดได้
- ☐ ทำงานบ้าน / ภาระงานส่วนใหญ่ได้ แต่อาการปวดเป็นอุปสรรคต่อการทำกิจกรรมที่มีความเครียดทางกายเพิ่มขึ้น (เช่น การยกของ, การดูดฝุ่น)
- ☐ อาการปวดเป็นอุปสรรคในการทำสิ่งใดๆ ยกเว้นภาระงานที่เบา
- ☐ อาการปวดเป็นอุปสรรค แม้แต่ภาระงานที่เบา
- ☐ อาการปวดเป็นอุปสรรคในการทำงานใดๆหรืองานบ้านประจำ

Source: Fritz JM, Irrgang JJ. A comparison of a modifdied Oswestry Low Back Pain Disablity Questionnaire and the Quebec Back Pain Disability Scale. Physical Therapy. 2001; 81: 776-788.

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APPENDIX C

DATA COLLECTION FORM

Subject no….. **( ) pregnant ( ) non pregnant**

Name..... Age…….. Gestational age……weeks.

Weight…… kg. Weight before pregnant……..kg.

Height…… cm BMI…….(kg/m²)

Address……

…….

Telephone…… Mobile……

Lt. Femur……cm Lt. Tibia…… cm

Rt. Femur..... cm Rt. Tibia.....cm

History of back pain before pregnant No ……. Yes……(about…….months)

Height from floor to both iliac crest ……..cm

Position of marker in standing X…… Y……(pixel)

Position of marker in Lt. hip flexion 90 X……... Y…….. .(pixel)

Position of marker in Rt. hip flexion 90 X……... Y…….. (pixel)

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APPENDIX D

RESULT OF THE PILOT STUDY

The aim of this pilot study was to investigate the agreement of palpation of bony landmark of sacroiliac joints. Thirty female subjects participated in this pilot study. The data of the agreement of palpation were presented in Table D.1.

Table D.1 Raw data of agreement of palpation of bony landmarks

Subject. No.	L4		Lt. PSIS		Rt. PSIS		S2	
	Agree	Disagree	Agree	disagree	Agree	disagree	Agree	disagree
1	A		A		A		A	
2	A		A		A		A	
3	A		A		A		A	
4	A		A		A		A	
5		DA	A		A		A	
6	A		A		A		A	
7	A		A		A		A	
8	A		A		A		A	
9	A		A		A		A	
10	A		A		A		A	
11	A		A		A		A	
12	A		A		A		A	
13		DA	A		A		A	
14	A		A		A		A	

A mean agreement DA mean disagreement

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Table D.1 Raw data of agreement of palpation of bony landmarks (cont.)

Subject. No.	L4		Lt. PSIS		Rt. PSIS		S2	
	Agree	Disagree	Agree	disagree	Agree	disagree	Agree	disagree
15	A		A		A			DA
16	A		A		A		A	
17	A		A		A		A	
18	A		A		A		A	
19	A		A		A		A	
20	A		A		A		A	
21	A		A		A		A	
22	A		A		A		A	
23	A		A		A		A	
24	A		A		A		A	
25	A		A		A		A	
26	A		A		A			DA
27		DA	A		A		A	
28	A		A		A		A	
29	A		A		A		A	
30	A		A		A		A	

A mean agreement DA mean disagreement

The agreement of palpation was confirmed by palpation of two qualified manipulative physical therapists (Roongtiwa Vachalathiti and Keerin Mekhora). The agreement of bony palpation was 95.83%.

This pilot study was to investigate intratester reliability of manual digitization the center of each marker. These markers were placed on left and right posterior superior iliac spine in each subject. The manual digitization was performed two times for one week apart in 10 healthy female subjects.

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Table D.2 Raw data of position of markers at left and right PSIS used to calculate reliability of manual digitization of pilot study

Subj. No.	L PSIS				R PSIS			
	L PSIS-X1	L PSIS-X2	L PSIS-Y1	L PSIS-Y2	RPSIS-X1	R PSIS-X2	L PSIS-Y1	L PSIS-Y2
1	125.2	125.4	173.2	172.6	241.4	231.6	175.8	178.8
2	162.2	153.2	170	164.2	258.2	259.6	167	161.6
3	185.45	173.64	158.18	153.18	293.86	286.59	158.18	156.36
4	174.67	166	103.78	109.11	284.44	267.11	96.44	107.11
5	138.7	131.47	214.13	210.65	258.48	238.48	205.43	208.26
6	138.48	133.26	196.52	205.65	237.17	231.96	208.7	213.7
7	177.78	177.11	170.89	165.78	287.11	280.22	171.56	177.33
8	185.11	185.11	127.56	142.89	287.56	286.67	135.33	151.33
9	155.45	144.77	145.23	155.23	280.45	265	137.95	152.05
10	171.14	155.45	178.18	152.27	291.82	281.82	178.86	158.41

X1* mean manual digitization center of marker at first trial of X coordinate

Y1* mean manual digitization center of marker at first trial of Y coordinate

X2* mean manual digitization center of marker at second trial of X coordinate at one week apart

Y2* mean manual digitization center of marker at second trial of Y coordinate at one week apart

All values were shown in pixel units.

The intratester reliability of manual digitization calculated from ICC 3,1 were 0.95 and 0.97 for x and y coordinates respectively.

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APPENDIX E

CALCULATION OF THE SAMPLE SIZE

The sample size for this study was calculated by the following equation

$$N = \frac{2S^2p[Z_{(1-\alpha/2)} + Z_{(1-\beta)}]^2}{(\mu_1-\mu_2)^2}$$

N = sample size for each subject group

S^2p = pooled variance

$\frac{S_1^2 + S_2^2}{2}$, if $n_1 = n_2$

n_1 = number of subject of pregnant women

n_2 = number of subject of non pregnant women

S_1^2 = variance of subject of pregnant women

S_2^2 = variance of subject of non pregnant women

$Z_{(1-\alpha/2)}$ = Z-value when set the confident level equal to 95% or significant level equal to 0.05 ($\alpha = 0.05$) = 1.96

$Z_{(1-\beta)}$ = Z-value when set the power of testing equal to 80% ($\beta = 0.2$) = 0.84

$\mu_1-\mu_2$ = the difference of means of parameter between pregnant women and non pregnant women group

From sample size calculation, the sacroiliac displacement is of concern for this study. Below is an example of sample size calculation using sacroiliac displacement.

$$N\ (SIJd) = \frac{2S^2p[Z_{(1-\alpha/2)} + Z_{(1-\beta)}]^2}{(\mu_1-\mu_2)^2}$$

$$= \frac{2(0.16)[1.96+0.84]^2}{(2.44-2.06)^2}$$

$$= 16.58$$

Accordingly, the appropriate sample size for each group in the present study is at least 17. In order to ensure the statistical analysis, therefore, this study selected 30 subjects for each group.

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APPENDIX F

RAW DATA OF THE STUDY

Table F.1 Characteristics of pregnant subjects

Pregnant women group						
No.	**Age (yrs)**	**Ht. (cm)**	**Wt. (kg)**	**BMI (kg/m²)**	**Pain VAS**	**% ODQ**
1	20	162	70	26.67	-	
2	28	155	39	16.23	-	
3	23	154	47	19.82	3	40
4	29	158	48	19.23	4	
5	35	162	48	18.29	3	8.3
6	21	155	50	20.81	4	6
7	27	160	50	19.53	2.5	25
8	23	170	53	18.34	-	
9	31	153	43	18.37	3	25
10	31	160	47	18.36	4	33
11	33	150	57	25.33	-	
12	26	151	50	21.93	-	
13	22	158	54	21.63	-	
14	25	157	57	23.12	-	
15	20	156	47	19.31	-	
16	20	156	58	23.83	-	
17	20	157	48	19.47	-	
18	27	161	58	22.38	2	16
19	24	159	42	16.61	-	
20	24	154	44	18.55	4	12
21	20	156	40	16.44	-	
22	23	155	48	19.98	3.5	34
23	22	165	43	15.79	3.5	14
24	20	156	46	18.9	-	
25	27	162	47	17.91	-	
26	30	153	57	24.35	-	
27	21	159	67	26.5	4	14
28	20	166	65	23.59	-	
29	30	153	47	20.08	3	12
30	24	150	48	21.33	-	

ODQ = Oswestry Disability Questionnaire.

BMI = body mass index, VAS = visual analog scale

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Table F.2 Characteristics of non pregnant subjects

Non pregnant women group				
No.	**Age (yrs)**	**Ht. (cm)**	**Wt. (kg)**	**BMI (kg/m²)**
1	35	163	47	17.69
2	20	155	40	16.65
3	25	154	50	21.08
4	27	158	50	20.03
5	24	163	47	17.69
6	20	155	49	20.4
7	23	168	49	17.36
8	29	165	52	19.1
9	21	152	46	19.91
10	30	160	45	17.58
11	22	150	56	24.89
12	35	150	48	21.33
13	20	157	54	21.91
14	35	158	55	22.03
15	20	155	47	19.56
16	27	156	55	22.6
17	21	158	42	16.82
18	21	160	56	21.88
19	30	157	43	17.44
20	21	156	42	17.26
21	35	156	49	20.13
22	21	155	48	19.98
23	27	166	47	17.06
24	21	156	50	20.55
25	24	160	48	18.75
26	22	153	54	23.07
27	21	160	49	19.14
28	21	168	46	16.3
29	27	153	78	33.32
30	20	151	43	18.86

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Table F.3 Sacroiliac joint displacement (mm.) of pregnant and non pregnant women

Pregnant women			Non pregnant women		
Subj. No.	**Lt. SIJ**	**Rt. SIJ**	**Subj. No.**	**Lt. SIJ**	**Rt. SIJ**
1	4.69	2.85	1	2.91	4.07
2	7.91	7.23	2	0.59	0.52
3	3.17	3.61	3	4.15	2.65
4	1.10	0.82	4	0.27	0.04
5	4.68	2.27	5	2.91	4.07
6	4.27	4.46	6	1.15	1.67
7	4.02	7.67	7	2.30	2.05
8	5.76	4.99	8	1.83	1.07
9	4.00	4.75	9	2.30	2.56
10	4.57	4.02	10	2.30	2.05
11	2.95	5.83	11	3.37	0.36
12	1.00	1.54	12	1.83	1.07
13	3.83	5.62	13	1.89	2.81
14	2.56	6.41	14	2.91	4.07
15	2.35	5.53	15	2.50	0.54
16	2.93	4.86	16	1.32	1.29
17	2.23	0.40	17	2.47	1.89
18	4.66	4.50	18	1.68	1.78
19	3.18	2.68	19	0.76	1.58
20	3.00	2.50	20	4.46	2.30
21	4.57	4.01	21	2.21	2.29
22	4.59	4.37	22	1.44	1.62
23	2.31	4.07	23	2.13	2.41
24	3.28	3.56	24	3.22	3.38
25	0.94	2.50	25	2.59	2.63
26	4.70	3.79	26	1.32	1.29
27	4.90	3.32	27	3.63	4.68
28	5.43	4.91	28	2.13	2.41
29	3.94	3.60	29	1.84	2.96
30	3.15	2.05	30	0.67	0.04

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