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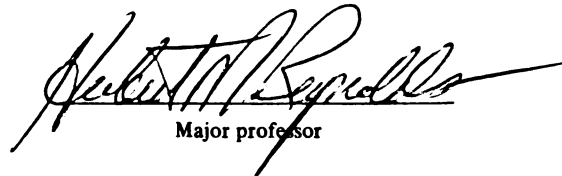
MOTION OF THE PELVIS DURING PASSIVE LEG
LIFTING ON NORMAL SUBJECTS

presented by

Jane Fåhlgren Grambo

has been accepted towards fulfillment
of the requirements for

Master of Science degree in Biomechanics



Major professor

Date November 7, 1989

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MOTION OF THE PELVIS DURING PASSIVE LEG
LIFTING ON NORMAL SUBJECTS

By

Jane Fahlgren Grambo

A Thesis

Submitted to

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ABSTRACT

MOTION OF THE PELVIS DURING PASSIVE LEG
LIFTING ON NORMAL SUBJECTS

By

Jane Fahlgren Grambo

Leg and pelvic motion were studied during passive straight leg raising on twenty-three male subjects without low back pain. A sonic digitizer was used to measure angular displacements of the pelvis during right and left straight leg raising. Angles of rotation were calculated for total leg lift motion in the sagittal plane, and pelvic motion in both the sagittal and transverse planes. The mean angle of rotation for leg lift motion was $59.3^{\circ} \pm 9.1$ and $60.6^{\circ} \pm 8.9$ for right and left leg trials, respectively. Mean angle of pelvic rotation in the sagittal plane was $16.9^{\circ} \pm 3.0$ and $17.1^{\circ} \pm 3.3$ for right and left leg trials, respectively. The ratio of pelvic rotation in the sagittal plane to leg lift rotation was 3.522 ± 0.751 and 3.491 ± 0.671 for right and left leg trials, respectively. Mean angle of pelvic rotation in the transverse plane was $1.6^{\circ} \pm 2.5$ and $-1.5^{\circ} \pm 2.6$, respectively, for right and left leg trials. Rotation of the pelvis in the transverse plane occurred toward the non-lifted leg.

Dedicated to my ever supportive Mother and Husband and to
the special memory of my Father.

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INTRODUCTION

The straight leg raising test is a frequently used clinical technique for assessing low back dysfunction and hamstring length. The exact physiological and biomechanical events that occur during the straight leg raising test have been difficult to identify and are thus under repeated study. Consequently, clinical and scientific interpretation of the straight leg raising test varies within and between the many specialities of medicine and research.

Classically, the straight leg raising test consists of passively raising a supine subject's leg slowly into hip flexion until pain is reported in the lower back and or posterior leg, or until the end of their physiological range of motion is reached. The knee is maintained in full extension during the entire test and a position of neutral hip rotation is also sustained. During passive straight leg raising, tension is placed on the lumbo-sacral nerve plexus and hamstring muscles. The hamstring muscles have their origin at the ischial tuberosity of the pelvis. Thus, when placed under increasing tension, they cause a posterior rotation of the pelvis. Posterior rotation of the pelvis then may cause flexion of the lumbo-sacral spine.

If pain does not limit the straight leg raise motion, the end of motion is defined as the point at which firm

resistance to leg raising is felt (Bohannon,1985). Some clinicians define the point at which the contralateral anterior superior iliac spine begins to move posteriorly as the maximum straight leg raising range of motion (Fisk, 1979) and use the angle the leg makes with the horizontal as a measure of hamstring length. Normal hip flexion range of motion during straight leg raising is approximately sixty to one hundred degrees (Kutsuna and Watanabe, 1980). The range of motion is noted by the examiner through goniometric measurement of the hip flexion angle or by gross observation, and is typically compared to the subject's contralateral side.

Range of motion in straight leg raising can be limited by pain, hamstring, low back and buttock muscle spasm, by inherent hamstring muscle length or by mechanical dysfunction of the lumbo-sacral complex (Grieves,1970; Fisk,1979). If pain is elicited in the first thirty to thirty-five degrees of the straight leg raising test, the test is generally considered to be positive for sciatic nerve or nerve root irritation. Pain occurring beyond thirty-five degrees of straight leg raising has a less well defined origin and interpretation.

Theories to explain the mechanism of pain during the straight leg raising test include the following:

1. As the lumbo-sacral nerve roots exit the spinal column they lie adjacent to their respective intervertebral discs. If a disc herniation occurs, the nerve root is stretched over the protruding disc material. Straight leg

raising increases the tension on the lumbo-sacral nerves and further stretches the nerve root over the disc (Breig and Troup, 1979). This typically elicits pain in the distribution of the nerve being stretched. Disc herniation commonly occurs at the L4/5 and L5/S1 intervertebral levels giving rise to pain in a sciatic nerve distribution with straight leg raising. Pain of this origin has been associated with pain occurring in the first thirty-five degrees of straight leg raising at which position slack has been taken out of the nerve (Fahrini, 1966).

2. A nerve root or nerve, that has become adherent to a disc or surrounding structures, may limit nerve tissue motion and produce pain when stretched (Goddard and Reid, 1965; Fahrini, 1966). Pain occurring between thirty-five and seventy degrees of straight leg raising has been associated with this phenomena in the sciatic nerve and lumbo-sacral nerve roots (Fahrini, 1966).

3. In addition to stretching neural tissue, straight leg raising motion also stretches the soft tissue of the thigh, buttock, and lumbar region. Thus, pain may arise from the hamstrings, gluteal or lumbar muscles during a straight leg raise if they are in acute spasm or inherently shortened (Breig and Troup, 1979).

4. Movement of the pelvis and lumbo-sacral spine occur during the straight leg raising motion. The joint structures related to this movement, such as the lumbo-sacral vertebrae and synovial facet joints, may elicit pain

during the straight leg raise if they are in an irritable or dysfunctional state (Grieves, 1979).

The anatomical events that occur within the soft tissue structures during a straight leg raise have been well documented in cadavers and lend support to the theories outlined above (Charnley, 1959; Goddard, 1965; Breig and Troup, 1979). Documentation of the mechanical events that occur between bony structures during the straight leg raise, and how they correlate to the soft tissue events is limited. Two dimensional motion of the pelvis in the sagittal plane during straight leg raising has been described by several researchers (Mundale, 1956; Kottke and Kubicek, 1956; Greives, 1970; Fisk, 1979; Bohannon, 1982 and 1985). The idea that pelvic motion during straight leg raising is not limited to the sagittal plane, but is really a three-dimensional event, has only been alluded to (Greives, 1970; Fisk, 1979; Bohannon, 1982) but not examined. A better understanding of these mechanical events and how they influence pain and motion restriction mechanisms would enhance our ability to utilize the straight leg raise for diagnostic and therapeutic purposes.

It was the purpose of this study to:

1. Collect normative data for leg lift range of motion on subjects without low back pain.
2. Describe component motions of the leg lift, in particular hip motion, and pelvic motion in both the sagittal and transverse planes.

3. Investigate the relationship between the leg lift motion and pelvic motion.

LITERATURE REVIEW

Attempts to accurately quantify femoral-pelvic relationships begin with Mundale et al. (1956). The researchers established a clinical method for evaluating the femoral-pelvic angle on live subjects in the sagittal plane. Thirty-six normal males and females were studied. Mundale noted that in order to accurately measure hip joint motion (femoral-pelvic angle) both the positions of the femur and the innominate bones must be defined. He created a transverse innominate axis from the anterior superior iliac spine (ASIS) to the posterior superior iliac spine (PSIS), and a longitudinal innominate axis by the line intersecting the transverse axis and the greater trochanter. The longitudinal axis of the femur was defined by a line from the greater trochanter to the lateral epicondyle of the femur. Masking tape was placed on the bare skin of the subject to mark the anatomical axes. The femoral-pelvic angle, between the longitudinal axes of the pelvis and the femur, was then measured in various static positions using a goniometer. The researchers found their method to vary $\pm 5^\circ$ from x-ray measurements.

Kottke and Kubicek (1956) used Mundale et al.'s methods to study further femoral-pelvic angles in the sagittal plane. Their goal was to study the influence that tilt of

the pelvis (femoral-pelvic angle) had on stability and balance during standing and walking. Axes of motion were marked with tape. The femoral-pelvic angle, in the sagittal plane, was then observed through a clear grid. This investigation was then an attempt to study femoral-pelvic angles during a dynamic activity.

Grieve (1970) discussed some of the mechanical factors involved in sciatica and the straight leg raise test and how they relate to manipulative therapy. Grieve described lumbar spine flexion to occur as a result of pelvic motion. He observed the pelvis to tilt backwards in the sagittal plane and upwards in the frontal plane, i.e. a lateral tilt upwards on the tested side. He also observed the pelvis to rotate slightly towards the untested side and noted all these events to occur at the end range of motion.

By observation, Fisk (1979) correlated an increase in resistance to passive leg raising to palpable movement at the contralateral ASIS. He studied ten normal subjects with hamstring tightness and measured leg angle at the point of palpable ASIS movement. Fisk then recorded the tension necessary to mechanically raise the leg five degrees. Results showed a dramatic increase in tension just prior to the clinically determined end range of motion. Fisk attributed the marked rise in tension to increasing resistance to flexion of the lumbar spine and extension of the opposite hip. He noted that lumbar flexion and opposite hip extension were a result of pelvic rotation which occurred when sufficient stretch had been placed on the

hamstring muscles. Fisks' study was primarily concerned with accurately measuring resistance to passive leg raising and did not attempt to verify his observations of rotation of the pelvis or flexion of the lumbar spine.

Bohannon (1982) adapted Mundale, Kottke and Kubiceks' methods of using bony landmarks to track pelvic motion during straight leg raising. Bohannon sought to determine if pelvic rotation continued to occur when the pelvis was stabilized during passive leg raising. Eleven subjects, nine women and two men, were studied. None of the subjects had any known orthopedic or neurologic dysfunction. Analysis of cinematographic films showed greater increases in the straight leg raise/horizontal angle than in the straight leg raise/pelvis angle throughout the motion. This discrepancy between straight leg raise/horizontal angle and straight leg raise/pelvis angle indicated to Bohannon that pelvic rotation in the sagittal plane had occurred. Bohannon reasoned that if no rotation of the pelvis occurred, straight leg raise/horizontal angle and straight leg raise/pelvis angle would have increased by equal amounts.

Hsieh et al. (1983) made comparisons between measurements of passive leg lifting using a goniometer, a flexiometer and a tape measure. The hip flexion angle, at the point of initial pelvic tilt, was measured on ten subjects, four men and six women. Initial pelvic tilt was noted as the point at which "a small amount of pelvic rocking movement was detected by the examiner" (1983, p.

1430). They noted the onset of pelvic rotation to begin after 44° - 53° of leg raising.

Bohannon et al. (1985) again used Mundale's masking tape method of targeting boney landmarks and cinematography to document motion of the pelvis and lower limb during passive straight leg raising in the sagittal plane. Thirteen women and four men, without known dysfunction, were studied. Film analysis showed that pelvic rotation began during the first nine degrees of passive straight leg raising and that pelvic rotation continued to increase along with the increasing angle of straight leg raising.

The mean maximum increase in the passive straight leg raise/horizontal angle was found to be $87.3^{\circ} \pm 15.3$ in Bohannon's study, the mean increase in pelvis/horizontal angle was $32.1^{\circ} \pm 4.9$ and the mean increase in passive straight leg raise/pelvis angle was $55.2^{\circ} \pm 12.2$.

Bohannon determined that every 2.7° of passive straight leg raise/horizontal angle was accompanied by an increase of 1.7° in passive straight leg raise/pelvis angle and 1.0° of pelvic rotation/horizontal angle. As the angle of passive straight leg raise increased, the relative contribution of pelvic rotation to the passive straight leg raise angle also increased. Pelvic rotation was found to occur within the first nine degrees of leg raising and usually occurred before the passive straight leg raise/horizontal angle increased four degrees. The authors suggested that these early increases in the pelvis/horizontal angle were probably not caused by hamstring muscle tightness but more likely

were the result of resting tension in the hip extensor muscles. In this study, Bohannon noted elevation of the contralateral pelvis and lateral flexion of the contralateral trunk to have occurred during straight leg raising but considered them not to affect measurement of straight leg raise or pelvic motion.

It was evident from the literature that researchers' descriptions of motion characteristics were a function of the methods used to collect and interpret their respective data. As more sophisticated means of measuring body segment motion are developed, our ability to accurately and completely describe a particular motion will also improve.

METHODS and MATERIALS

Sample: The sample consisted of twenty-three male student volunteers. Their ages ranged from 18.2 to 35.4 years with an average of 27.1 +/-4.53 years. The anthropometric measures of height, weight and general leg size are presented in table 1. Complete anthropometric data for each subject will be found in Appendix 1.

Table 1. Sample anthropometry with weight in kg and all other dimensions in mm. *

	Standing Hgt	WGT	Thigh Circ	Calf Circ	ASIS Hgt
MEAN	1772.5	72.54	523.0	373.5	997.3
ST. DEV.	73.1	11.04	33.0	23.2	53.0
MIN.	1635.0	57.10	461.0	332.0	863.0
MAX.	1890.5	111.50	611.0	437.0	1079.0

* [WGT = clothed weight. ASIS Hgt measured from floor to right ASIS.]

Each subject completed a medical questionnaire (Appendix 4) and underwent a physical screening exam (Appendix 5). The questionnaire was used to identify subjects who were inappropriate for the study. No subject was eliminated from the study because of related medical problems or history of injury. Activity level was also recorded, and the population tended to have a minimally to moderately active lifestyle. No subject was currently

experiencing low back pain, was on pain medication or had undergone back surgery. Seven subjects reported previous history of minor back injury or pain, ranging from eighteen years to one week prior to testing.

The physical examination used was a modification of the "Ten Step" musculoskeletal screening examination by Mitchell (1979). Cervical and thoracic motion testing were not performed as in the full ten step screening exam, however a more complete examination of the pelvis and sacro-iliac joint were included. The examination and interpretation was performed by a licensed Physical Therapist. Seven subjects were identified as having possible lumbo-sacral or sacro-iliac dysfunction and eight showed asymmetry or restriction of normal trunk range of motion. None had evidence of clinically significant dysfunction. Trunk active range of motion for each subject will be found in Appendix 2.

Straight leg raising range of motion was measured on each subject. The point at which the contralateral ASIS could be palpated to move posteriorly was measured goniometrically (RT MOVT and LT MOVT). Goniometric measurements were also taken at the physiologic end range of motion (RT MAX and LT MAX), (Table 2). Complete measurements for each subject will be found in Appendix 3.

Materials:

Sonic Digitizer: Motion data were collected by use of a GP-8-3D Sonic Digitizer by Science Accessories Corporation. The system had an active digitizing volume of

Table 2. Straight leg raising range of motion measured goniometrically (in degrees).

	RT MOVT	RT MAX	LT MOVT	LT MAX
MEAN	52.3	67.6	53.7	70.8
ST. DEV.	10.0	12.0	10.1	13.0
COEF. VAR.	0.2	0.2	0.2	0.2
MIN.	43	46	40	50
MAX.	80	85	85	92
N	21	22	21	22

3.5 cubic meters. A 1524 mm by 1524 mm square frame was constructed from Unistrut steel and mounted to the ceiling. Four microphones were rigidly attached to the four corners of the frame, each equidistant from the center of the square frame (Figure 1) A single spark gap was rigidly mounted at the center of the microphone frame for use during system calibration.

The raw data collected was in the form of slant rays and stored as a four digit hexadecimal number. A slant ray represents the time from spark gap firing to recording. Thus, the distance from spark gap to microphone is measured as a function of time for sound to travel from spark gap to microphones.

As outlined in the Operator's Manual for the GP-8-3D Sonic Digitizer (1985) the mathematics of conversion from raw sonic data into spatial coordinates require that the acoustic reception points of the microphones be located in a planar, orthogonal configuration. To ensure that these requirements were met, several provisions were made in the construction of the microphone frame.

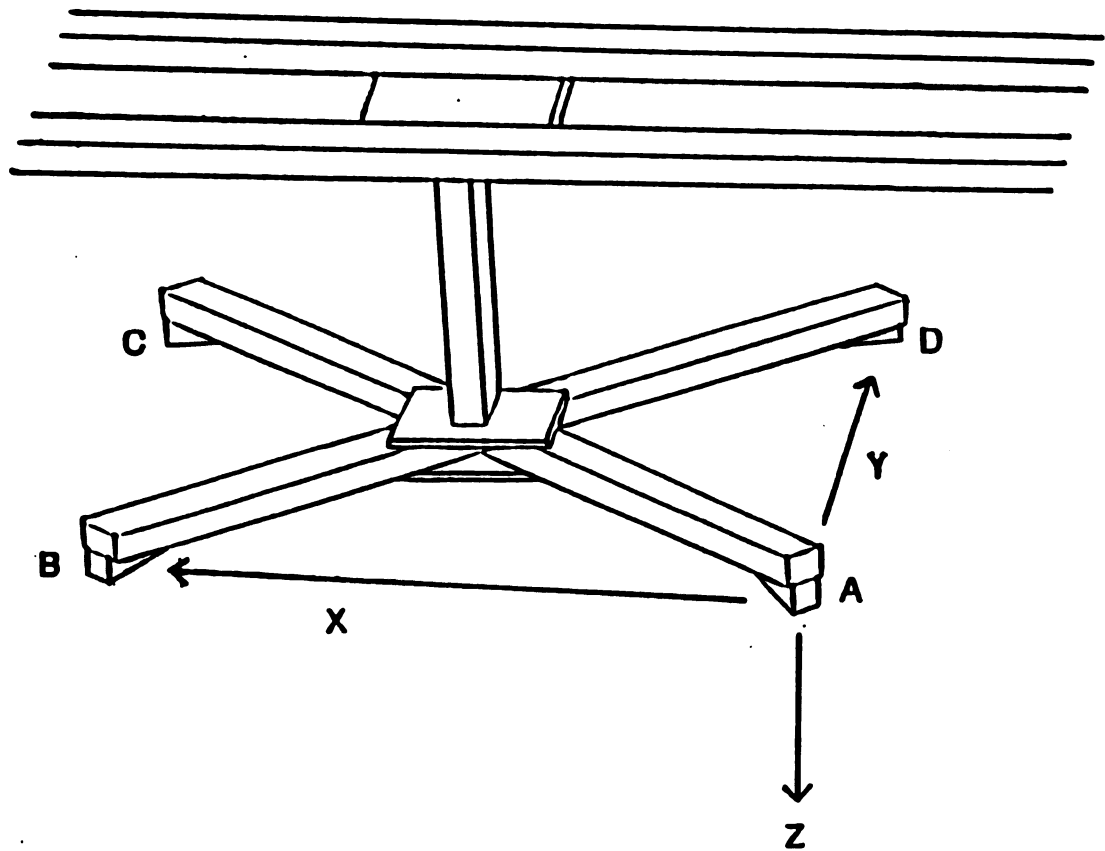


Figure 1. Microphone Frame and Laboratory Axis System

The microphone frame was constructed of P1000 Unistrut steel channel, roll formed from 12 gauge strip steel, 2.667 mm thick. Three channels (1 x 1800 mm, 2 x 900 mm) were held in a plane by two steel plates (6.53 mm thick) with eight precision aligned holes. Along each diagonal of the 304.8 mm square steel plates, two orthogonal lines were scribed and four 0.63 mm holes were centered and drilled. Equivalent holes were drilled through the Unistrut steel channels so that the plates and channels were aligned at 90° to each other as defined by the precision aligned holes in the steel plates. The microphones were then attached to the ends of the Unistrut channel as depicted in Figure 1. The strength of Unistrut P1000 channel and the steel plates guarantees that the microphone plane is stable and well-defined.

To test the microphone system, the spark gap mounted at the center of the microphone frame was fired for approximately ten seconds and the slant rays recorded from the center spark gap to each of the microphones were compared. If the four recorded slant rays were within ± 1.5 mm of each other, the microphones were considered equidistant from the central spark gap and thus were considered equidistant from each other. Calibration of the sonic digitizer was performed before each subject was tested to ensure that no disruption of the microphone system had occurred.

The collection of sound data from the spark gap system also included the potential for collecting noise. The

testing area was enclosed by curtains to absorb sound echos from the walls. Occasional reflection of sound, off of equipment surfaces within the active digitizing volume, and an echo phenomena, as reported by Engin et al. (1984), still occurred. Consequently, the raw data had to be filtered. Hexidecimal values of less than 167F (approximately 500 mm at 23° C) were filtered because they represented distances smaller than the smallest distance a spark gap could theoretically have come to a microphone in this experimental design. If a microphone became blocked from a particular spark gap emission, or did not have a clear path of sound transmission, a hexidecimal value of 7FFF was registered. These data were also filtered from the raw data. Filtering was accomplished by flagging the 7FFF's and the values below 167F, then excluding them from use in any data analysis.

A slant ray was generated for each of the four microphones: A, B, C, and D. Each raw data record consisted of four slant rays, a spark gap identification number and a time stamp. A data set consisted of six data records, one for each of the six spark gaps fired. All data records in a given data set were considered to have occurred at the same time. Actual time elapsed between consecutive records was 0.01 seconds. Time elapsed between the first record in a data set and the last record in a data set was 0.05 seconds.

Only three of the four slant rays were necessary for later conversion of sound data into coordinate data thus a selection of the best three microphone readings was made. If any one of the three slant rays had been flagged, the

three remaining slant rays were chosen for use in the conversion process. If more than one slant ray in any data record was flagged, the entire data set was not used in any analysis. If none of the four slant rays in a data record were flagged, the three slant rays in that record that had the least amount of difference between them were selected. This eliminated large and small values and selected values that were closest in magnitude to each other.

Because the speed of sound varies with air temperature, it was necessary to correct each subject's raw data according to the room temperature, measured by a mercury thermometer, during that subject's testing. The room temperature was input into the following equation for calculating the speed of sound (SS) at sea level:

$$SS = [4.0396 (273.15 + C) 10,000,000]^{1/2} \quad (1)$$

where C was the temperature in Celsius and SS = mm/sec.

The GP-8-3D counters ran at 4 megahertz. Consequently, the following formula was used to find the number of counts per unit length digitized (Scientific Accessories Corp., Operator's Manual, 1985):

$$(SS \text{ mm/sec}) / (4 * 1,000,000 \text{ counts/sec}) = X \text{ mm/ counts} \quad (2)$$

Each slant ray was then multiplied by this calculation of mm/count to give distance in millimeters.

All raw data was corrected for a standard amount of positive internal circuit delay within the multiplexer and other uncontrollable external environmental factors. The

magnitude of the internal circuit delay component was 2.85 mm. The correction factor of .9976 was calculated as follows:

$$\text{Factor} = 1 / [(\text{Digitized Distance} - 2.85 \text{ mm}) / \text{Known Distance}] \quad (3)$$

$$\text{Real Distance} = (\text{Digitized Distance} - 2.85 \text{ mm}) \times \text{Factor} \quad (4)$$

Next, the temperature corrected distances were converted into coordinate data by use of the pythagorean theorem as follows:

Microphones

$$\begin{aligned} \text{ABC} \quad X &= A^2 - B^2 + (AB)^2 / 2(AB) \\ Y &= B^2 - C^2 + (BC)^2 / 2(BC) \\ Z &= (A^2 - X^2 - Y^2)^{1/2} \end{aligned} \quad (5)$$

Similar equations were used to accommodate the selection of microphones ABD, ACD and BCD made earlier.

The data were now in X,Y,Z coordinates with the A microphone referenced as the 0,0,0 position and the axis system set up as shown in Figure 2. The coordinate data collected from the leg and the pelvis were then separated.

Spark Gap Instrumentation:

Pelvic Plate: Three spark gaps were mounted on a rigid T-shaped aluminum plate designed to track pelvic motion (Figure 3). The pelvic plate and the three legs extending from it were constructed of aluminum and the surfaces in contact with the subject's body were molded out

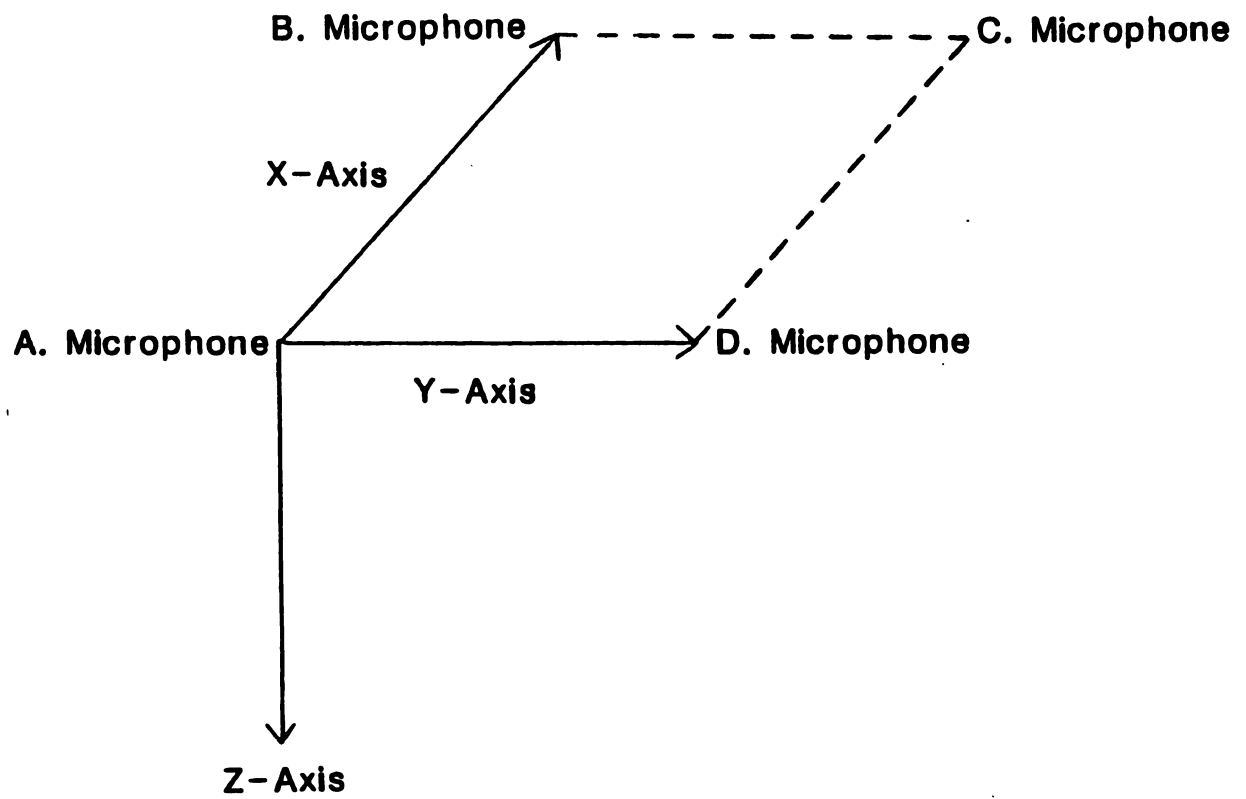


Figure 2. Laboratory Axis System

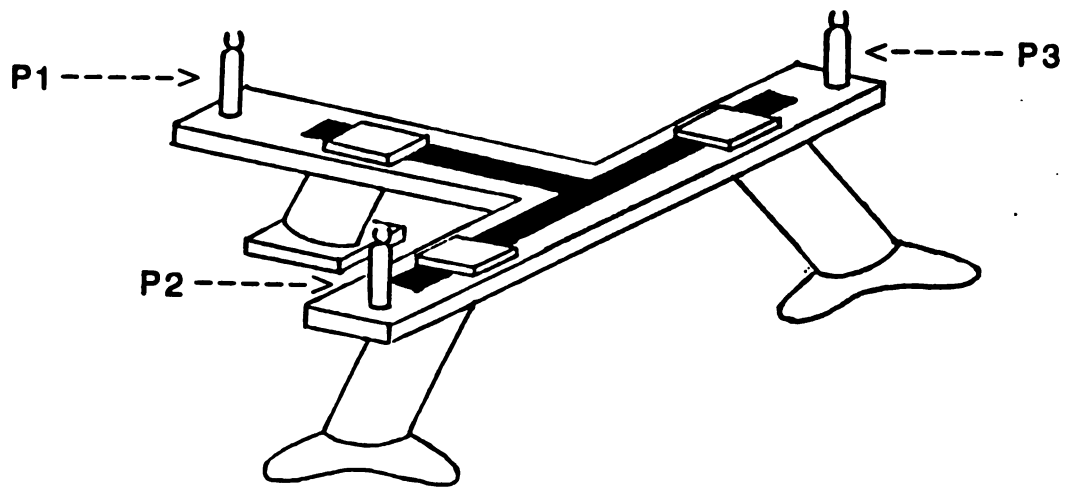


Figure 3. Pelvic Plate and Spark Gaps P1, P2, P3

of Orthoplast. The contact surfaces were designed to rest on the right and left anterior superior iliac spines and the pubic symphysis. The pelvic plate was strapped on the subject. One nylon strap ran posteriorly around the subject's waist, a second strap ran posteriorly around the subject's buttock, and a third strap ran between the subject's thighs attaching posteriorly to the buttock strap. The distance between spark gaps P1 and P2 was 175 mm, between P1 and P3 was 175 mm, and between P2 and P3 was 279.5 mm.

Leg Frames: Three spark gaps were mounted on a right aluminum leg frame, and three spark gaps were mounted on a left aluminum leg frame both designed to track leg motion (Figure 4). The leg frame had three arms, each holding a spark gap. The arms were positioned at right angles to each other so as to maximize the distances and angles between spark gaps. The distal piece of the leg frame was extendable to accommodate varying subject leg length. The distance between the superior (L3) and lateral (L2) spark gaps was 410 mm. The distance (approximately 450 mm) between the superior or lateral spark gap and the distal (L1) spark gap was variable depending on subject leg length. An orthopedic knee immobilizer with posterior stays was used to keep the subject's knee in full extension. The leg frames were attached to the lateral side of the knee immobilizer with velcro and further secured with athletic tape.

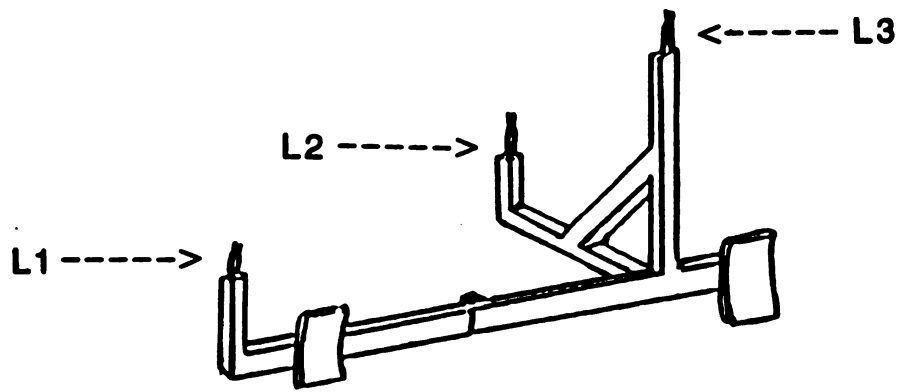


Figure 4. Right Leg Frame and Spark Gaps L1, L2, L3

The sonic data were collected at 100 Hz with each spark gap firing sequentially. During a given trial, the three spark gaps on the pelvis fired first followed by the three spark gaps on either the right or left leg. This created a sequential spark gap firing rate of 16 firings per second, or every .06 seconds per spark gap. Sound emissions from the spark gaps were recorded by the four microphones and the time from emission to recording was multiplexed to a General Automation 16/480 mini-computer.

In addition to collecting sound data, electrical potentials were also collected for a separate investigation of passive muscle activity during the leg lifts. Silver-silver surface electrodes were used to measure the electrical potentials on bilateral abdominal and thigh muscles. The electric potentials were rectified and amplified by a Grass Model 7 polygraph.

Both sonic and EMG data were collected via the GA 16/480 minicomputer and stored on 80 mbyte hard-disc packs. The sonic digitizer data was input via parallel lines at 100 Hz and the analog EMG data were input via serial lines and digitized by the GA minicomputer at 1000 Hz. The GA stored both the EMG and sonic inputs into one data record along with a time stamp. The sonic data was separated from the EMG data on the GA and the sonic data was transferred to the Datamark minicomputer for analysis.

Experimental Procedure: After the subject signed the consent form and completed the questionnaire and screening

examination, he was prepared for testing. Silver-silver surface electrodes were attached to bilateral rectus abdominus, rectus femoris and biceps femoris muscles. The mid-point of each muscle belly was marked and the surrounding area was shaved of body hair. The area was cleaned with isopropyl alcohol, then lightly abraded with emory cloth to decrease skin resistance. This last process was repeated until a skin resistance of 300 ohms or less was measured with a digital ohmmeter.

Kinematic gear, consisting of the pelvic plate, knee immobilizers and leg frames, were then positioned on the subject. The contact surfaces of the pelvic plate were placed so that they cupped the right and left ASIS's. The distance between the sagittal mid-line of the pelvic plate and the right and left contact surfaces were adjusted until they were equidistant to within ± 1 mm. The pubic crest was palpated and the inferior contact surface was positioned so that its superior border was aligned with the pubic crest. The nylon straps were then tightened to further approximate the contact surfaces to the boney landmarks. The subject was then instructed to remain passive during the leg lift trial. The subject was instructed to raise a finger if a painful range was reached during the leg lift or he noted slippage of any equipment. The subject was then put through a trial leg lift on each leg to ensure that the kinematic and EMG gear were stable.

Each leg lift trial began with a two second resting period for collection of initial position kinematic data and

baseline EMG values. The leg was then lifted through its full physiological range of motion, or until the subject indicated that the lift was causing pain. The leg was then lowered to its resting position and a one second baseline period of data was again collected. Seven seconds were allowed for the leg to be lifted at a rate of approximately 15 degrees/second which provides sonic data at approximately 1.0° per sample. Seven seconds were allowed for lowering the leg. Total length of time for data collection was seventeen seconds.

Throughout the trial, the leg was held by the examiner in a position of neutral hip rotation and neutral hip abduction/adduction. Leg motion was kept as close as possible to the sagittal plane. Trials of left and right legs were randomized to avoid any systematic errors due to subject training or experimental protocol. Three trials were performed on the right leg and three on the left leg. Approximately three to ten minutes elapsed between each leg lift trial.

RESULTS

Statistical Analysis: Statistical analysis was done using SYSTAT statistical software package (Wilkinson, 1986) on an IBM-PC. Data on one subject was lost completely, thus the maximum N was 22. Univariate repeated measures F-tests were computed on the three right leg trials for 22 subjects and the three left leg trials for 21 subjects. The sample size for the left leg trials was reduced because data from one left leg trial on one subject was not able to be processed. Results showed no significant difference between the three trials when checked for maximum leg lift angle, pelvic angle in the sagittal plane, pelvic angle in the transverse plane, and length of time for the lift to be completed (Table 3). Because of this consistency between trials, the values for the right trials were averaged and the values for the left trials were averaged.

The reproducibility associated with distance measurements recorded by the sonic digitizer was analyzed statistically. From coordinate data on the third leg lift trial from each of the twenty-two subjects, the distances between each of the spark gaps on the pelvis and the leg frames were calculated. Six subjects were randomly chosen from the sample and from these, fifteen distance

measurements were again randomly selected. The error was calculated as the difference of each distance

Table 3. Consistency between trials :Univariate repeated measures F-tests.

Variable	Leg	F	p*
Max. Leg lift Angle	Rt.	1.245	0.298
	Lt.	0.086	0.918
Pelvic Angle- Sagittal Plane	Rt.	0.051	0.951
	Lt.	0.351	0.732
Pelvic Angle- Transverse Plane	Rt.	1.101	0.346
	Lt.	0.248	0.782
Time of Leg Lift	Rt.	0.538	0.588
	Lt.	2.437	0.100

* level of significance < 0.05

from the mean distance for that subject. The mean and standard deviation of this difference were calculated for each subject. The combined mean and standard deviation of this value for all six subjects was found to be 0.000 $\pm$ 0.0902. A mean of zero indicated that the digitizing error was random. From this analysis the investigator concluded that approximately ninety-five percent of distance measurements made with this system would fall within $\pm$ 1.8 mm of each other.

Standard Initial Position of Subject: To ensure that analysis for each subject was performed from a comparable body orientation within the laboratory axis system, each subject's data was rotated through an angle ($\emptyset$) in the XY plane so that the vector from P2 to P3 at the initial

position was aligned parallel with the Y axis. The rotation was performed by the following equations:

$$\begin{aligned}x' &= x \cos(\theta) - y \sin(\theta) \\y' &= x \sin(\theta) + y \cos(\theta)\end{aligned}\tag{6}$$

The mean rotation in the XY plane was $2.9^\circ \pm 6.28$ degrees.

Initial Leg Position: Two to three seconds of resting position data were collected before each leg lift test was performed, thus the data set that best represented the beginning of each leg lift test needed to be identified. The average and standard deviation of the first twenty data sets (1 second) were calculated. A series of four consecutive data sets were then checked sequentially. The first group that contained four progressively decreasing values was identified. All four values were also required to be greater than 2 SD of the mean initial value. The first value in this group was selected as the initial starting position.

Leg lift Angle in the Sagittal plane: The leg lift angle described the motion of the leg during the passive leg lift, it thus included both hip joint and pelvic motions. The leg lift angle was calculated by determining the angle between an initial position vector and a final position vector in the sagittal plane (XZ). The initial position data set was used to create a vector from the position of the lateral leg spark gap (L2) to the position of the distal leg spark gap (L1). Only the X and Z coordinates were used in the calculation of this angle as they correspond to the

sagittal plane of motion. The angle between the initial position vector and the final position vector was calculated from the dot product formula:

$$\cos(\theta) = \frac{I \cdot F}{(|I|)(|F|)} \quad (7)$$

where I is the initial position vector ($L1_i L2_i$) and F is the final position vector ($L1_f L2_f$). The rotation angle was calculated between the initial position data set and each of the next consecutive data sets.

Maximum Leg lift Angle: The maximum leg lift angle of rotation was manually chosen from the output. The value that had the greatest frequency of occurrence within 1° of the absolute maximum value was identified. The first occurrence of this identified value was selected as the maximum leg lift angle of rotation. The data set in which the maximum leg lift angle occurred was recorded and used to identify the pelvic angles of rotation at that same time.

The mean maximal leg lift angle for right and left leg trials was found to be 59.3° and 60.2° respectively (Table 4). The sample size was reduced from twenty-two to twenty-one for the left leg because data from one left leg trial on one subject was not able to be processed. The average time to achieve the maximal leg lift angle was 4.281 seconds for the right leg trials and 4.235 seconds for the left leg trials. The average speed of lift was 14.0 degrees/second on the right leg trials and 14.4 degrees/second on the left leg trials.

Table 4. Leg lift, pelvis and hip rotation angles in degrees.

Variable	Leg	Mean	SD	N
Leg Lift	Rt	59.3	9.1	22
	Lt	60.6	8.9	21
Pelvic- Sagittal	Rt	16.9	3.0	20
	Lt	17.1	3.3	16
Pelvic- Transverse	Rt	1.6	2.5	16
	Lt	-1.5	2.6	16
Hip	Rt	41.1	8.5	20
	Lt	41.2	8.3	16

Pelvic Angle in the Sagittal Plane: The pelvic angle of rotation in the sagittal plane (XZ) was derived by calculation of the angle between initial and final position vectors using the same algorithm as in the calculation of the leg lift angle of rotation. The initial position vector was constructed from the mid-point of the (P2) and (P3) spark gap positions to the (P1) spark gap position. As in the calculation of the leg lift angle of rotation calculation, only the X and Z coordinates were used. The initial position data set number, determined previously from the leg lift data, was also used as the initial position for the pelvic angle calculations, i.e. the coordinates for the initial pelvic angle calculation corresponded in time to the initial leg lift coordinates. The angle between the initial position vector and the next consecutive position vector was repeatedly calculated. The angle at the data set number corresponding to the maximum leg lift angle data set number was recorded as the pelvic angle in the sagittal plane.

The average pelvic angles for right and left leg raises are 16.9° and 17.1° respectively (Table 4). In two right leg and four left leg trials, the pelvic rotation angle increased by greater than five degrees between consecutive data sets. Thus, the sample size number for pelvic rotation in the sagittal plane was reduced from twenty-two to twenty for the right leg trials and sixteen for the left leg trials. This discontinuity indicated that the pelvic plate may have slipped from its position on the boney landmarks and thus subjects with discontinuous data were not used for this analysis.

Pelvic Angle in the Transverse Plane: The angle of rotation of the pelvis in the transverse plane (YZ) was determined using the P2 and P3 spark gaps. Only the Y and Z coordinates were used in this calculation as they correspond to the transverse plane of motion. The angle between the initial position vector ($P2_i P3_i$) and the final position vector ($P2_f P3_f$) was calculated by the same method as the calculation for leg lift angle rotation.

The mean pelvic angle in the transverse plane, at the time of the maximal leg lift angle, was 1.6° and -1.5° for the right and left leg trials respectively (Table 4). As with the data for pelvic rotation in the sagittal plane, subjects with discontinuous data were excluded from this analysis.

Hip Angle in the Sagittal Plane: The hip angle of rotation describes the motion between the femur and the

pelvis in the sagittal plane. The angle of rotation for hip motion was found by subtracting the pelvic rotation angle from the total leg lift rotation angle.

The mean maximal hip angle of motion was found to be 41.1° and 41.2° for the right and left leg trials, respectively (Table 4). Because the pelvic rotation angle was not available on several subjects, the angle of rotation for hip motion could not be calculated on all subjects. The sample size was hence reduced to twenty for the right leg trials and sixteen for the left leg trials.

The ratio of leg lift motion to pelvic motion in the sagittal plane and the ratio of leg lift motion to pelvic motion in the transverse plane were calculated for the right and left leg trials. Results are presented in Table 5. Again, sample sizes reflect the exclusion of subjects whose pelvic rotation data were discontinuous.

Paired sample t-tests on right versus left maximal leg lift angle showed no significant difference between the two sides as did a t-test on right versus left pelvic rotation angle in the sagittal plane, and hip angle of rotation

Table 5. Ratios of leg lift to pelvic motion

Variable	Leg	Ave	SD	N
Leg Lift/Pelvic Sag.	Rt	3.522	0.751	20
	Lt	3.491	0.671	16
Leg Lift/Pelvic Trans.	Rt	17.933	58.233	16
	Lt	-16.479	55.101	16

(Table 6). Ratios of leg lift rotation to pelvic rotation in the sagittal plane also did not differ significantly between right and left legs. A significant difference was noted between right and left leg lifts for rotation in the transverse plane, which supports the current studies finding that rotation occurs in opposite directions during right and left leg trials.

Table 6. Right vs left paired samples t-tests

Variable	Mean Difference (deg)	t	p*
Max. Leg Lift Rot.	-1.8	1.196	0.246
Pelvic Rot., Sag. Plane	0.2	0.211	0.835
Pelvic Rot., Trans. Plane	3.4	3.333	0.005
Hip Rot.	-1.9	0.941	0.362
Max. Leg Lift/Pelvic- Sag.	-8.3	0.581	0.570

* level of significance < 0.05

Pearson correlation coefficients were calculated on measurements made by the sonic digitizer and those made during the clinical exam using a goniometer (Table 7). The maximal leg lift angle measured sonically, and the maximal leg lift angle measured goniometrically were compared (Sonic: Gonio. Max Leg Lift). Moderate correlations were seen for both right and left leg trials for maximal leg lift angle. Theoretically, the point at which the contralateral ASIS begins to move posteriorly during a passive leg lift represented the hip (femoral-pelvic) motion that occurred.

Goniometric measurements of the point at which the ASIS began to move were thus compared to sonic measurements of hip motion (Sonic Hip: Gonio. ASIS Movt.). A moderate correlation was found on the right leg trials, and a poor correlation was found on the left leg trials, for hip motion to ASIS movement comparisons.

Table 7. Pearson correlation coefficients between measurements of leg and hip angles by sonic digitizer and goniometric methods.

Variables	Correlation Coefficients	
	Rt leg	Lt Leg
Sonic: Gonio. Max Leg lift	0.713	0.705
Sonic Hip: Gonio. ASIS Movt.	0.745	0.435

DISCUSSION

Comparison with Previous Studies: The mean leg lift range of motion in this study was found to be well below the mean straight leg raise range of motion documented by Kutsuna and Watanabe (1981) and by Bohannon (1985). In the current study, knee extension was very rigidly maintained by the knee immobilizer and aluminum leg frames. Details of how rigidly the limb was maintained in extension were not outlined by Bohannon or Kutsuna and Watanabe. The hamstring muscles and the sciatic nerve traverse both the posterior hip joint and the knee joint. Hip flexion and knee extension elongate or take slack out of these soft tissues. If knee extension is not maintained during a passive leg lift, greater hip flexion may be achieved before pain and or increased resistance is encountered. The differences in maintenance of rigid knee extension in the three studies may account for the lower mean leg lift angle reported in this study.

The samples measured by Katsuna and Watanabe, Bohannon and this study had some significant differences that may account for variations seen in the reported range of motion measurements. Katsuna and Watanabe's sample were males, age range 20-49 years. Bohannon's sample consisted of 13 females and four males, mean age of 22.2 ± 2.8 years. The

current study's sample were males, mean age 27.1 ± 4.53 years. Age and sex are both factors that are thought to affect range of motion through tissue extensibility, joint flexibility, or lifestyle (Holland, 1968).

Another variation in passive leg raising technique, seen in Bohannon's study, was an attempt to stabilize the pelvis during the leg lift by anchoring the opposite leg to the table. The current study did not attempt to anchor the opposite leg. Exactly what effect anchoring the opposite leg has on straight leg raising range of motion and/or pelvic motion has not been thoroughly researched to date, but it may have effected the angles seen for both the total leg lift and the pelvic rotation.

The mean pelvic rotation angle in the sagittal plane found in this study was nearly one half of that found in Bohannon's leg lift study (16.9° on the right and 18.2° on the left versus Bohannon's 32.1°). Because Bohannon theoretically took the leg raise further into hip flexion than did this study, the amount of pelvic rotation that occurred may have increased commensurately. The mean hip angles of rotation found in this study were also lower than that determined by Bohannon which could be due to the same reasons outlined for differences in mean leg lift range of motion and mean pelvic range of motion.

The ratio of leg lift angle to pelvic angle, at maximal range of motion in the sagittal plane, was approximately 3.5:1 in the current study versus 2.7:1 reported by Bohannon. This difference indicated that pelvic motion in

the sagittal plane contributed less to the total leg lift motion than previously observed by Bohannon. Bohannon reported lower leg lift to pelvic motion ratios at all but the first third of the leg lift motion. Thus, differences in leg lift to pelvic motion ratios cannot be explained by the fact that the leg was lifted further into flexion in Bohannon's study than in this study. Again, a closer look at the differences in methodologies used in the two studies lends some insight in the variation in leg lift to pelvic motion ratios reported.

Bohannon measured pelvic movement by monitoring the change in angle a tape marker, extending from the right ASIS to the right PSIS, made with the horizontal plane. How accurately this method was able to measure motion of the pelvis in the sagittal plane was dependant on how well the boney landmarks were tracked by the tape marker. Tape markers can be displaced from their intended position overlying boney landmarks as the skin they are attached to is displaced. The PSIS is obscured from visual observation during a straight leg raise making it difficult to verify the position of the marker over a boney landmark. Thus, although Mundale's method gave a reasonable estimate of pelvic movement, it actually represented the movement of the soft tissue and the pelvis to which the tape marker was attached.

This leg lift study was not without similar problems in terms of difficulty ensuring that boney landmarks were accurately tracked throughout the leg lift procedure.

Through observation, it appeared the pelvic plate slipped superiorly or laterally during large leg lift angles. It was hypothesized that in these instances, the soft tissue of the anterior thigh came into contact with the pelvic plate and moved it from its position on the ASIS's. Because of the possible extraneous motion of the pelvic plate, some pelvic motion data may have been lost. How much undetected slippage of the pelvic plate occurred needs to be investigated. An estimate of this slippage can be attained by calculating the location of the hip joint center of rotation. If the plate accurately tracked the pelvis throughout the leg lift motion, the distances from the each of the three pelvic plate spark gaps to the hip joint center of rotation, should remain constant throughout the test. The experimental design of this study was established to permit accurate determinations of the center of rotation of the hip joint. This was achieved by positioning the leg frame spark gaps at ninety degrees to each other and by placing them at appropriate distances from the estimated center of rotation as outlined by Panjabi (1979). This analysis remains to be completed.

Loss of data due to blocking of sound emissions by a body part or the motion apparatus was another difficulty encountered in digitizing a complex motion such as the straight leg raise. Engin et al. (1984) recommended targeting each body segment with more than three spark gaps so that body segment position was not lost if one target was obscured from the microphones. The test protocol for the

current experiment was designed to measure leg motion in approximately 1.0° increments. Because the spark gaps fire sequentially at 100 Hz, increasing the number of targets would have decreased the sampling rate to below the needed level and thus was not done.

An obvious complication of this method of study was that the experimental design required attaching motion monitoring devices to the subject's body that were not present in the clinical straight leg raising test, namely the pelvic plate and the leg apparatus. Exactly what effect these devices had on the passive leg lift tests was not quantified but it was recognized that they could have affected the tests through atypical subject and or examiner response to the equipment or by mechanically altering the leg raising motion.

Obviously, many of the factors discussed above make comparisons between clinical straight leg raising tests and sonically digitized leg raising tests difficult. They do not however preclude the understanding that this type of study can add to our relative understanding of joint and body segment motion and their interactions with surrounding soft tissues.

Pelvic Rotation in the Transverse Plane: The pelvic rotation angles that were measured in the transverse plane indicated that there tends to be a left rotation of the pelvis in the transverse plane during the right leg lifts and a right rotation of the pelvis during the left leg

lifts. Thus, as the leg was lifted during the straight leg raise, the ASIS on the contralateral side moved more posteriorly than the ipsilateral side. This information was consistent with Grieve's observation that rotation of the pelvis in the transverse plane occurred toward the non-lifted leg. The current investigation's overall findings were not consistent with either Bohannon's or Fisk's observations of transverse pelvic motion however, very small rotations were occasionally seen to occur toward the side of the leg being lifted.

Rotation of the pelvis in both the transverse and sagittal planes verifies that motion of the pelvis during the straight leg raise is three-dimensional. The use of sonic digitization for studying the straight leg raise test allowed motion to be analyzed in an objective, controlled manner in either two or three dimensions. Motion analysis in this study was done in two dimensions to allow comparisons with data collected during clinical tests of the straight leg raising motion using goniometers. Because pelvic motion during straight leg raising does not occur in a single plane, measurements of this motion taken in only two dimensions are subject to parallax. In Bohannon's study, measurements of the angle of posterior pelvic rotation in the sagittal plane were subject to projection errors due to simultaneous rotation in the transverse plane. In the current study, the initial body position was corrected mathematically to align it with the theoretical plane of motion. In neither study was the actual plane of

motion used for the analysis. Pelvic motion angles measured in one plane must thus be interpreted judiciously.

Anatomically, there are only small amounts of motion between the innominate bones and the sacrum (Hamilton, 1976), thus the pelvis was considered to constitute a rigid body for this analysis. Despite the small movement between the innominate bones and the sacrum, motion of the pelvis is effectively translated to the lumbo-sacral spine. Axial rotation of the pelvis in the transverse plane thus causes rotation between the L5 and S1 vertebrae. Rotation of L5 on S1 is reported to be approximately five degrees in normal individuals (White & Panjabi, 1978). Rotation of the pelvis in the transverse plane of one to six degrees, as seen in this study, may have significant consequences during straight leg raising performed on an individual with lumbo-sacral facet joint restrictions or irritation. Because the leg lift motion is now proposed to induce both flexion and rotation of the lumbo-sacral vertebrae, pain and motion restrictions related to this area may be manifested during the leg lift.

The presence of pelvic motion in both the sagittal and transverse planes raises questions about the palpation of motion of the contralateral ASIS to determine hamstring length. Fisk (1979) observed contralateral hip extension and posterior pelvic rotation to occur along with movement of the contralateral ASIS. Fisk's descriptions of pelvic rotation and hip extension were consistent with the present studies description of posterior pelvic rotation in the

sagittal plane which could have been observed as relative hip extension or an increased femoral-pelvic angle. Fisk's description was not consistent with the current study's finding of rotation of the pelvis away from the lifted leg, as this would have been observed as relative hip flexion. Palpation and interpretation of contralateral ASIS movement is thus not a simple task, as ASIS motion could be occurring as a result of sagittal plane pelvic motion, transverse plane pelvic motion, and or a change in femoral-pelvic angle. The examiner must be cognizant of all these motion patterns when palpating for ASIS movement.

Pelvic rotation in the transverse plane was shown by this study to be a subtle but integral part of the passive leg raising motion. Awareness of the three-dimensional quality of pelvic rotation during passive leg lifting should assist the clinician in better evaluating an individual's lower quarter function.

SUMMARY

Sonic digitization was found to be a viable method for measuring motion of the leg and pelvis during passive leg lifts. Statistical analysis of the leg lift data show that the experimental procedure used in this study produced results that were consistent and repeatable within and between subjects as was evidenced through the repeated measures tests and small standard deviations reported. The goals of the experimental design were met by measuring leg lift rotation angles in approximately one degree increments, and by measuring pelvic motion in both the sagittal and the transverse planes.

Mean angles of rotation were found for the total leg lift motion, hip motion, pelvic motion in the sagittal plane and pelvic motion in the transverse plane. Angular rotations for leg, hip and pelvic motion in the sagittal plane were lower than those reported previously in the literature. However, the ratio of total leg lift angle of rotation to pelvic rotation in the sagittal plane was larger than expected. Differences that were found to exist between the current study and previous studies, can largely be accounted for by differences in methodologies and sample gender and age.

Rotation of the pelvis in the transverse plane was seen to occur toward the direction of the non-lifted leg. The magnitude of transverse pelvic rotation was such that it may have significant consequences during straight leg raising on individuals with low back dysfunction.

APPENDIX

Appendix 1.

SUBJECT ANTHROPOMETRIC DATA

SUB	AGE	HGT	WGT	TH.C	CLF.C	ASIS HGT
1	21.16	1772.5	72.73	511	373	998.0
2	27.19	1759.5	69.70	514	385	989.0
3	24.22	1753.0	77.27	539	363	986.0
4	26.21	1635.0	66.00	528	380	863.0
5	25.32	1792.0	68.10	512	365	983.0
6	27.03	1847.0	75.50	528	383	1058.0
7	32.53	1688.0	65.80	525	332	973.0
8	18.15	1733.5	57.10	503	363	951.5
9	21.76	1767.0	84.40	577	406	982.0
10	22.86	1876.0	81.05	536	375	1053.5
11	35.39	1763.0	70.60	530	374	973.0
12	27.29	1640.0	62.60	500	366	958.0
13	26.76	1872.5	75.30	510	398	1060.0
14	31.86	1770.0	70.25	522	386	975.0
15	34.80	1800.5	111.05	611	437	1009.5
16	30.01	1752.0	70.30	494	360	1006.5
17	26.88	1828.2	73.75	529	388	1063.5
18	25.20	1890.5	78.45	521	375	1079.0
19	23.88	1839.0	65.00	481	341	1052.0
20	28.76	1679.0	67.65	522	374	925.5
21	26.77	1810.0	82.00	581	383	1044.0
22	34.80	1825.0	63.20	461	348	1027.0
MIN	18.15	1635.0	57.10	461	332	863.0
MAX	35.39	1890.5	111.50	611	437	1079.0
MEAN	27.22	1777.0	73.10	524	375	1000.5
ST. DEV	4.57	71.3	10.96	33	22	52.1
COEF.VAR.	0.17	0.04	0.15	0.06	0.06	0.05

SUB = subject no., HGT = height from floor to top of head in mm, WGT.= weight in kilograms, TH.C = thigh circumference in mm, CLF.C = calf circumference in mm, ASIS HGT = height from floor to right ASIS in mm.

Appendix 2.

SUBJECT TRUNK ACTIVE RANGE OF MOTION

SUB.	LAT.FLEX	FWD.FLEX	ROT	EXT
1	2	2	1	2
2	2	2	2	2
3	2	2	1	2
4	2	2	2	2
5	2	2	2	2
6	2	2	2	2
7	1	2	1	2
8	2	2	2	2
9	2	2	2	2
10	1	2	2	2
11	2	2	2	2
12	2	2	2	2
13	2	2	1	2
14	2	2	2	2
15	2	2	2	2
16	1	2	1	2
17	2	2	2	2
18	2	2	1	2
19	2	2	2	2
20	2	2	2	2
21	2	2	2	2
22	2	2	1	2
Totals	1-3 2-19	1-0 2-22	1-7 2-15	1-0 2-22

SUB= Subject Number. LAT.FLEX= Lateral Trunk Flexion.
 FWD.FLEX= Forward Trunk Flexion. ROT= Trunk Rotation. EXT=
 Trunk Extension. 1= Restricted Range of Motion. 2= Range of
 Motion Within Normal Limits.

Appendix 3.

SUBJECT STRAIGHT LEG RAISING RANGE OF MOTION MEASURED GONIOMETRICALLY

SUB.	RT MOVT	RT MAX	LT MOVT	LT MAX
1	80	*	85	*
2	44	50	50	54
3	43	50	40	55
4	80	84	73	77
5	45	46	43	50
6	53	82	62	84
7	45	55	50	55
8	50	62	52	76
9	50	66	50	67
10	52	75	52	77
11	47	64	46	67
12	56	84	54	89
13	49	74	50	71
14	57	85	58	92
15	45	77	50	85
16	50	60	47	62
17	45	60	45	65
18	58	78	61	89
19	45	61	46	56
21	50	64	55	67
22	55	76	60	84
23	51	66	52	65
MIN	43	46	40	50
MAX	80	85	22	92
N	22	21	22	21
MEAN	52.27	67.57	53.68	70.81
SD	9.99	11.99	10.12	13.01
CV	0.19	0.18	0.19	0.18

SUB= Subject Number. RT MOVT= Right leg lift range of motion when contralateral ASIS begins to move. RT MAX= Right leg lift range of motion at physiologic end range. LT MOVT= Left leg lift range of motion when contralateral ASIS begins to move. LT MAX= Left leg lift range of motion at physiologic end range. *= Motion not measured.

Appendix 4.

SUBJECT QUESTIONNAIRE

QUICK PARTICIPANT SCREEN

1. Are you presently on any medication for pain? _____

2. Are you presently experiencing any back or neck pain?

- 3) Are you presently being treated by a medical
professional for neck or low back problems?

- 4) Have you undergone any surgeries on your back or neck?

If you have answered YES to any of the above questions, unfortunately you are not a candidate for this section of our study. You need not complete the remainder of the form. Thank you for your interest in our study.

MEDICAL HISTORY QUESTIONNAIRE

Subject No.: _____ Date: _____

Name: _____

Birthdate: _____ Sex: Male _____ Female _____

Height: _____ Weight: _____ Handedness: Rt. _____ Lt. _____

HISTORY OF INJURY

1) Have you ever injured your back _____ hip _____ leg _____
neck _____

When _____

How _____

What type of injury was it? (ie. fracture, sprain, nerve damage) _____

Did you seek medical attention? Yes _____ No _____

2) If yes, check what type of treatments you received:

medication	_____	x-rays	_____	surgery	_____
physical therapy	_____	exercise	_____	rest	_____
manipulation	_____	traction	_____	heat	_____
massage	_____	cane/ crutches	_____	cast	_____
change in activity	_____	heel lift	_____	brace	_____
change in job	_____	other	_____		_____

3) How long were you affected/ limited by the injury? _____

4) Do you currently have lowback _____ hip _____ leg _____
neck _____ pain? If yes, continue. If no, go to question number 11.

Where is the pain located? _____

Does the pain spread to other areas? _____

5) What makes the pain worse:

standing for long periods	_____	twisting	_____
sitting for long periods	_____	standing	_____
putting weight on leg	_____	lifting	_____
bending forward	_____	coughing	_____
bending backward	_____	sneezing	_____
getting up from sitting	_____	lifting leg	_____
no change in pain with activity or positioning	_____		_____
other	_____		_____

6) What makes pain better:

lying on back with knees bent	_____	sitting	_____
lying on back with legs straight	_____	standing	_____
lying on stomach	_____	exercising	_____
lying on side with knees bent	_____	stretching	_____
not moving affected area	_____	medication	_____
nothing lessens the pain	_____	heat	_____
other	_____		_____

7) Which of the following describe your pain:

sharp	_____	prickling	_____	stiffness	_____
dull	_____	stabbing	_____	throbbing	_____
ache	_____	burning	_____	catching	_____
soreness	_____	vague	_____	other	_____

8) How intense is your pain (rate from 0 to 10, 0 being no pain and 10 being severe pain) _____

9) Is the pain constant _____ or intermittant _____ ?.

10) Does your pain affect your work or daily activities?
If yes, briefly describe what is limited _____

GENERAL HEALTH

11) Do you or have you had any of the following problems?

arthritis	_____	stroke	_____	kidney disease	_____
heart disease	_____	bone disease	_____	cancer	_____
high blood pressure	_____	other	_____		

12) Are you currently under a physician's care? For what problem? _____

What type of treatment have you received? (ie. medications, exercise, surgery) _____

13) Do your joints hurt, swell or feel stiff? If yes, describe where and state how long the discomfort lasts _____

ACTIVITY LEVEL

16) Have you changed your activity pattern (either increased or decreased) recently? If yes, why? _____

17) What percent of your daily activities involve the following?

standing	_____	walking	_____
sitting (including driving)	_____		

18) Do you lift as part of your job or daily activities?
If yes, how many pounds?

<5 _____ 5-20 _____ 20-50 _____ 50-100 _____ >100 _____

How many times per day?

1-10 X _____ 10-20 X _____ 20-50 X _____ >50 X _____

What sports or recreational activities do you participate in
and how frequently? _____

Appendix 5.

SUBJECT SCREENING EXAMINATION

SUBJECT NO.: _____ NAME: _____
WEIGHT: _____ HEIGHT: _____ SEX: _____

STANDING:

- STANDING FLEXION TEST

NEG ___ POS ___ PSIS HIGH RT./ LT.
UNCLEAR ___
- ILIAC CREST HEIGHT

EQUAL ___ HIGH SIDE RT./LT.
- SCOLIOSIS SCREEN

NEG ___ POS ___
- STANDING TRUNK LAT. FLEX.
(MIDDLE FINGER TO KNEE JNT. LINE)

WNL ___ RESTRICTED RT./ LT.
- ASIS HEIGHT
(TIP OF RT. ASIS TO FLOOR IN CM.)

- CIRCUMFERENCE OF THIGH
(MEASURE RT. MID-THIGH IN CM.)

- CIRCUMFERENCE OF CALF
(MEASURE RT. MAX. CALF GIRTH IN CM.)

SEATED:

8. SEATED FLEXION TEST NEG ___ POS ___ PSIS HIGH RT./ LT.
9. SEATED TRUNK FLEXION ROM WNL ___ RESTRICTED RT./ LT.
(MIDDLE FINGER TOUCHES FLOOR)
10. SEATED TRUNK ROTATION ROM WNL ___ RESTRICTED RT./ LT.
(ROTATE SHOULDER TO MIDLINE)

SUPINE:

- | | |
|--|---------------------------------|
| 11. SUPINE LEG LENGTH AT MED. MALL.
(MARK IF GREATER THAN 1/2 INCH) | EQUAL _____
LONG ON RT./ LT. |
| 12. ASIS HEIGHT | EQUAL _____ SUPERIOR RT./ LT. |
| 11. PUBIC HEIGHT | EQUAL _____ SUPERIOR RT./ LT. |
| 13. PASSIVE HAMSTRING/SLR ROM | RT. LT. |

PRONE :

13. PASSIVE KNEE FLEXION RT. ____ LT. ____
(MARK IF LESS THAN 90)

14. PRONE LEG LENGTH AT MED. MALL. EQUAL _____
(MARK IF GRT. THAN 1/2 INCH) LONG ON _____ RT./ LT.
15. ILA HEIGHT POST. _____ INF. _____ RT./LT.
16. SPHINX PRONE ON ELBOWS SYM. _____ ASYM. _____ SAME _____
(MARK IF HAS SACRAL DYSFUNCTION)
17. TRUNK EXTENSION ROM WNL _____ RESTRICTED _____
- NO DYSFUNCTION _____
POSSIBLE DYSFUNCTION _____

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