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UNIVERSITY OF ALBERTA

POSTURAL ABERRATIONS IN LOW BACK PAIN

BY ©

HEATHER JOYCE CHRISTIE

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of **Master of Science**.

DEPARTMENT OF PHYSICAL THERAPY

Edmonton, Alberta

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UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **Postural Aberrations in Low Back Pain** submitted by **Heather Christie** in partial fulfillment of the requirements for the degree of **Master of Science.**

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Hazel Clarkson

David Reid
Dr. D. Reid

26 AUGUST 1993

DEDICATION

To my family and friends whose patience and support carried me through the rough times allowing me to fulfil my dreams.

ABSTRACT

Low back pain is a significant problem in today's society with high lifetime incidence rates and recurrence rates. Posture is one of the many factors reported to be associated with low back pain. Some deviations in posture are considered to be normal while others are associated with various disease states. Much of the previous research in this area investigates the posture of certain body regions whereas it is important to have an understanding of the complete postural profile and any relationships between the individual parameters.

The purpose of this study was to determine the existence of postural aberrations in chronic and acute low back pain patients in comparison with healthy individuals and to describe these postural profiles objectively. Seven postural parameters were studied for the standing posture. Five postural parameters were studied for the sitting postural profile.

The study sample included 59 subjects who were recruited to three study groups: 1) chronic, 2) acute, or 3) no low back pain. All pain subjects had a diagnosis of disc disease, mechanical back pain or osteoarthritis. The postural parameters were measured using a photographic technique.

Three conclusions were reached based on the results of this research. Discrete postural profiles existed for chronic pain, acute pain and normal control groups in the standing posture. The chronic pain group exhibited an increased lumbar lordosis as compared to the control group. The acute pain group exhibited an increased thoracic kyphosis and a forward head position as compared to the control group. A discrete postural profile existed for the acute pain group in the sitting posture. The acute pain group had an increased thoracic kyphosis as compared to the control group. No further factors were found to discriminate between the chronic and control groups. The postural parameters studied in this project were able to identify discrete postural profiles but they only had moderate value in the prediction of study group. Therefore other postural or non-postural factors, not addressed in this study, must also be important in the prediction of low back pain.

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ABBREVIATIONS AND SYMBOLS

ASIS	Anterior superior iliac spine
BMI	Body Mass Index
cm	centimeter
EMG	Electromyogram
Horiz	Horizontal
Ht	height
kg	kilogram
lbs	pounds
m	meter
mm	millimeter
N	number of subjects
Pos	Position
PSIS	Posterior superior iliac spine
Sh	Shoulder
Sig	Significant/significance
Std Dev	Standard Deviation
VAS	Visual Analogue Scale
Vert	Vertical
<	angle
Λ	lambda

CHAPTER ONE

INTRODUCTION

PROBLEM STATEMENT

Low back pain is a significant problem in today's society with lifetime incidence rates of 50-90% reported in the literature.[1,2,3,4,5,6] Low back pain has recurrence rates of up to 90%[7,8,9,10] even though many cases are self-limiting and require minimal treatment.[10,11,12] Many factors associated with low back pain are reported in the literature including degenerative disc disease, sprains and strains, age, occupation, and socioeconomic status.[9,13,14,15] Low back pain may have an insidious onset where the specific cause of the pain is unknown.[9,16] Low back pain may be acute or chronic in nature.

Clinical observations suggest that aberrations of posture may play a role in the development of low back pain.[17,18,19,20] Posture is both static and dynamic and is assessed in a variety of positions including sitting and standing.[21,22,23,24] Alignment of body parts with respect to the centre of gravity may change between sitting and standing,[25,26] and with the use of different chairs.[22,25,27,28]

Ideal posture has not been clearly defined with several different definitions being advanced.[17,19,24,29,30,31] Even so, there is clinical consensus in the measurement of posture. Commonly used indicators of posture are head position, shoulder position, shoulder level, spinal curves, pelvic tilt and leg length.[17,21,32]

Some changes in posture are considered to be normal while others have been associated with disease states such as low back pain. It is not uncommon to find the dominant shoulder to be lower[17] or to find leg length discrepancies of up to 1.0 cm.[33] On the other hand, forward head posture is one postural adaptation likely related to occupations and activities requiring anterior head positions for prolonged periods.[34] Signs and symptoms in the lumbar spine and pelvis are correlated with this posture.[35] There is controversy in the literature regarding lumbosacral posture and low back pain. Thoracic kyphosis, lumbar lordosis, pelvic tilt, and abdominal strength have all been investigated with respect to low back pain in various groups of subjects with varying results.[18,36,37,38,39,40]

Photographs have been used to assess anterior and lateral aspects of posture objectively. Head and shoulder position have been measured this way successfully in numerous studies but were only validated when digitizing and computer analysis were used.[41,42,43,44] Flint,[45] Burdett et al[46] and Moore et al[38] have used photographs to measure thoracolumbar posture and Flint[45] validated the photographic measure of lumbar lordosis against X-ray analysis. X-ray analysis, considered the standard of spinal curve measurement, was not appropriate for this study due to the potential risks of X-ray exposure. Photographs can be used instead and reflect what would be seen on clinical assessment of posture.

SIGNIFICANCE OF THE STUDY

The general purpose of this study was to determine the existence of postural aberrations in chronic and acute low back pain patients in comparison with healthy individuals, and to describe these postural profiles objectively.

Much of the research cited in the literature review investigates only certain aspects of posture in any single study. As health care professionals we are concerned with the total individual not just single joints or limited body regions. Therefore, it is important to have an understanding of the complete postural profile and any relationships between the individual parameters.

Traditionally, postural evaluation and education have been an important aspect of rehabilitation in individuals with low back pain. The postural profiles developed as an outcome of this research could be used in clinical practice as a tool for comparison between actual and expected posture.

The knowledge of which postural parameters have an association with low back pain could be useful in the development of future research to investigate the causality, prevention and/or treatment of low back pain and/or postural aberrations.

OBJECTIVES OF THE STUDY

The first objective of this study was to objectively describe the static standing and sitting postures of individuals with chronic low back pain, acute low back pain or no low back pain. The parameters used to describe these postural profiles were:

In standing -
- a) degree of lumbar lordosis
- b) degree of thoracic kyphosis
- c) head position
- d) shoulder position (retraction/protraction)
- e) relative shoulder height
- f) pelvic tilt
- g) leg length

In sitting -
- a) degree of lumbar lordosis
- b) degree of thoracic kyphosis
- c) head position
- d) shoulder position (retraction/protraction)
- e) relative shoulder height

The second objective of this study was to determine if the postures described for the first objective varied significantly between individuals with chronic low back pain, acute low back pain or no low back pain. The postural parameters noted above were used in this analysis. The potential association of nine other non-posture variables with study group was examined: a) age, b) sex, c) body mass index (BMI), and d) occupational category for all three groups, and e) pain intensity, f) duration of pain, g) diagnosis, h) vertebral level of pain, and i) mechanism of injury for the two pain groups.

RESEARCH HYPOTHESES

1. Unique postural profiles for static standing and sitting postures would be described for each of the three study groups.
2. The study groups would vary significantly with respect to the postural parameters.

OPERATIONAL DEFINITIONS

1. Low Back Pain was the subjective complaint of pain or discomfort in some region of the back corresponding to the lumbar and sacral vertebrae.
2. Chronic Low Back Pain was low back pain of a continuous or recurrent nature for a minimum of six months.
3. Acute Low Back Pain was low back pain which was present for less than six months in individuals without prior history of low back pain for the previous twelve months or prior history of low back pain lasting longer than one month.
4. Standing Posture was the posture adopted when the individual was instructed to stand in their normal relaxed

standing position.

5. <u>Sitting Posture</u> was the posture adopted when the individual was instructed to sit in an upright position. The individual's thighs were parallel to the floor and their feet were supported.

DELIMITATIONS

This study was delimited to:

1. Volunteers who fit one of the three study groups: individuals with 1) chronic low back pain, 2) acute low back pain, or 3) no low back pain.
2. Individuals in the 20-45 year age group having a diagnosis of degenerative disc disease with or without herniation, mechanical back pain (facet joint syndrome, muscular injury, ligamentous injury), or osteoarthritis of the back where appropriate.
3. Evaluation of objective lateral and anterior postural profiles for static standing and sitting postures.
4. Participants were excluded if they met the following criteria: diagnosis of 1) spondylolisthesis, 2) spondylolysis, 3) myofascial pain syndrome, 4) sacroiliac joint problems, 5) osteoporosis, 6) scoliotic deformity, 7) pregnancy, 8) metabolic diseases and 9) neoplasm. In addition, individuals with a history of congenital deformities, spinal surgery, or recent general surgery (last 12 months) were excluded.

ASSUMPTIONS AND LIMITATIONS

Potential limitations of the study design and measurements exist. The representativeness of this non-probability sample was a limitation of the project. A sample of convenience may not represent the general population of low back pain sufferers adequately with respect to age, sex, mechanism of injury, diagnosis, or occupation.

Ambiguity of cause and effect was a major limitation of this study design as it was difficult to determine whether the low back pain or postural aberration was present first.

The subjects and the researcher were not blinded in this experimental design. This limitation was minimized somewhat by taking the measurements from a photograph which is less manipulatable than direct clinical measurements.

A common criticism of previous studies was that external measures of spinal curves cannot conform to X-ray analysis of these curves. The method used in this study was validated for lumbar lordosis by Flint[45] in comparison with X-rays.

One criticism of using photographs and markers has been that the markers may be obscured by other body parts.[47] The point of contact between skin and pointers was not important for T_{12} and L_5 because the pointers were required only for an angular measurement between two lines extended from these pointers, and this measurement could be made as long as the pointers extended beyond all body parts. The marker length for the C_7 marker was known and therefore the point of contact could be determined, if necessary, as this point was required for the head and shoulder position measurements. Another study suggested that gluteal prominence influences the assessment of lumbar lordosis.[48] Again, since bony landmarks were being used, which were not related to the gluteal soft tissues, this was not a problem in this study.

The accuracy of the spinal process landmarking has been questioned frequently.[46,49,50,51,52] Salisbury and Porter[49] reported only a 3% error rate in landmark location with non-medical examiners, and Bryan et al[51] reported an accuracy of 85% for landmarking the L_2 spinous process.

Another limitation of this study was that the psychological factors of low back pain were not addressed but it was thought to be beyond the scope of the current project.

Several authors[51,53,54] have identified postural sway as a potential limiting factor as it may influence any photograph taken at a single point in time. In the pilot study, pelvic tilt varied significantly between measurements with and without visual fixation even though Gajdosik et al[54] found that postural sway did not need to be controlled in pelvic tilt measurements. In this study, the point in the sway at which pictures were taken was random. Postural sway was also minimized by having subjects focus on some point at eye level in the distance.[53]

Scoliosis, a spinal curve in the frontal plane, was not measured in this study. There is no non-invasive measure of scoliosis that had been validated and would be appropriate for use in this study. This limits the generalizability of the study results to individuals with low back pain who do not have scoliotic deformities.

Finally, there was potential for bias with respect to the exclusion criteria as the use of these criteria was based on the subject's knowledge of having the diagnosis in question and their reporting so on questioning.

CHAPTER TWO

LITERATURE REVIEW

EPIDEMIOLOGY OF LOW BACK PAIN

Low back pain is a significant problem in Western society. Nachemson[1] reported that at some point in our active lifestyle, 80% of us will have some form of back pain. Epidemiological studies have shown lifetime incidence rates of 50-90% for low back pain.[2,3,4,5,6] In studies where the low back pain was specified to be of a severe nature and lengthy duration, these incidence rates dropped to 12-24%, with Frymoyer having reported that 0.4% of the population is disabled by low back pain.[3,5,11] The incidence of low back pain in industrial workers is approximately 50 per 1000 workers per year[1] with an average of 14 lost work-days per injury (highly variable).[55] Low back pain is one of the most frequent causes of activity limitation especially in those under 45 years.[11,56] Frymoyer, in quoting the National Centre for Health Statistics, indicated that low back pain accounted for 14.3% of initial visits to physicians in the United States.[11] In addition 2.8% of hospital discharges were related to low back pain.[11] Although many cases of low back pain are self-limiting and require minimal treatment,[10,11,12] the chronicity of low back pain makes it a significant problem with a recurrence rate of up to 90%[7,8,9,10] and decreasing productive employment rates with time absent from work.[57,58]

There is a multitude of potential causes of low back pain including disc degeneration or herniation, degenerative joint disease, spinal fractures, sprains and strains of the ligaments and muscles, and any combination of the above.[1,9,15,23,59,60,61] In many cases low back pain has an insidious onset and the specific cause of the pain is unknown.[9,16] Several authors have claimed that mechanical changes in the intervertebral discs and/or the facet joints were the most common factors leading to low back pain.[16,23,62,63] Further discussion of these potential causes of pain can be found in the section on anatomy and biomechanics of the spine.

Many studies have investigated the risk factors of low back pain. These risk factors may vary depending on the specific diagnosis underlying the pain.[4] Increasing age appears to be a risk factor for the development of low back pain, particularly up to age 60 years.[2,3,6,13,64,65,66] Some investigators have also found an increase in the severity of the back pain with aging.[3,5] Andersson[67] reported the above pattern for women but found that men had a higher incidence of sick leave at 20-30 years, while Biering-Sorensen[6] reported an increase at 40 years. Dillane et al[9] found an increased rate of acute attacks in the 50-59 year age group. Although only approximately 25% of workers blame accidents or lifting for their back pain,[7] in the United States, it has been shown that men were at higher risk of sustaining a back injury (76-86% of work related back injuries) and that the most common age range for these injuries was 20-44 years (74%).[55,59] Frymoyer et al[13] found that bending precipitated low back pain more often in females while the most frequent precipitating event for males was lifting. On the other hand, others have reported that there is no difference in incidence of low back pain between the sexes, unless type of work is accounted for, in which case women in heavy jobs had an increased incidence of pain.[57,68] No clear consensus exists in the literature with respect to the influence of height, weight or body mass index (BMI) on low back pain. Review articles have indicated an association between increased height and weight and low back pain in some studies,[56,57,64,67,69] while in other studies, height, weight and BMI have been shown to have no correlation with low back pain.[14,16,66,68,70] Cady et al[71] found that a decreased physical fitness level in firefighters was a risk factor for low back injuries but controversy remains over the effect of physical fitness.[5] Burton and Tillotson[72] and Kelsey[70] were unable to show any association between leisure sports activity and low back pain. Andersson[67] reported that decreased physical fitness was not a risk factor but an increase in fitness level could improve post-injury recovery. Finally, radiographic changes were not well correlated with signs and symptoms of low back pain.[1,57,64]

It was often reported that decreased socioeconomic status and a lower educational level were associated with increased incidence of low back pain.[14,57,73] Low back pain has also been linked to psychological factors such as anxiety, stress, decreased work satisfaction and depression.[8,13,65,73,74] One risk factor for low back pain that received clear consensus was smoking history.[5,13,14,75]

There are two major occupational groups of individuals at high risk of incurring episodes of low back pain: (1) manual workers who regularly lift heavy loads, make repetitive stressful movements, or receive sudden maximal loads;[5,8,13,14,64,74,76] and (2) sedentary workers who maintain fixed postures for long periods of time and may or may not have superimposed vibrational stresses.[3,8,13,14,64,70,77,78] Back pain occurring in the second group of workers appears less frequently in the statistics since these workers can usually continue their occupational activities despite the pain and no lost work-days are reported.[64] Riihimaki et al[4] found that there was a higher incidence of low back pain with an increase in heavy work load, whereas Damkot et al[79] and Kelsey[70] reported no significant difference in work load. Other factors commonly related to low back pain were lifting, twisting, pushing and pulling.[8,59,75,79] Many authors have reported a causal relationship between vibration and low back pain in occupations such as truck driving and helicopter pilots.[5,65,70,75,77,78,79]

Controversy exists over the relationship of postural factors in low back pain. Roncarati and McMullen[65] found increased incidence of anterior pelvic tilt, lordosis, scoliosis and genu recurvatum in individuals with low back pain. Magora[80] found hypolordosis and scoliosis to be significant indicators of low back pain but thoracic postural changes were of minimal importance. Andersson[67] claimed that postural abnormalities were of minor importance and may have been related to muscle spasm when present. Pope,[57] in his review article, reported that scoliotic, kyphotic and lordotic deformities did not appear to increase the risk of low back pain. There was no clear consensus with respect to the relationship between leg length inequality and low back pain.[16,33,67,69]

ANATOMY, BIOMECHANICS AND PATHOLOGY OF THE SPINE

Low back pain is commonly believed to be a result of mechanical stresses to the spine.[63,76,81,82] These stresses can lead to degenerative problems in the intervertebral disc and/or the facet joints.[81,82] It is therefore important to have a basic understanding of the spinal anatomy and biomechanics relevant to posture.

The lumbar intervertebral disc is subjected to different loads as different static and dynamic postures are adopted.[1,15,81] Disc degeneration starts early in life but these changes are difficult to demonstrate until the process has progressed.[82,83] Degeneration is characterized by circumferential tears between the lamellae of the annulus fibrosus, followed by radial tears in the annulus extending into the nucleus pulposus.[82,83] Experimentally induced disc ruptures secondary to torsional trauma had a similar appearance.[84] This allowed for disc protrusion and herniation along with a loss of disc height.[82,83] This process of degeneration becomes important when considering the postural loads placed on the lumbar intervertebral disc, as greater loads can lead to increased risk of herniation in a degenerated disc. The load of the lower lumbar discs in standing has been calculated to be 70-80 kg.[1,15] In general, the load decreases as natural lordosis is approached.[15] Other postures created a change in the load: sitting - 100 kg, twisting - 90 kg, bending forward 20° - 120 kg and lifting 20 kg with knees bent - 210 kg are examples of these postural variations.[15] The use of good lumbar support and arm rests in sitting, and moving heavy objects closer to the body for lifting have been shown to decrease disc pressures.[1,85]

Degeneration may also occur in the facet joints. This degenerative process is no different than that of any other synovial joint.[83] Age appears to influence the level at which arthritic changes occur. In the younger population (26-45 years) the upper lumbar segments are more frequently involved, whereas after 45 years the lower lumbar segments are involved with multiple level involvement half of the time.[64] The area of involvement is also influenced by the type of problem: acute problems involve the middle portion of vertebral regions whereas the junctional regions, such as thoracolumbar and lumbosacral, are more often involved in chronic problems.[64,86] Abnormalities that affect one of the three joints of the spine (one intervertebral disc, two facet joints) may eventually affect the other two joints.[83,87] In which structures the first pathological changes occur (disc, facet joints, muscles or ligaments) and the universality of these changes is not known.[83] Three overlapping phases exist in the degenerating three-joint complex. In the dysfunction phase, physical signs are minimal and the movement of the three-joint complex is normal. As degeneration progresses to the instability phase with capsular laxity and internal disruption of the disc, the motion segment becomes unstable and movement is abnormal. Finally, with osteophyte formation, the motion segment movement is decreased (stabilization phase).[83]

McKenzie[10,62] stated that low back pain (postural syndrome) could result from prolonged overstretching of the innervated soft tissues when poor sitting or standing postures were maintained. The ligaments of the spine (excluding ligamenta flava) are highly innervated and therefore may be of importance in the development of low back pain.[86,88,89] In the experiments conducted by Hedtmann et al,[90] they found that the anterior longitudinal ligament was stretched during an extension movement. With axial loading of the motion segment the ligament shortened and was subsequently required to stretch even further to maintain the same extension range of motion. Removal of the nucleus pulposus, which simulated loss of disc height, required further stretching of the shortened ligament in a similar manner. Conversely, the posterior longitudinal ligament was stretched during flexion. As with the anterior longitudinal ligament, axial loading of the motion segment and loss of disc height led to further ligament stretching on flexion.[90]

Hedtmann et al[90] also found that the capsular ligaments of the facet joints had varied fibre orientation between individuals.[90] Therefore, the pattern of stretching, during flexion and extension with loaded or unloaded motion segments and with loss of disc height, differed markedly. In general it was found that in a degenerated motion segment, the capsular ligaments were at the resting length when in 20-45% total flexion.[90] Therefore, it would appear that a certain amount of flexion may lead to decreased facet joint capsular ligament strain and thus decreased irritation of the pain receptors.[89,90]

The literature often implicated rotation of the spine in low back injuries. The morphology of the lumbar facet joints suggests that with flexion of the spine, distraction occurs which could allow increased rotational mobility.[91]

Hindle and Pearcy[91] were able to show that rotation increased with flexed postures. The angle of maximal movement was quite variable between individuals. Therefore, the lumbar spine, in particular the intervertebral discs, could be at greater risk of injury when flexion and rotation are combined.[91] Farfan[84] found that the normally oriented facet joints protected the disc in erect standing postures. Disruption of the facet joint complex decreased the strength to resist torsional forces by one-half.[84]

The trunk musculature can also be an important factor related to low back pain. Biomechanically this musculature is important in providing stability.[92] Alston et al[93] were unable to find a significant muscle imbalance between trunk flexors and extensors but did find significant trunk weakness in chronic low back syndrome. Leino et al[94] also found that trunk muscle function (dynamic and isometric trunk flexion and extension) was decreased in individuals with chronic low back pain but there was no muscle imbalance. Similarly, Biering-Sorensen[69] found that good isometric endurance of the trunk extensors was a preventative factor for low back pain. Janda[95] claimed that there was a unique, typical response of muscles to pain. The hamstrings and trunk extensors tended to respond by tightening while the abdominals and glutei tended to weaken and atrophy. Muscles which tended to tighten usually had a postural function while dynamic muscles tended to get weak.

Alston et al[93] found hamstring tightness in individuals with low back pain and postulated that postural adjustments would be necessary to compensate for this tightness. In recent literature, the function of the paraspinal, abdominal and hip extensor muscles, as tested by EMG activity, was found not to be increased in individuals with chronic low back pain compared to those without.[96,97] The balance of muscle activity altered between sitting and standing postures; upper lumbar and thoracic regions were more active in sitting while lower lumbar regions were more active in standing.[26,85]

Sitting is a widespread work posture of the present times.[27,98] In standing, the primary support passes through the acetabulum whereas in sitting the ischial tuberosities provide the support. With sitting, as compared to standing, there was flattening of the lumbar lordosis and a posterior pelvic tilt.[25,26] A posterior pelvic tilt facilitated bringing the ischial tuberosities into position.[87] The results of several studies indicated that posture changed when different chairs or sitting surfaces were used.[22,25,27,28] Keegan[22] found that the hip flexors and hip extensors were in a position of balanced relaxation when there was a 135° angle between the trunk and the thighs; neutral position for the lumbar spine. Muscle length of the hip flexors and extensors effects the lumbar curve due to the muscles' attachments to the pelvis. As the hip was flexed past the neutral position, as in sitting, shortened hamstrings tended to create a posterior pelvic tilt flattening the lumbar curve. The hip flexors lengthened with hip extension past the neutral position (standing), and decreased flexibility in these muscles increased the lumbar lordotic curve.[22,40] These conclusions have been supported by several studies.[22,27,28]

LOW BACK PAIN AND POSTURE

An assessment of posture, especially in low back pain patients, is an important part of any physiotherapist's assessment.[17,19,21,23,32,41] Clinical observations suggest that aberrations of posture may play a role in the development of low back pain.[17,18,19,20] Abnormal habitual postures can cause abnormal stresses (increased shear or compressive forces) on the joints which lead to excessive wear of the articular surfaces.[17,18] With postural changes, a change in alignment with respect to the line of gravity occurs that may lead to other adaptive postural changes.[17,29] For example, thoracic hypomobility often leads to adaptive changes in other regions,[64] anterior pelvic tilt may lead to increased lumbar lordosis,[22,40] and increased lordosis can lead to forward head posture.[17] Soft tissues may have increased tension placed on them due to postural changes and thus become weak, stretched or injured.[10,17] Regardless of the above, it must be remembered that many individuals who exhibit poor posture are symptom free. One explanation for this is the difference in ability to adapt to postural changes between individuals who are strong and flexible and those who are weak and either hypermobile or immobile.[17]

IDEAL POSTURE

A general understanding of ideal posture exists.[17,19,29,30] Several definitions of the ideal posture have been advanced. The most commonly encountered definition of ideal posture uses the line of gravity as a reference point and indicates that this line passes through the external auditory meatus, through the cervical vertebral bodies, anterior to the shoulder joint, through the third lumbar vertebral body, posterior to the hip joint, anterior to the centre of the knee joint and anterior to the lateral malleolus.[19,24,30,31] This line of gravity corresponds to the intersection of the coronal plane passing through the above noted points and the mid-sagittal plane.[99] Ideal posture has also been described as the posture in which the least amount of joint stress occurred and the least amount of muscular activity was required to maintain the position.[24,29,30,31,100,101] Reference to the spinal curves has been used in defining posture such that in ideal posture the three usual spinal curves were maintained and stress to the discs, muscles and ligaments was minimal.[10] Ideal posture has also been described as the positions in which the constituent parts remained within their normal ranges.[18] Thus, it is clear that ideal posture has yet to be clearly defined and there is great variation in the elements used to define posture.

The measurement of posture has traditionally been observational and subjective. Despite the above noted ambiguity in the definition of ideal posture, there is consensus in the clinical orthopaedic evaluation of posture (Figure 2.1). Anteriorly, the head is straight on the shoulders with eyes and mouth horizontal, the tip of the nose is in line with the sternum, the neck and shoulder line is symmetrical and level with equal muscular bulk, the clavicles and sternoclavicular joints are level, the waist contours are symmetrical with the arms equidistant from the body, the high points of the iliac crests are level, and finally, the anterior superior iliac spines (ASIS) are level. From the posterior view, the head is midline, the shoulders are level, the inferior angles of the scapulae are level, the spine is straight, the waist contours are symmetrical, the iliac crests are level, the posterior superior iliac spines (PSIS) are level, and the gluteal folds and knee creases are also level. From the lateral view, the ear lobe is in line with the acromion process and the top of the iliac crest. The degree of cervical lordosis, thoracic kyphosis and lumbar lordosis are noted, the pelvic angle is noted and the presence/absence of pelvic rotation is determined.[17,21,32] It is not uncommon to find a

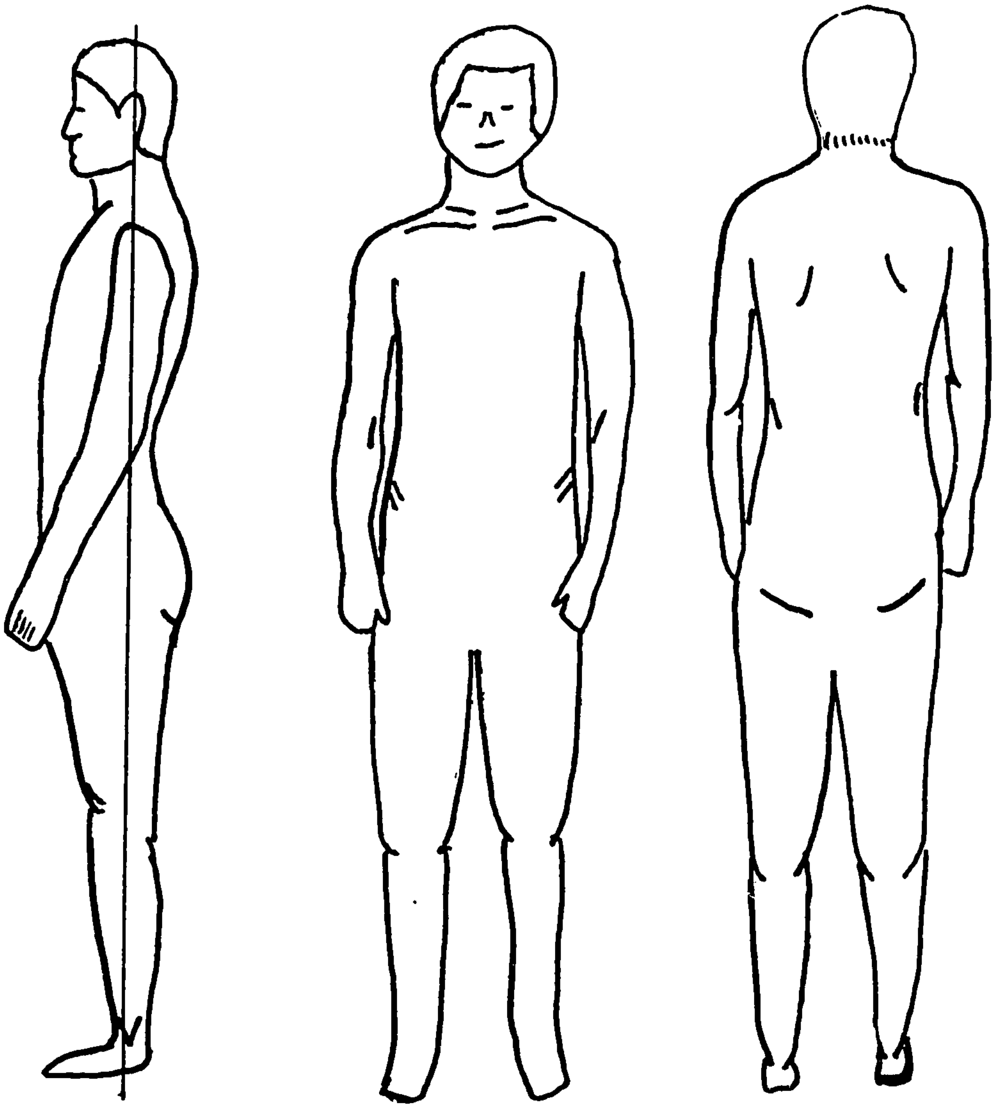


Figure 2.1. An example of anterior, posterior and lateral views of normal posture.

lower shoulder on the dominant side with hip deviation in that direction.[17] It is also not uncommon to find leg length discrepancies as 60% of the normal population has a discrepancy[31] and 7% has a difference of 1.2 cm or more.[32] Leg length discrepancy can lead to pelvic obliquity and subsequent scoliosis.[29,31]

To properly assess posture a variety of positions should be examined. The relaxed standing posture is assessed as much of our daily lives is spent in this posture either statically or dynamically. The sitting posture is also assessed as it is becoming increasingly important in Western society with increasing numbers of individuals having sedentary lifestyles.[98] Normal sitting posture is described in similar terms to standing posture and is measured in the same manner.[20] By altering the sitting surface, posture is also altered.[20,22,25,27,28,102] In addition, by evaluating sitting posture, it is possible to eliminate postural changes (levels in particular) which result as adaptations to lower extremity problems such as leg length inequality.[21]

POSTURAL ABNORMALITIES

Forward head posture is one postural adaptation frequently noted in today's society. One study showed an occurrence of forward head posture in 66% of healthy volunteers.[103] Forward head posture is defined as an increased anterior placement of the head with respect to the line of gravity.[35] This posture may be related to the fact that many occupations and activities require placement of the head and upper extremities further anterior to the trunk than is normal, for prolonged periods of time.[34] Along with this head placement, mouth breathing and altered tongue position occurs. Since the head is anterior to the line of gravity, the posterior cervical muscles contract and thus the face is turned upwards. To bring the face and gaze back to a horizontal orientation, the lower cervical and upper thoracic vertebrae flex. With so many changes occurring with respect to the head, cervical and upper thoracic spines, compensation may occur in the lumbar spine and pelvis resulting in signs and symptoms in this region.[35] In Braun's study on head and shoulder posture in asymptomatic men and women, she found that postural differences existed between the two groups; women were more round shouldered than men, and men had a more anterior head placement. Regardless of these differences both men and women fell within previously cited normal values for head position.[43] Braun also found that women with craniofacial pain were more round shouldered and had a forward head placement of clinical significance as compared to asymptomatic women.[43] Griegel-Morris et al[103] found an occurrence of rounded shoulders in approximately 70% of healthy volunteers. This study could not show a relationship between the amount of pain and the severity of head and shoulder postural changes but there was an increased incidence of pain in those with increased postural changes.

Several studies have been undertaken to investigate various aspects of lumbosacral posture. Walker et al[36] found that there was no correlation between pelvic tilt, lumbar lordosis and abdominal muscle activity. Pope et al[104] did find a modest association between low back pain and decreased abdominal strength and tight hamstrings. During et al[18] found that lumbosacral posture differed significantly between spondylosis patients and healthy volunteers (the upper sacral surface was steeper and the position of the line of gravity was altered), but patients with narrowed L_5S_1 disc spaces could not be differentiated from healthy subjects. On the other hand, Bergenudd et al[37] were unable to find a relationship between the degree of kyphosis or lordosis and back pain and therefore postulated, from previous work, that workload and psychosocial factors may be more important in the aetiology of low back pain. Day et al[40] also found that minimal thoracic changes occurred with pelvic tilt. Several other studies were unable to show a relationship between the shape of the lumbar lordosis and various forms of low back pain.[40,104,105] Moore et al[38] investigated postural changes and low back pain in pregnancy. They found, in general, that the thoracic kyphotic curve did not change but following an initial decrease in lumbar lordotic curvature the lumbar lordosis increased and was correlated with low back pain. Finally, Ohlen et al[39] also found a significant correlation between the degree of lordosis and low back pain in young female gymnasts.

A relationship has been shown between leg length discrepancy and low back pain, by some authors, even though 8% of the normal population has leg length inequality of greater than 10 mm.[33] The overall incidence of leg length inequality in the normal population has been reported as 60%.[31] Leg length inequality is the most common cause of pelvic obliquity and may result in compensatory scoliosis.[29,31] Other studies have shown no clear relationship between leg length inequality and low back pain.[16,69,104]

MEASURING POSTURE

There is good consensus in the literature on the method of measuring head position. Using a lateral view the angle between a horizontal line through the C_7 spinous process and the line between the C_7 spinous process and the tragus of the ear was measured and reflected head position.[41,42,43,44] The normal angle was 50-60° with a more acute angle reflecting a forward head position.[42] Relative shoulder protraction/retraction or rounded shoulders can be measured in a similar manner. The angle between a horizontal line through the posterior angle of the acromion process and the line between this point and the C_7 spinous process was measured. A more obtuse angle reflected rounding of the shoulders.[41,43] The only reliability figures found were calculated when the photographs were digitized and measurements calculated via computer program.[41] Shoulder level has been measured anteriorly using the angle between the shoulder line (not well defined) and horizontal.[44]

Many different approaches for measuring thoracolumbar posture have been used. Opila et al[53] used multiple photographs and a force platform to record posture. The line of gravity was determined and the distances from this line to markers at points such as the acromioclavicular joint, spinous processes, greater trochanter and ASIS's were calculated. They attempted to validate this method of measurement but no reliability results were given. Several studies have investigated the use of a flexible rule for measuring lumbar lordosis. There was good intratester reliability reported with this method[50,106] but intertester reliability was questionable.[50] The validity of the measure was found by Hart and Rose[106] to be good but they used only eight subjects while Bryan et al,[51] using 45 subjects, found poor validity as compared to X-rays. This form of analysis may involve the drawing of tangents which introduces secondary error to the measurement.[49] Two other well studied methods of measuring the spinal curves were the inclinometer and the kyphometer. Double or single inclinometers have been shown to give equally satisfactory results.[107] In measuring spinal range of motion the inclinometer was accurate to within 10% of the total range of motion[52] and in comparison with X-rays there was a correlation coefficient of 0.91.[108] Measurements taken with the kyphometer and inclinometer were well correlated (.88 kyphosis and .89 lordosis).[39] The reliability of kyphometer measures was found to be high by Ohlen et al.[109] The pantograph reproduces the spinal curve on paper and is another method of measuring the thoracic kyphosis and lumbar lordosis which is reliable and valid.[110] Finally, posture has been investigated through the use of photographs. Moore et al[38] used photographs to measure both thoracic and lumbar curves by marking tangents and using trigonometric calculations. By using these tangents secondary error was introduced to the measurement. Burdett et al[46] compared photographs to three other methods including the inclinometer and found them to be reliable for measuring lumbar curvature. The validity of the measure was questioned (10 subjects) but was equal between all measurement devices. Flint[45] also investigated the use of a lateral photograph for documenting posture in 31 female university students with sujectively determined exaggeration of the lumbar and pelvic positions. She found a correlation between the photographs (angle measured: L_2 to L_5S_1) and X-rays which was significant at the .01 level. Therefore, the use of photographs to measure lumbar lordosis and thoracic kyphosis has been shown to have validity and it is at least as reliable as other methods in use. Of course X-rays have the highest validity but are contra-indicated due to the risks of radiation exposure.

Pelvic tilt is another important aspect of posture analysis. Sanders and Stravrakas[111] developed a method of measuring pelvic tilt where the distance between the ASIS and the PSIS was measured using callipers (A). Then the distances from the floor to the ASIS and from the floor to the PSIS were measured and the difference between the two was calculated (B). Finally the angle of the pelvic tilt (θ) is calculated using the formula: $\sin \theta = B/A$. Gajdosik et al[54] found the reliability of this method to be .88. The validity of this measurement remains theoretical.[36] Walker et al[36] proposed the use of an inclinometer between the ASIS and PSIS to simplify the measurement. Cummings and Crowell[112] investigated potential error in the measurement secondary to innominate rotation and found it to be insignificant.

Gogia and Braatz[113] studied the reliability and validity of leg length measurements. Measurements taken from the ASIS to the medial malleolus had an intertester reliability of .98 and in comparison with X-ray analysis a validity of .98. Woerman and Binder-MacLeod[114] compared several direct measures of leg length and found that measurements from the ASIS to the lateral malleolus were more accurate and precise than measurements from the ASIS to the medial malleolus but the latter measure remained more accurate than other direct measures. The measure from ASIS to medial malleolus was chosen for this study because it is used clinically most often and a validity and reliability of 0.98 remains acceptable.

SUMMARY

In conclusion, low back pain is a significant problem in our present society. Aberrations of posture may be important in the aetiology of low back pain and therefore posture is an important aspect in the assessment of low back pain patients.[17,18,19,20] Ideal posture has been defined using several different parameters, but clinically posture is described using various levels such as shoulder level and pelvic level, and analysing spinal curves and head position with respect to the line of gravity.[17,21,32] Both standing and sitting postures are commonly assessed and postural parameters can vary between positions.[25,26] Lateral view photographs can be used to assess head position and shoulder position and will differentiate a forward head posture.[41,42,43,44] Photographs can also be used to assess thoracic and lumbar curves with good validity and reliability.[38,45,46] Sanders and Stravrakas[111] have developed a reliable and theoretically valid measure of pelvic tilt. Finally, tape measure measurements of leg length are reliable and valid and will represent pelvic obliquity.[113,114]

Minimal research has been reported assessing total posture rather than specific aspects of posture.[18,22,26,27,33,36,40,42,43,53,102,103,105,111,115, 116] No research was found that assesses total posture in chronic or acute low back pain patients in comparison with healthy individuals.

CHAPTER THREE

METHODS AND PROCEDURES

STUDY DESIGN

This was a retrospective, cross-sectional study. Participants who fell into one of three study groups were recruited and their posture was assessed as a one-time measure at that time. This design met the needs of the study objectives within the limits set by subject selection. Ambiguity of cause and effect was a major limitation of this study design as it was difficult to determine whether the low back pain or postural aberration was the starting point.

Three subject groups were created: individuals with 1) chronic low back pain, 2) acute low back pain, or 3) no low back pain (normal controls).

The measures of posture used for standing and sitting postural analysis included: a) degree of lumbar lordosis, b) degree of thoracic kyphosis, c) head position, d) shoulder position, e) relative shoulder height, f) pelvic tilt, and g) leg length.

Nine other non-posture variables were documented. Age, sex, BMI and occupational category were to be included in the analysis only if significantly different groups were recruited with respect to these variables. Pain intensity, pain duration, diagnosis, vertebral level of pain and mechanism of injury were documented for descriptive purposes in the two pain groups.

Prior to the commencement of data collection a pilot study was undertaken to check the feasibility of the data collection procedure and to clarify several issues identified at the proposal defense. Results of the pilot study are reported in Appendix A.

SUBJECT RECRUITMENT

Subjects were recruited from physical therapy departments of major hospitals in Edmonton, selected private practice physical therapy clinics in Edmonton, selected medical facilities, selected chiropractic clinics, Canadian Forces Base Edmonton and Canadian National Rail. These facilities were approached for their cooperation and provided with contact information for potential subjects (Appendix B). They were also provided with the appropriate inclusion/exclusion criteria for the selection of potential subjects (Appendix C). Subjects were also recruited via posters on the University of Alberta campus. Once contact was made with the primary investigator an appointment was set for data collection at a mutually convenient time.

The normal control group was recruited using the same inclusion/exclusion criteria (where appropriate) as the pain groups.

A goal of 75 subjects (25 per group) was determined using a sample size calculation (Appendix D) based on the seven posture parameters being measured and the potential of up to four non-posture variables (age, sex, BMI, and occupational category) being used in the analysis.

STUDY PARTICIPANTS

Informed participants with low back pain were recruited to two study groups, categorized by chronic versus acute low back pain. A group of subjects with no history of low back pain were recruited to a third group. Thus the study groups were: Group 1) individuals with chronic low back pain, Group 2) individuals with acute low back pain, and Group 3) normal control group.

Participants in all groups were in the 18-46 year age group. The following exclusion criteria were used: participant knowledge of a diagnosis of 1) spondylolisthesis, 2) spondylolysis, 3) myofascial pain syndrome, 4) sacroiliac joint problems, 5) osteoporosis, 6) scoliotic deformity, 7) pregnancy, 8) metabolic diseases and 9) neoplasm. In addition, individuals with a history of congenital deformities, spinal surgery, or recent general surgery (last 12 months) were excluded. Self-reporting was used as a means of determining the presence or absence of these conditions.

Participants in group 1 presented with low back pain of a continuous or recurrent nature for longer than six months. Diagnoses from the following categories were used:

degenerative disc disease with or without herniation, mechanical back pain (facet joint syndrome, muscular injury, ligamentous injury), or osteoarthritis of the spine.

Participants presenting with low back pain as a result of a recent acute low back pain episode were included in group 2 . Prior to this episode subjects had not experienced low back pain for 12 months. Diagnoses were from one of the categories outlined for chronic low back pain.

Participants in group 3 had no history of low back pain occurring in the past year and had no prior history of low back pain lasting longer than one month to exclude those with latent chronic pain.

DATA COLLECTION

Initially potential subjects were approached by the health practitioner regarding participation in the study and were provided with the patient information sheet (Appendix B) which included the contact name and telephone number. If the individual was responding to a poster, he/she was provided with the information contained on the information sheet verbally. The individual was also questionned regarding inclusion/exclusion criteria to determine eligibility for the study. Following initial contact with the study investigator, an appointment was made. All postural assessments took place in Corbett Hall at the

University of Alberta. The assessment took approximately one-half hour per subject and was a one-time measure. Data was collected solely by the primary investigator.

All subjects were questioned with respect to the demographic data being collected - age, sex, and occupation. Pain patients were also questioned with respect to diagnosis, pain intensity and duration, vertebral level of pain, and the manner in which they were injured. Date of birth and sex were recorded. Occupation was recorded and classified according to The Canadian Classification and Dictionary of Occupations.[118] In this classification system, the physical activity requirements for each occupation have been determined and are rated as sedentary, light, medium, heavy or very heavy. Students were classified as sedentary except those in professional fields doing practical work who were classified by those occupations. Graduate students were classified as light if they had a graduate assistantship as per the classification system. Diagnosis, where appropriate, was requested from the subject based on their knowledge of same. This diagnosis could not be verified. Pain intensity, in sitting, at the time of assessment was recorded using a visual analogue scale (VAS)(Figure 3.1). Subjects were requested to mark the scale using the following instructions: "This is a visual analogue scale with no pain being at one end of the line and the worst pain you can imagine at the other. Please mark

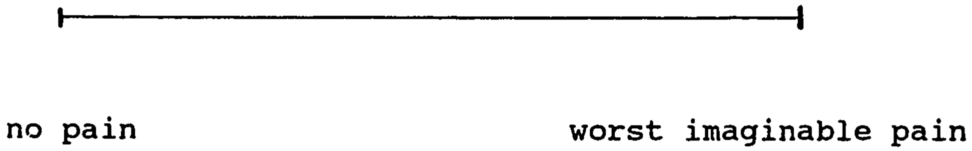


Figure 3.1 Visual Analogue Scale

the scale at the point which represents the amount of pain you have right now sitting in that chair." A standard 10 cm horizontal line was used with "no pain" and "worst imaginable pain" as descriptors of the extremes. This type of scale has been shown to be highly correlated to pain levels with the understanding that pain is always subjective.[119,120] Price et al[121] found the VAS to be reliable and valid in measuring pain intensity in chronic or experimental pain and Duncan et al[122] found similar results in experimental pain. After the scale was marked, the pain intensity was recorded as the distance, in millimetres, of this mark from the "no pain" end. The duration of pain was recorded in years based on the patient's recall. Vertebral level of pain was requested from the subject and recorded. The participant was requested to describe the manner in which they were injured if an injury was sustained. This was a descriptive variable only, and was subject to recall bias.

Height and weight were measured using a standard scale. BMI was then calculated using the Quetelet index (weight/height^2 in kg/m^2).[123,124] This index correlated strongly with measures of body fat having a correlation coefficient of 0.70 with percent body fat and 0.76 with skinfold measurements.[123,124] The specificity of this index was found to be 95.1 and the sensitivity was 50.6; therefore it is a better measure of leanness than obesity.[123]

The study group was determined by the primary investigator using the appropriate inclusion/exclusion criteria and the clinical diagnosis.

The subject's postural profile was measured according to the following procedure.

Anterior, posterior and lateral photographic slides were taken in a relaxed upright standing position with the appropriate surface markers exposed. Subjects were instructed to stand with their heels against a line marked on the floor which was either parallel or perpendicular to the camera as appropriate. Slides were taken with a 35mm camera mounted on a tripod stand at a standardized distance. Slides were taken in front of a screen and a horizontal/vertical crossbar with a measurement scale marked directly on it. Patients were then instructed to sit in an upright position on a backless stool. The stool height was adjusted so that their feet were supported and their thighs (greater trochanter to centre of the knee joint) were parallel to the ground. Lateral and anterior slides were then taken in the sitting position from the preselected standard distance with a tripod mounted camera.

The slides were rear projected onto a ground glass screen for making measurements. All distances were measured using a pointer and single ruler, and angles were measured with a single standard protractor. Lumbar lordosis, thoracic kyphosis, head position and shoulder position were calculated from lateral views in both standing and sitting. Relative shoulder height was recorded from anterior views in both standing and sitting. Pelvic tilt was measured in standing only, as it is fixed in sitting, and was calculated using anterior and posterior views.

a) Degree of lumbar lordosis

The degree of lumbar lordosis was measured using the method described by Flint.[45] Small balsa wood pointers were used to mark the T_{12} spinous process and the L_5 spinous process. These pointers were placed perpendicular to the surface of the curve. A lateral photograph was then taken in sitting and standing postures as previously described. Lines were extended from the pointers and the angle (<L) at their intersection was recorded (Plate 3.1). Validity has been documented by Flint[45] and the correlation between X-rays and this measure was significant at the .01 level.

b) Degree of thoracic kyphosis

This variable was measured using an extension of Flint's[45] method for lumbar lordosis. Pointers placed perpendicular to the surface of the curve were used to mark the C_7 and T_{12} spinous processes. Using a lateral photograph, lines were extended inwards and the angle (<T) at their intersection was recorded (Plate 3.2). Validity results have not been specifically documented for the thoracic spine but can be implied from the lumbar curve.

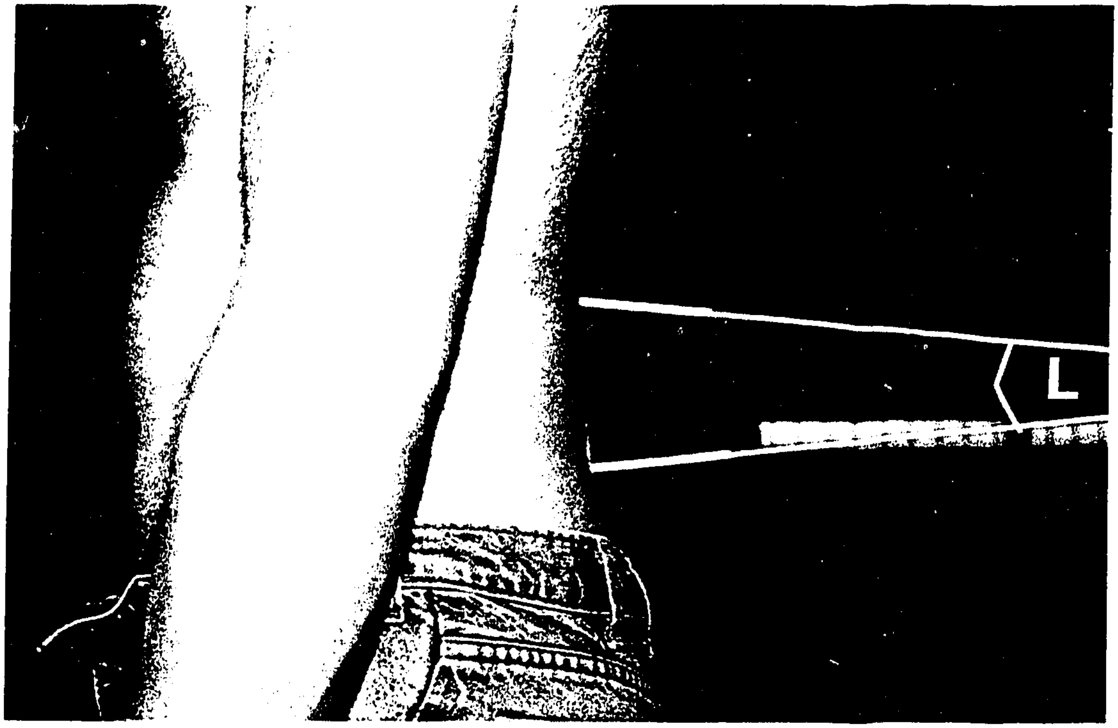


Plate 3.1 Degree of lumbar lordosis measured from T_{12} to L_5 (<L).

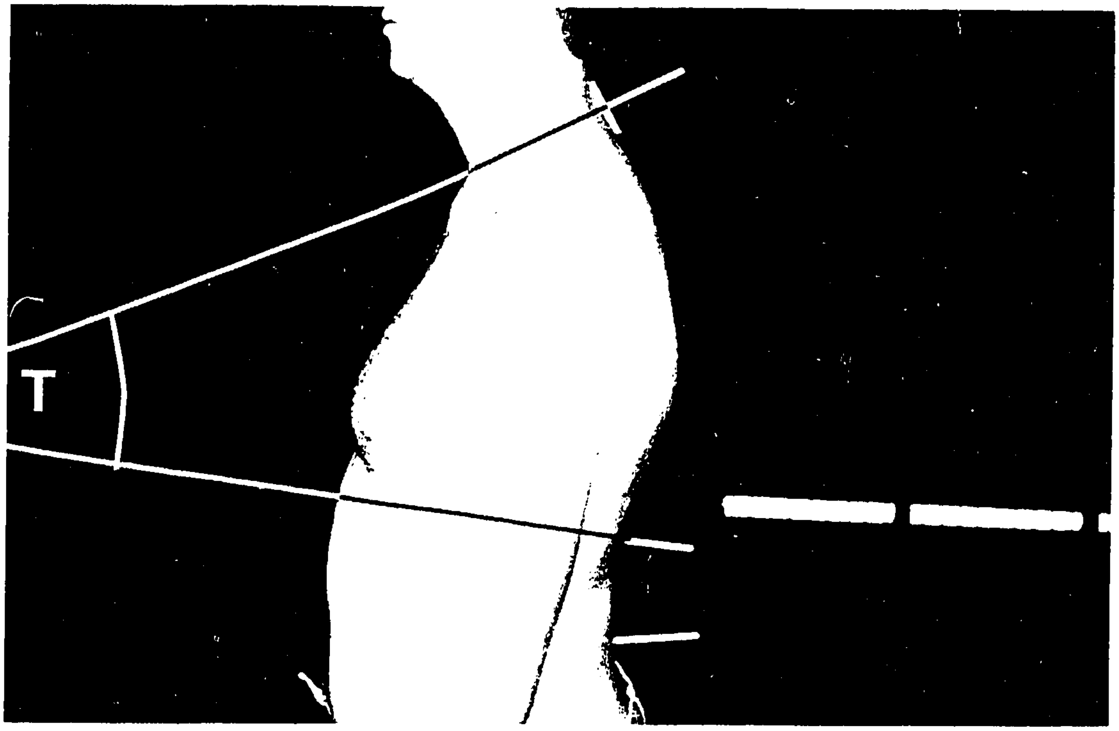


Plate 3.2 Degree of thoracic kyphosis measured from C_7 to T_{12} (<T).

c) Head position

Head position was also measured from a lateral photograph. The tragus of the ear was marked with a dot and the C_7 spinous process marked with a pointer. The angle (<H) between the tragus-C_7 line and horizontal was then calculated (Plate 3.3). Validity and reliability values have not been calculated except where digitizing and computer analysis have been used and found to be valid and reliable.[41]

d) Shoulder position

The relative protraction/retraction of the shoulders was similarly measured.[41] In addition to the C_7 pointer the posterior angle of the acromion process was marked. The angle (<S) between horizontal and the C_7-acromion process line was measured (Plate 3.4). Validity and reliability are not yet concretely established as per head position.

e) Relative shoulder height

This variable was measured in a manner similar to that described by Shiau and Chai.[44] The acromioclavicular joints were marked bilaterally. The angle (<R) between a line connecting these points and horizontal was measured. If the dominant side was higher, it was recorded as a positive angle; if the non-dominant side was higher, it was recorded as negative (Plate 3.5). Reliability measures have not been recorded in the literature.

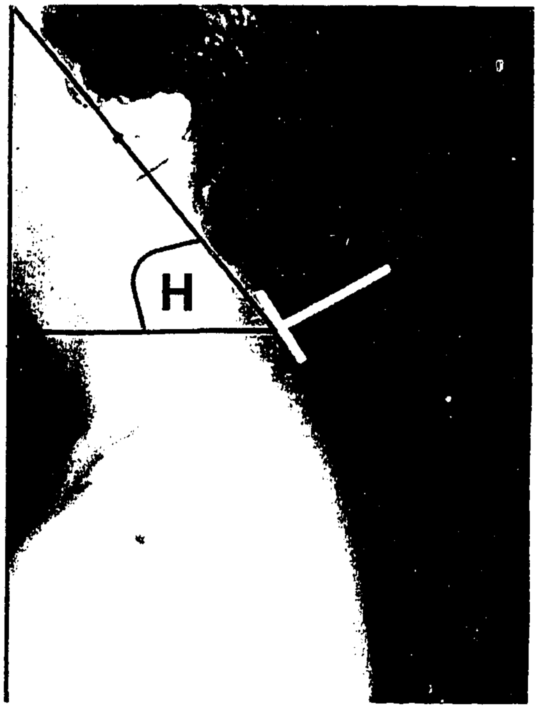


Plate 3.3 Head position measured as an angle between the tragus-C_7 line and horizontal (<H).

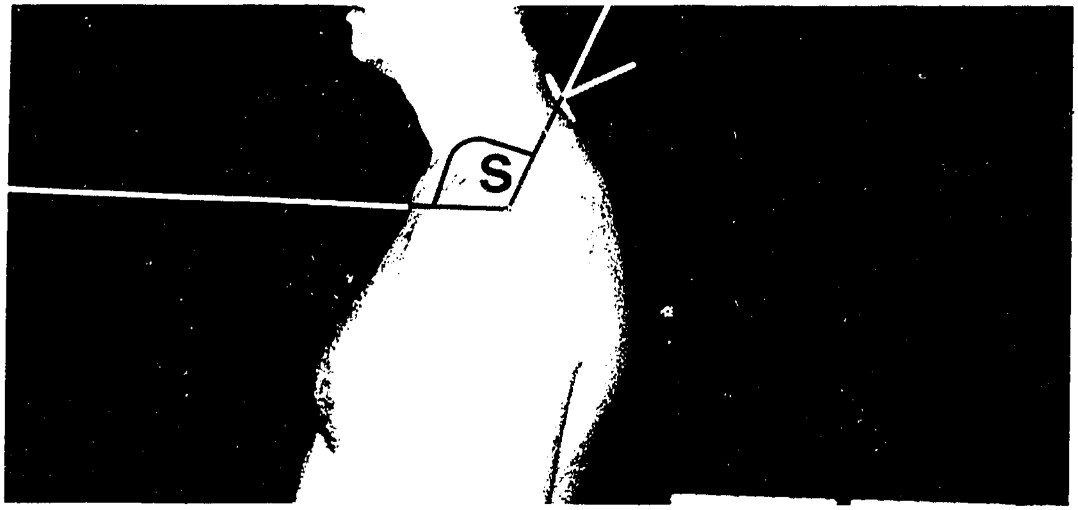


Plate 3.4 Relative protraction/retraction of the shoulders measured as an angle between the C_7-acromion process line and horizontal (<S).

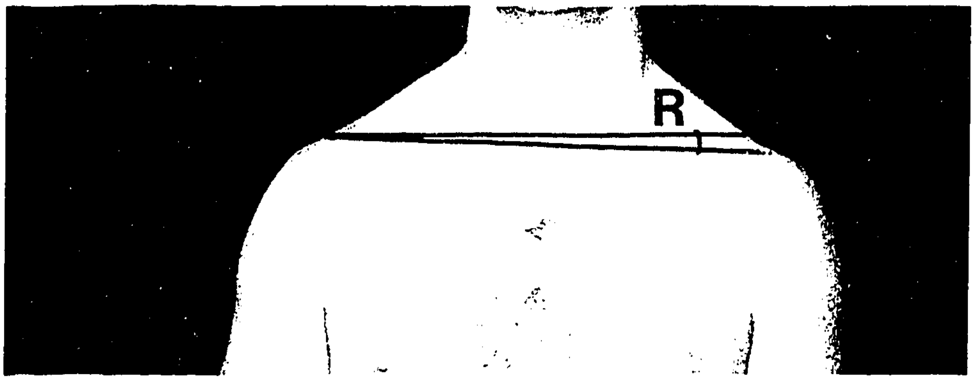


Plate 3.5 Relative shoulder height measured as an angle between the acromioclavicular joint line and horizontal (<R).

f) Pelvic tilt

Pelvic tilt was measured using the method described by Sanders and Stravrakas.[111] Callipers were used to measure the distance between the ASIS and PSIS (A). The distance from a horizontal line to the ASIS was measured from the anterior view and the posterior view was used to measure the distance between the PSIS and the same horizontal line. The difference in these measures was calculated to give the height between the ASIS and the PSIS (B). Finally the angle of the pelvic tilt (θ) was calculated using the formula:

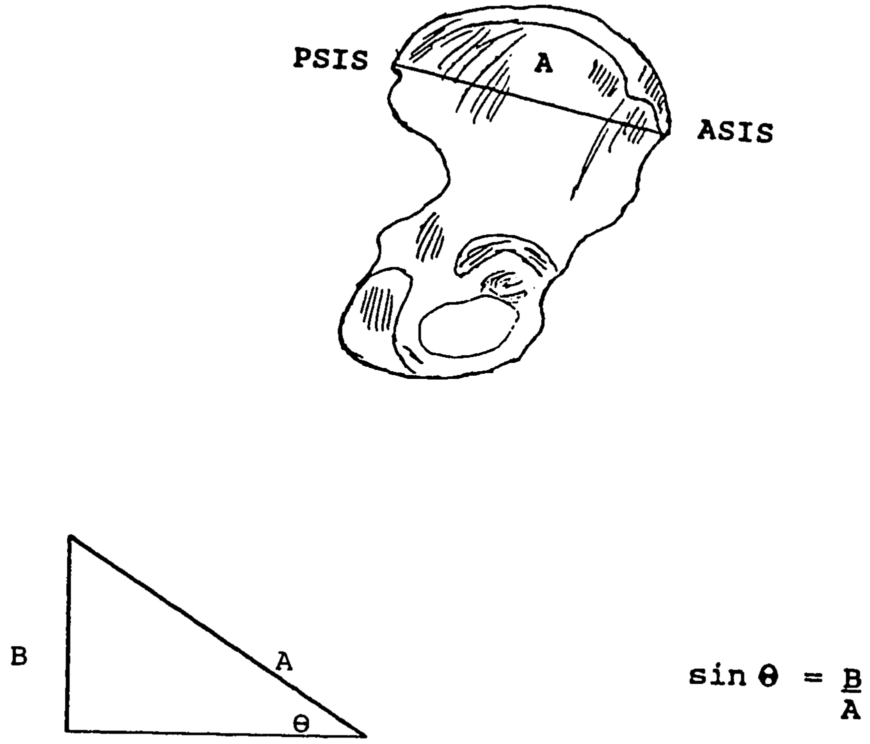
$$\sin \theta = \frac{B}{A}$$

(Figure 3.2). The reliability of this measurement has been calculated to be .88 using a Pearson product-moment correlation coefficient.[54]

g) Leg length

Leg length was measured in supine after first squaring the pelvis using a bridging technique. The distance from the inferior aspect of the ASIS to the medial malleolus (distal aspect) was recorded bilaterally. Any difference was recorded as a positive discrepancy.

Data collection forms for the initial assessment and raw data calculations prior to analysis are included in Appendix E.



$$\sin\theta = \frac{B}{A}$$

Figure 3.2 Measuring pelvic tilt

DATA ANALYSIS

Appropriate descriptive statistics[125] were used to characterize study participants in each of the study groups. For age and BMI the means and standard deviations were calculated for each group. For sex and occupational category the percentage of subjects in each category were calculated. Diagnosis, vertebral level, pain intensity and duration, and mechanism of injury were only factors in the two pain groups and were therefore not measured in the normal control group. For diagnosis and vertebral level the percentage of subjects in each category was calculated and for pain intensity and duration the means and standard deviations were calculated for each group. The mechanism of injury was a verbal description classified into comparable injuries such as falling, twisting, whiplash or insidious onset. The percentage of subjects in each category was calculated. The postural parameters yielded six angular measures and one distance in standing and five angular measures in sitting. For each of these angles and the distance, the means and standard deviations were calculated for each of the three study groups.

The data was divided into two components: sitting posture and standing posture. These two components were analyzed separately yielding two separate postural profiles for each of the study groups.

The statistical significance of any differences between the three study groups with respect to the studied parameters was analyzed as follows:[125] a) age and BMI - one-way ANOVA, b) sex and occupational category - chi-square test, and c) the seven postural parameters - one-way ANOVA. For the two pain groups, the statistical difference for pain intensity was analyzed with a t-test, and clinical diagnosis, vertebral level of pain and mechanism of injury were analyzed with a chi-square test.[125]

The postural profiles (first objective) were then described using the information obtained from these tests.

Finally, those variables found to be statistically significant were analyzed using linear discriminant analysis for sitting and for standing. This is similar to the technique of multiple regression but is used with a nominal dependent variable and multiple independent variables. This analysis was used to determine the relative importance of the postural factors in predicting the low back pain group, and what proportion of the three subject groups was correctly classified by the scores on these factors.[125,126] An alpha level of 0.05 was set as the acceptable level of significance for this data.

For those parameters which were not significantly different a power analysis was carried out to determine the power of the analysis.

ETHICAL CONSIDERATIONS

This study received approval from the Student Projects Ethical Research Review Committee June 3, 1992. All participants read the information sheet for study participants and were given the opportunity to ask questions. All participants signed an informed consent form prior to participation in the study (Appendix F).

CHAPTER FOUR

RESULTS

SUBJECTS

Subject recruitment and data collection took place between September 1992 and May 1993. In all, seventy-six participants were tested. Three subjects who were outside the original age limit by more than two years were replaced with the next volunteers who fit the age requirement. One subject with an extremely large abdomen was replaced due to the high potential for measurement error in the pelvic tilt analysis. One subject was eliminated due to a loss of photographic data.

There was a scarcity of volunteers who fit the requirements for group 2 (acute low back pain). Therefore, once 19 acute pain volunteers had been successfully recruited a power analysis was done using the first 20 volunteers recruited to the chronic pain and control groups and the 19 recruited to the acute pain group. The results of the power analysis are reported at the end of the chapter; these results supported a sample size of 59 (20 chronic, 19 acute, 20 control) being used. Therefore the last five volunteers in the control group and seven in the chronic group were eliminated from the analysis to equalize group size.

STUDY GROUP DESCRIPTION

The raw data for subject demographics and pain group descriptive variables are reported in Appendix G. All statistical analyses were done using SPSS/PC+ Release 4.0.1 and graphs were produced using SPSS for Windows Release 5.0.1 (SPSS Inc., 444 North Michigan Ave., Chicago, Illinois, 60611.) Table 4.1 shows the summary statistics for age and BMI.

Table 4.1 Demographic data. Means, standard deviations (in brackets), and ANOVA results reported.

	Group 1 Chronic	Group 2 Acute	Group 3 Control	p Value ANOVA
Age (years)	28.9 (6.3)	31.4 (7.8)	27.2 (5.9)	0.14
BMI (kg/m^2)	24.7 (3.3)	25.9* (4.2)	22.8 (2.3)	0.02

* Significantly different from group 3 using a Tukey post hoc analysis at the 0.05 level.

No significant differences were found, using an ANOVA, in the mean ages for the three study groups, but the mean BMI for group 2 was significantly higher than the mean BMI for group 3.

The frequencies and percentages of each category for gender (table 4.2, figure 4.1) and occupational category (table 4.3, figure 4.2) were calculated. The most frequently observed occupational category, in each of the study groups, was the light physical activity level. Using

Table 4.2 Demographic data. Frequencies and percentages (in brackets) are reported for gender in each study group.

	Group 1	Group 2	Group 3
Male	12 (60.0)	11 (57.9)	7 (35.0)
Female	8 (40.0)	8 (42.1)	13 (65.0)

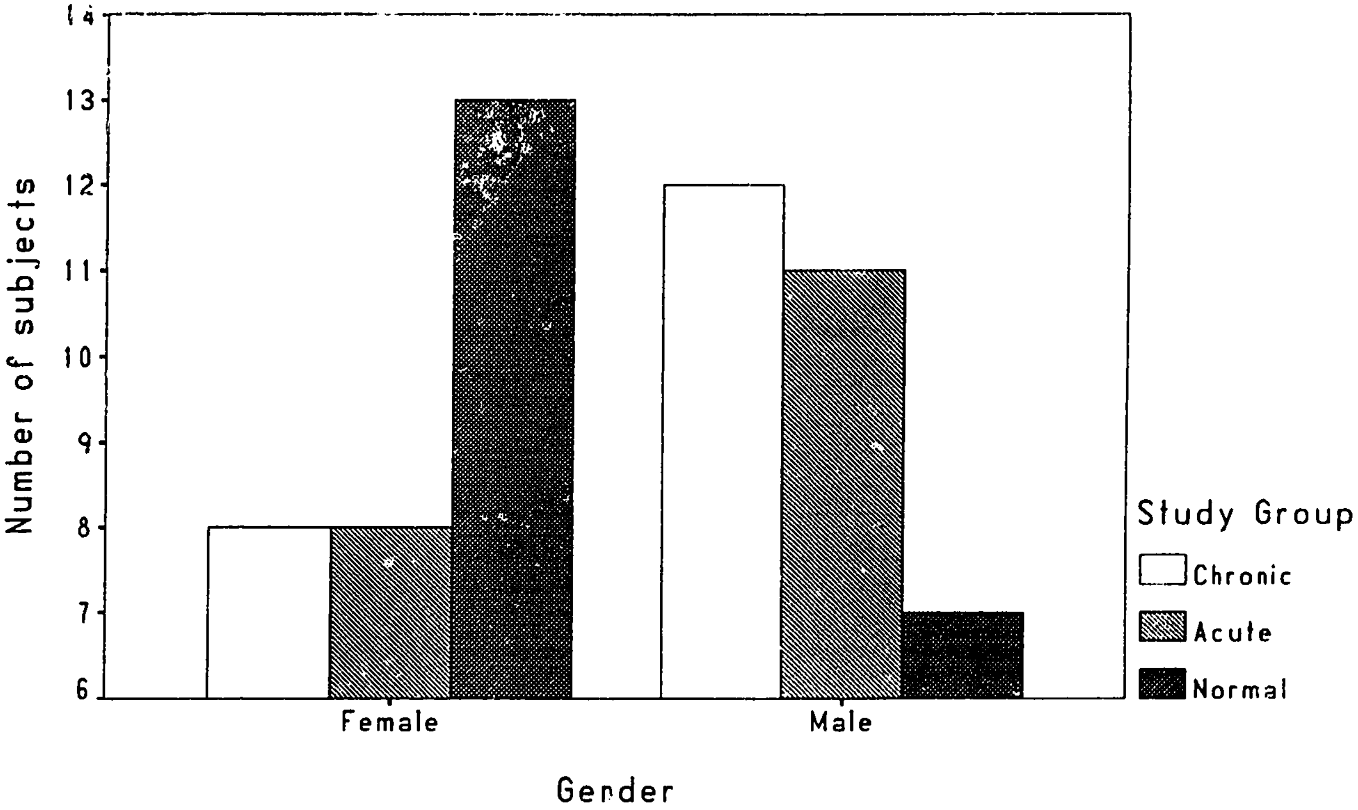


Figure 4.1 Description of study groups by gender.

Table 4.3 Demographic data. Frequencies and percentages (in brackets) are reported for occupational category in each study group.

	Group 1	Group 2	Group 3
Sedentary	7 (35.0)	3 (15.8)	4 (20.0)
Light	12 (60.0)	9 (47.4)	13 (65.0)
Medium	1 (5.0)	5 (26.3)	2 (10.0)
Heavy	0 (0)	2 (10.5)	0 (0)
Very heavy	0 (0)	0 (0)	1 (5.0)

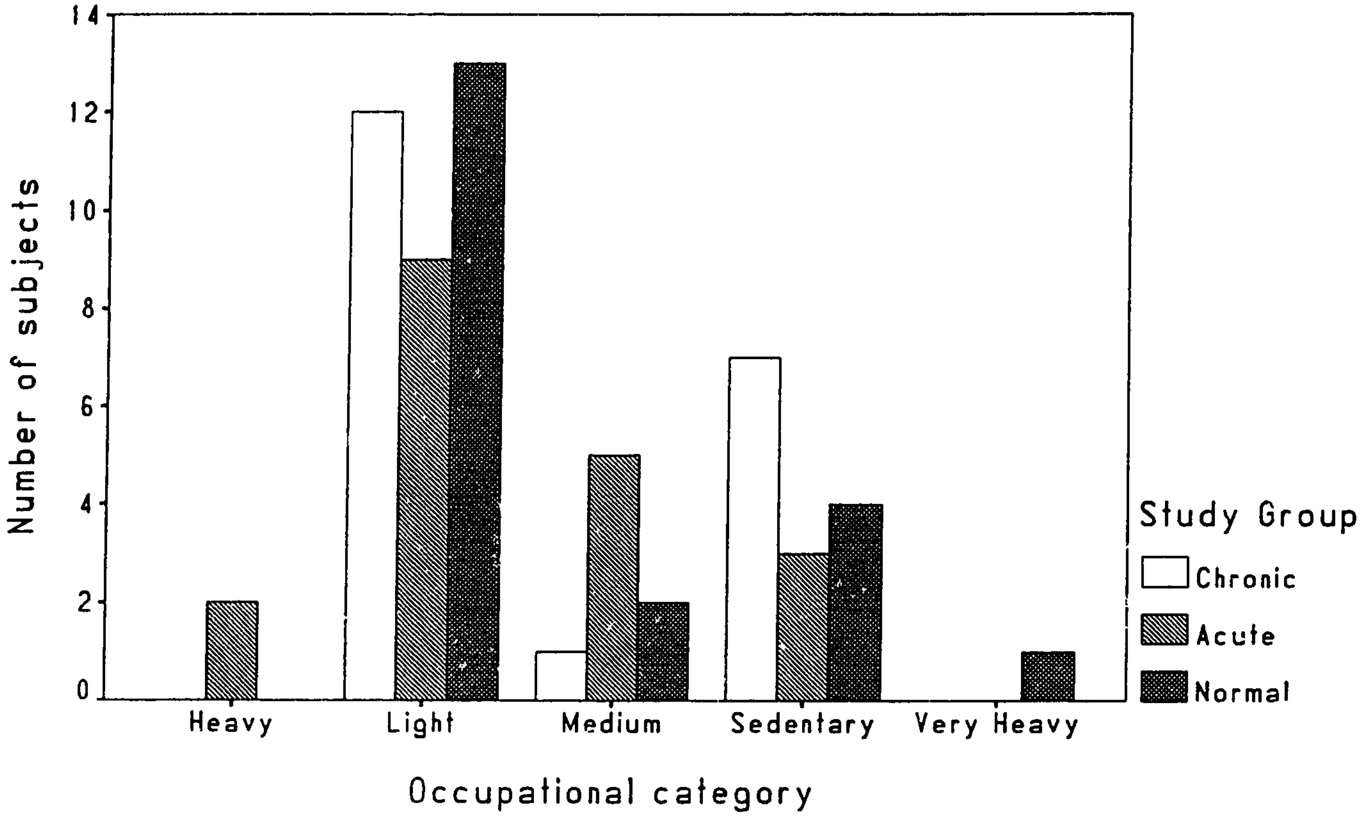


Figure 4.2 Description of study groups by occupational category.

chi-square statistical analysis, no significant differences were found between study group and gender as well as study group and occupational category (table 4.4), even though the male/female distribution for the two pain groups appears to be different from the control group.

Table 4.4 Chi-square statistics for demographic data.

	Chi-square value	Significance
Gender	3.06	0.22
Occupational Category	11.96	0.15
Vertebral level of pain	0.67	0.88
Mechanism of injury	8.31	0.60
Clinical diagnosis	1.51	0.91

The chronic and acute pain groups can be described further with respect to pain intensity and duration (table 4.5), clinical diagnosis (table 4.6, figure 4.3), vertebral level of pain (table 4.7, figure 4.4), and mechanism of injury (table 4.8, figure 4.5). A Student's t-test was used to test the difference between groups for pain intensity

Table 4.5 Demographic data for the two pain groups. Means, standard deviations (in brackets), and t-test results are reported.

	Group 1	Group 2	p Value t-test
Pain Intensity (mm)	13.9 (17.5)	19.1 (24.2)	0.44
Pain Duration (years)	8.0 (5.0)	0.3 (0.2)	- - -

Table 4.6 Demographic data. Frequencies and percentages (in brackets) are reported for clinical diagnosis in the two pain groups.

	Group 1	Group 2
Musculoligamentous	9 (45.0)	9 (47.4)
Facet joint syndrome	2 (10.0)	1 (5.3)
Osteoarthritis	0 (0)	0 (0)
Nerve root irritation	1 (5.0)	1 (5.3)
Disc disease	2 (10.0)	3 (15.8)
Vertebral fractures	1 (5.0)	0 (0)
Misc. mechanical problems	5 (25.0)	5 (26.3)

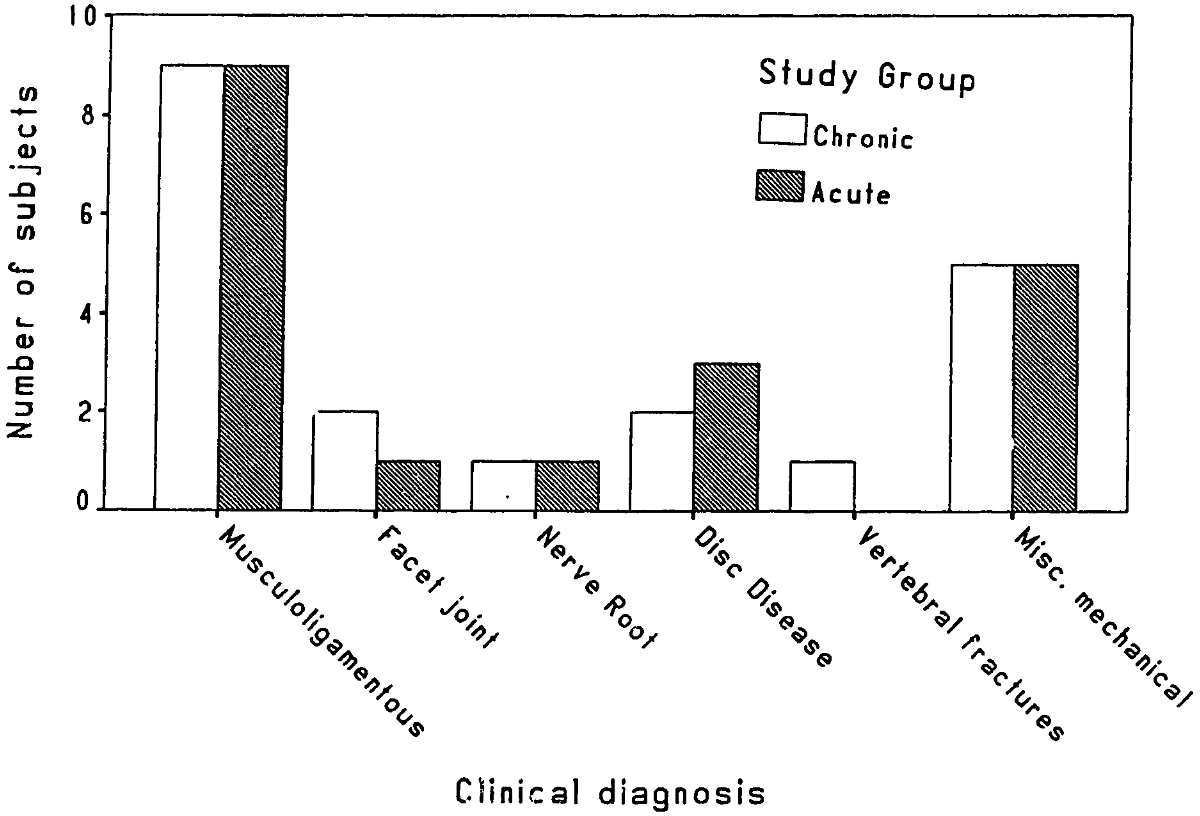


Figure 4.3 Description of pain groups with respect to clinical diagnosis.

Table 4.7 Demographic data. Frequencies and percentages (in brackets) are reported for vertebral level of pain in the two pain groups.

	Group 1	Group 2
Upper Lumbar (L_1-L_3)	2 (10.0)	1 (5.3)
Lower Lumbar (L_3-L_5)	16 (80.0)	15 (78.9)
Total Lumbar (L_1-L_5)	1 (5.0)	1 (5.3)
Other (Sacral)	1 (5.0)	2 (10.5)

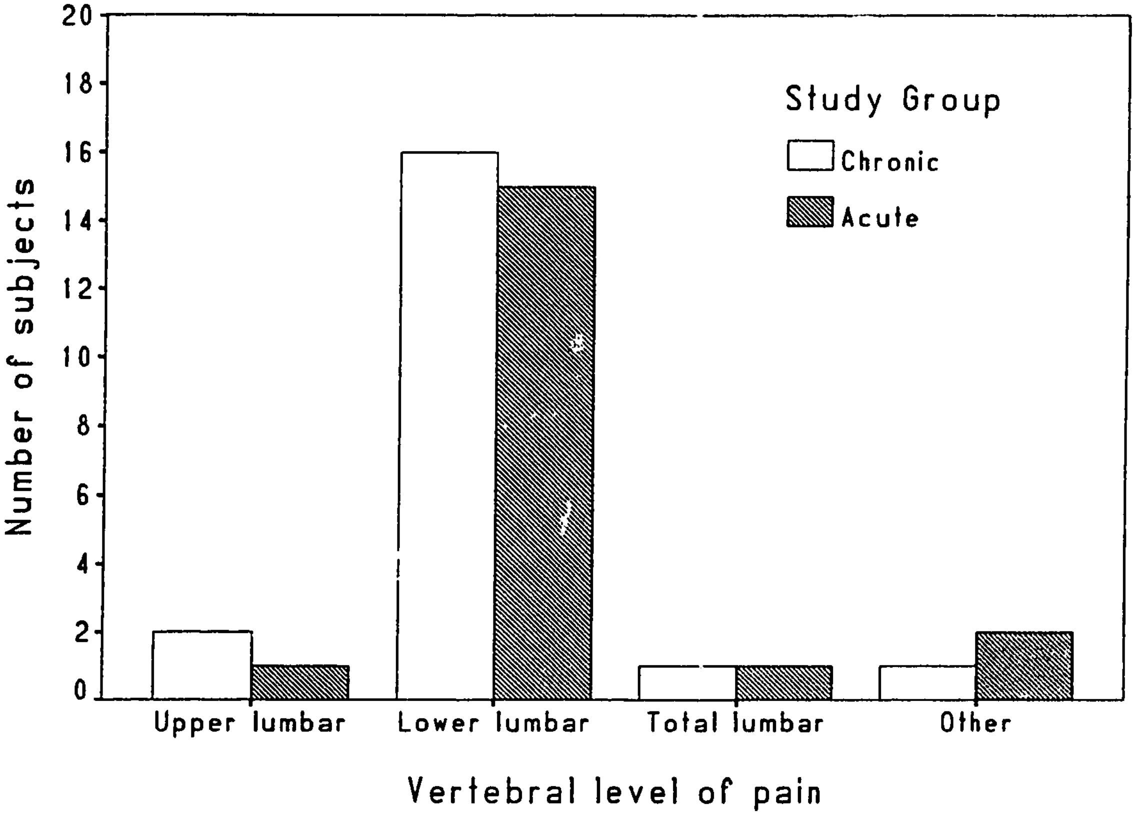


Figure 4.4 Description of pain groups with respect to vertebral level of pain.

Table 4.8 Demographic data. Frequencies and percentages (in brackets) are reported for mechanism of injury in the two pain groups.

	Group 1	Group 2
Insidious onset	11 (55.0)	11 (57.9)
Twisting	0 (0)	2 (10.5)
Twisting and bending	0 (0)	1 (5.3)
Twisting and lifting	2 (10.0)	0 (0)
Lifting	1 (5.0)	2 (10.5)
Fall from height	1 (5.0)	0 (0)
Stretching	1 (5.0)	0 (0)
Post motor vehicle accident	1 (5.0)	1 (5.3)
Whiplash	1 (5.0)	0 (0)
Extension injury	1 (5.0)	1 (5.3)
Repetitive trauma	1 (5.0)	1 (5.3)

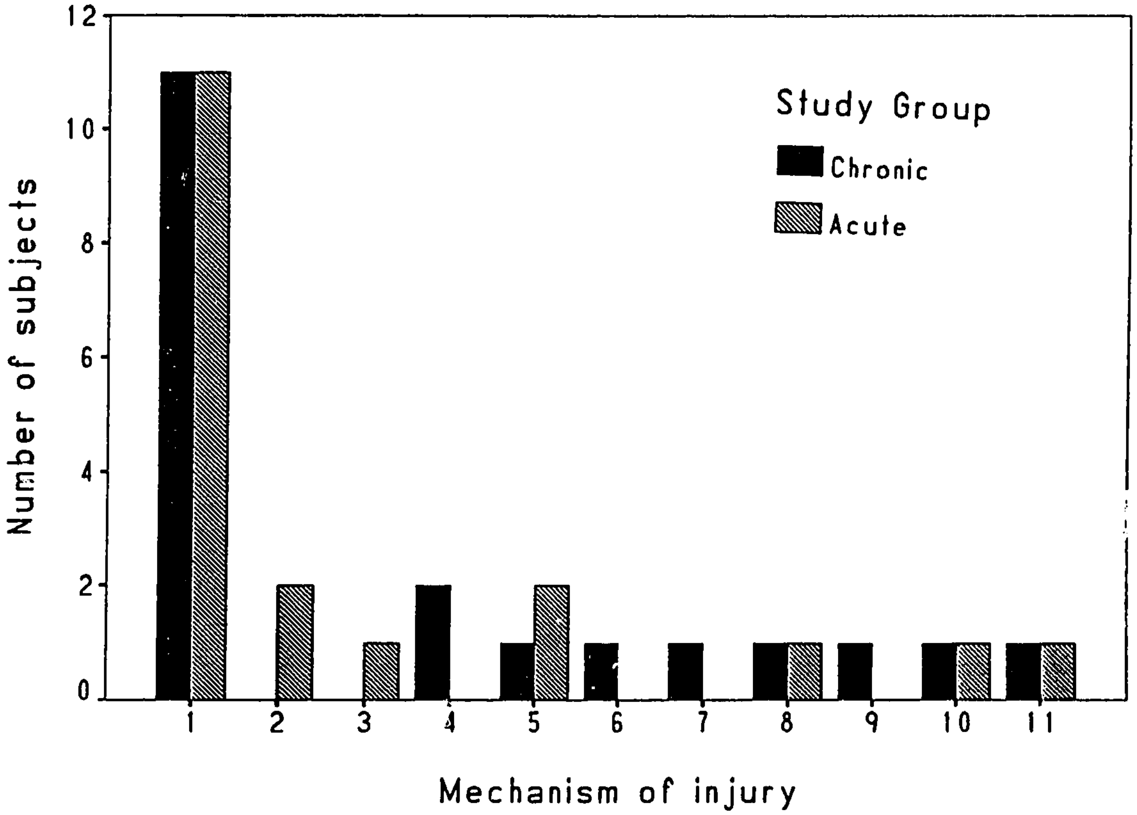


Figure 4.5 Description of pain groups with respect to mechanism of injury. (1=Insidious onset, 2=Twisting, 3=Twisting and bending, 4=Twisting and lifting, 5=lifting, 6=fall from height, 7=Stretching, 8=Post motor vehicle accident, 9=Whiplash, 10=Extension injury, 11=Repetitive trauma)

which was not found to be significant. Likewise, no significant difference was found between the two pain groups for clinical diagnosis, vertebral level of pain, or mechanism of injury using the chi-square statistic (table 4.4).

The study groups were not significantly different with respect to seven of the nine non-posture variables. By definition, pain duration was necessarily different between groups. Therefore, only BMI was included in further analysis of the data.

STANDING POSTURAL PARAMETERS

The raw data for the standing postural parameters is reported in Appendix G, table G.3. Table 4.9 and figure 4.6 outline the group summary statistics and provide a postural description for each group. Lumbar lordosis, thoracic kyphosis, and head position had significant differences between groups as shown by an ANOVA (p=0.05, p=0.04, p=0.03 respectively). It should be noted that the homogeneity of variance assumption was violated (Cochran's C p=0.03) in the ANOVA calculation for shoulder position but since the sample sizes in each group were similar and the ANOVA test is robust under these conditions this was not a concern.[127] A Tukey post hoc analysis with a 0.05 significance level was used to determine where the group differences lay. For lumbar lordosis, the chronic pain group had a significantly

Table 4.9 Means, standard deviations (in brackets), and ANOVA results reported for standing postural parameters.

	Group 1	Group 2	Group 3	p Value ANOVA
Lumbar Lordosis (°)	26.4* (9.0)	22.6 (7.9)	19.3 (9.2)	0.05
Thoracic Kyphosis (°)	45.1 (9.2)	47.4* (9.3)	39.6 (9.9)	0.04
Head Position (°)	51.1 (6.2)	49.1* (5.4)	53.5 (3.0)	0.03
Shoulder Position (°)	113.1 (16.3)	108.2 (24.2)	104.1 (15.1)	0.32
Relative Sh Height (°)	-1.1 (1.6)	-0.8 (1.8)	-1.4 (1.9)	0.56
Pelvic Tilt (°)	12.8 (8.8)	11.2 (6.2)	10.7 (9.0)	0.69
Leg Length Discrep (cm)	0.6 (0.5)	0.4 (0.4)	0.4 (0.4)	0.13

* Significantly different from Group 3 using a Tukey post hoc analysis at the 0.05 level.

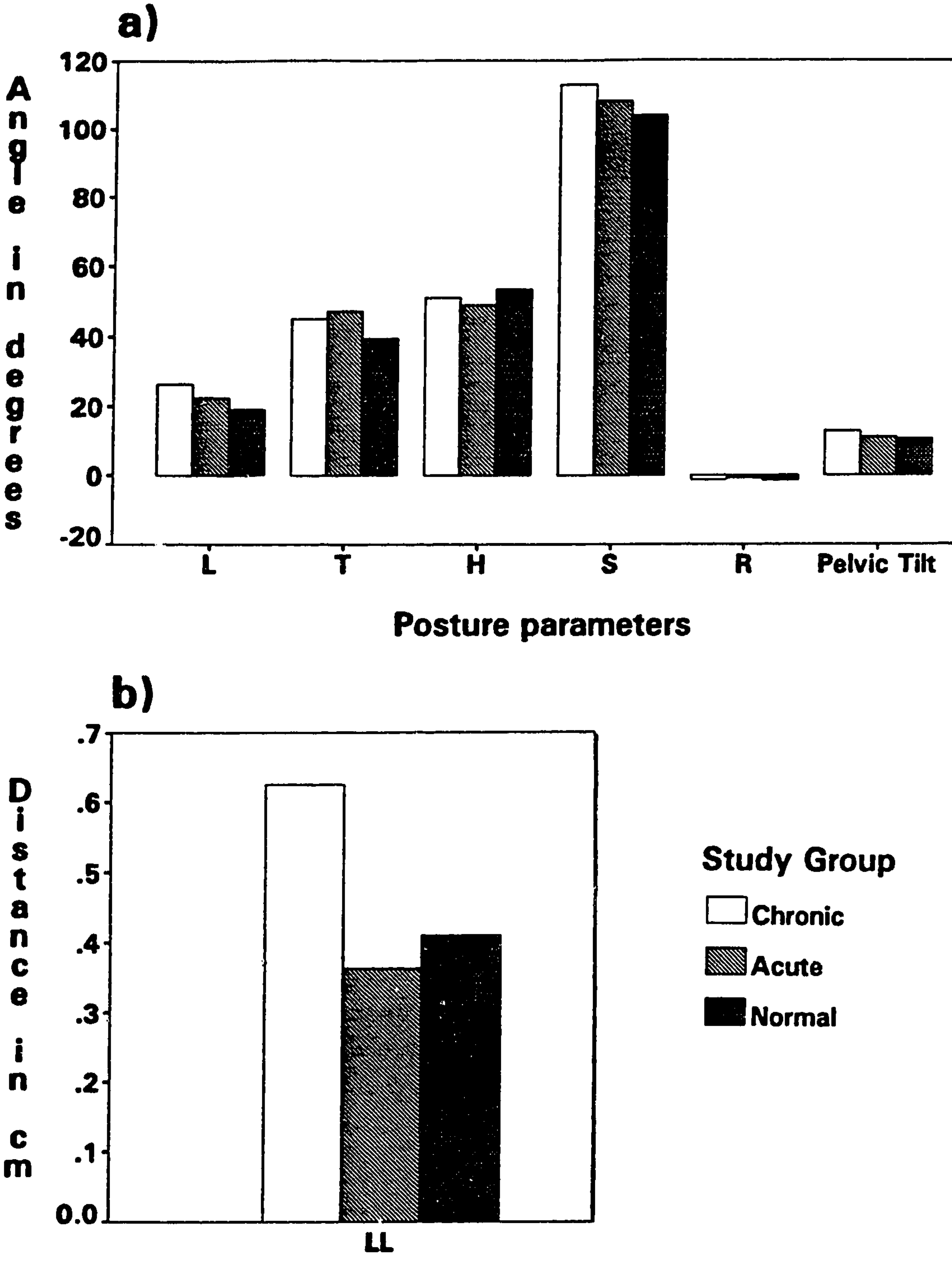


Figure 4.6 Comparison of group means for standing postural parameters. a) Lumbar lordosis (L), thoracic kyphosis (T), head position (H), shoulder position (S), relative shoulder height (R), and pelvic tilt are illustrated. b) Leg length discrepancy (LL) is illustrated.

increased lordosis as compared to the normal group. For thoracic kyphosis and head position the differences occurred between the acute and normal groups. The acute group had an increased kyphosis and a more forward head position than the normal group.

Linear discriminant analysis was carried out using BMI, lumbar lordosis, thoracic kyphosis and head position as predictors for the standing postural profile. The results are outlined in tables 4.10 through 4.12. The predictor variables were included in the analysis by a stepwise variable selection using minimization of Wilks' lambda (table 4.10). Using a three-group discriminant analysis, two discriminant functions were calculated. The first function accounted for 75.9% of the between group variability. The standardized canonical discriminant function coefficients (table 4.11) suggest that there was much variation in the contribution of the variables dependent upon which function was employed. It should also be noted that there was a high correlation (0.60) between lumbar lordosis and thoracic kyphosis which interferes with interpretation of the results somewhat; using function 1 BMI, head position and thoracic kyphosis were most strongly correlated with the discriminant function (table 4.11). Using discriminant analysis only 52.5% of the cases were correctly classified into the three study groups (table 4.12). The percent of variance explained by the predictor

Table 4.10 Summary table and canonical discriminant functions for discriminant analysis using BMI, lumbar lordosis (L), thoracic kyphosis (T) and head position (H) for the standing posture.

Step	Action		Wilk's Lambda	Significance
	Entered	Removed		
1	BMI		0.87	0.02
2	L		0.79	0.01
3	H		0.75	0.01

Function	Percent of Variance	Canonical Correlation		After Function	Wilks' Lambda	Sig
			:	0	0.75	0.01
1	75.9	0.44	:	1	0.93	0.13
2	24.1	0.27	:			

Table 4.11 Standardized canonical discriminant function coefficients and pooled within-groups correlation matrix.

Standardized Canonical Discriminant Function Coefficients

	Function 1	Function 2
BMI	0.57	-0.31
L	0.36	0.94
H	-0.53	0.31

Pooled-within-groups correlations between discriminating variables and canonical discriminant functions

	Function 1	Function 2
BMI	0.78	-0.24
H	-0.71	0.33
T	0.65	0.32
L	0.49	0.87

Table 4.12 Classification results for discriminant analysis of the predictor variables for the standing posture.

Actual Group	Predicted Group Membership		
	1	2	3
Group 1	8 40.0%	4 20.0%	8 40.0%
Group 2	5 26.3%	9 47.4%	5 26.3%
Group 3	6 30.0%	0 0%	14 70.0%

Percent of 'grouped' cases correctly classified: 52.5%

variables is calculated by the formula $1-\Lambda^{128}$ and was 25% (table 4.10).

SITTING POSTURAL PARAMETERS

The raw data for the sitting postural parameters is reported in Appendix G, table G.4. Table 4.13 and figure 4.7 outline the group summary statistics and provide a postural description for each group. Only thoracic kyphosis showed a significant difference between groups with the ANOVA (p=0.02). A Tukey post hoc analysis showed that individuals with acute pain had an increased thoracic kyphosis as compared to the control group.

Table 4.13 Means (°), standard deviations (in brackets), and ANOVA results reported for sitting postural parameters.

	Group 1	Group 2	Group 3	p Value ANOVA
Lumbar Lordosis	3.6 (9.8)	6.1 (8.3)	0.3 (6.4)	0.10
Thoracic Kyphosis	35.8 (10.6)	39.9* (8.0)	31.6 (7.6)	0.02
Head Position	47.9 (5.8)	47.4 (6.6)	49.2 (3.7)	0.56
Shoulder Position	113.9 (12.0)	115.4 (18.1)	107.5 (12.4)	0.19
Relative Sh Height	-1.8 (1.6)	-0.6 (2.2)	-1.4 (1.9)	0.13

* Significantly different from group 3 using a Tukey post hoc analysis at the 0.05 level.

Linear discriminant analysis was carried out using BMI and thoracic kyphosis as predictors for the sitting postural

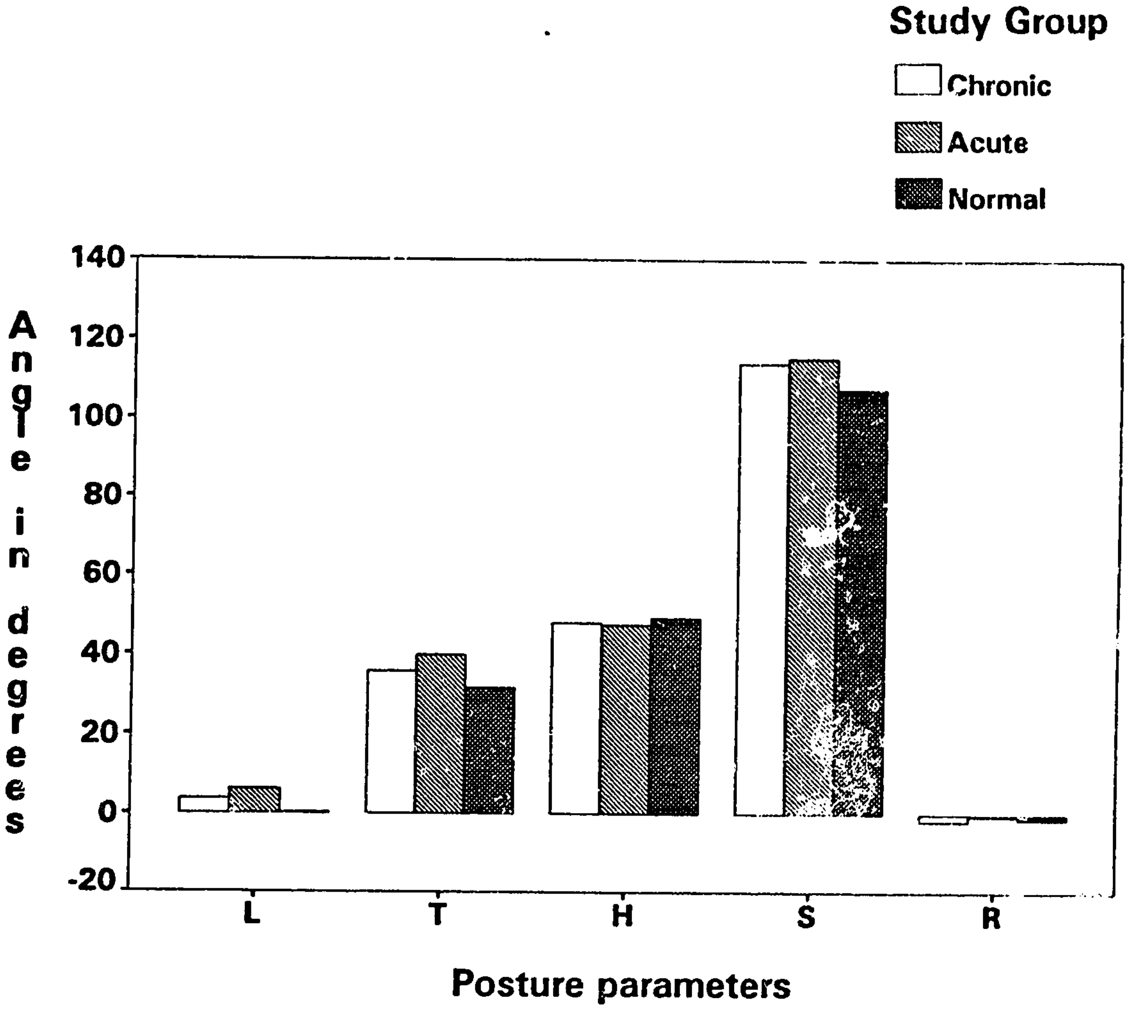


Figure 4.7 Comparison of group means for sitting postural parameters. Lumbar lordosis (L), thoracic kyphosis (T), head position (H), shoulder position (S), and relative shoulder height (R) are illustrated.

profile. The results are outlined in tables 4.14 through 4.16. The predictor variables were included in the analysis by a stepwise variable selection using minimization of Wilks' lambda (table 4.14). Using a three-group discriminant analysis, two discriminant functions were calculated. The first function accounted for 99.3% of the between group variability. The standardized canonical discriminant function coefficients and the correlation coefficients between the variables and the functions (table 4.15) both indicated that BMI and thoracic kyphosis had a similar contribution to the discriminant function. As with the standing postural profile, only 55.9% of the cases were correctly classified into the three study groups (table 4.16) using discriminant analysis. The percent of variance explained by the predictor variables was 19% for sitting (table 4.14).

Table 4.14 Summary table and canonical discriminant functions for discriminant analysis using BMI and thoracic kyphosis (T) for the sitting posture.

Step	Action Entered	Removed	Wilk's Lambda	Significance
1	T		0.87	0.02
2	BMI		0.81	0.02

Function	Percent of Variance	Canonical Correlation		After Function	Wilks' Lambda	Sig
			:	0	0.81	0.02
1	99.3	0.43	:	1	1.00	0.76
2	0.7	0.04	:			

Table 4.15 Standardized canonical discriminant function coefficients and pooled within-groups correlation matrix.

Standardized Canonical Discriminant Function Coefficients

	Function 1	Function 2
BMI	0.61	0.86
T	0.62	-0.85

Pooled-within-groups correlations between discriminating variables and canonical discriminant functions

	Function 1	Function 2
T	0.81	-0.58
BMI	0.81	0.59

Table 4.16 Classification results for discriminant analysis of the predictor variables for the sitting posture.

Actual Group	Predicted Group Membership		
	1	2	3
Group 1	6 30.0%	6 30.0%	8 40.0%
Group 2	3 15.8%	11 57.9%	5 26.3%
Group 3	3 15.0%	1 5.0%	16 80.0%

Percent of 'grouped' cases correctly classified: 55.9%

SAMPLE SIZE AND POWER

Power analysis[129] was carried out on the data collected for all three study groups in areas where significance was not achieved with a study sample size of 59. Age, standing shoulder position, leg length discrepancy, sitting lumbar lordosis, sitting shoulder position and sitting relative shoulder height all had a power of greater than 0.80 which was considered sufficient for this study. The variables which did not have sufficient power (standing relative shoulder height, pelvic tilt, sitting head position) required sample sizes of 43-68 subjects per group to reach a power of 0.80 which was not feasible for this study.

With respect to the discriminant analysis, a sample size of 59, a study power of 0.80 and an alpha level of 0.05 allowed 5-6 variables to be analyzed at a single time (Appendix D).[117] A maximum of 4 variables were found to be significant for each profile and therefore sufficient power was maintained.

CHAPTER FIVE

DISCUSSION

STUDY GROUP DESCRIPTION

The acute and chronic low back pain groups were defined by duration of pain. Therefore, some individuals in the acute pain group may ultimately belong to the chronic pain group. The groups were not differentiated using diagnosis or severity of pain and therefore the results cannot be generalized to specific diagnostic categories.

Treatment history of pain patients was not requested and therefore prior postural correction was not controlled for. This may be a confounding variable even though all subjects were requested to adopt a relaxed standing posture and an upright sitting posture rather than a "correct" posture.

The study groups in this study showed no significant differences with respect to mean age. This is partly a result of the recruitment procedure which restricted subject age to 20-45 years. It was noted by the investigator that recruitment of control subjects, with no history of low back pain, who were over age 30 was more difficult than recruiting subjects age 20-30. This reflected the literature finding that there is a high lifetime incidence of low back pain[2,3,4,5,6] and that age is a risk factor for the development of low back pain.[2,3,6,13,64,65,66]

Individuals with acute low back pain had a significantly higher BMI than the control group while the chronic group had a BMI which was not significantly different from the controls. Even though there was a statistically significant difference, the mean BMI for the acute group was 25.9 kg/m^2 which is not considered obese[123] and thus the difference was not clinically significant. In addition, those individuals in the control group had a BMI which was on the low side for the general population. Revicki and Israel[124] found a mean BMI of 27.0 kg/m^2 for men aged [illegible] years. Therefore, the data was consistent with th[illegible] in the literature that there is no strong evidence indicating BMI as a risk factor for low back pain.[16,56,57,66,67,69,70] Height was not investigated separately from BMI although there is controversy over its association with posture.[57,66,67,68,70] The three study groups were equivalent with respect to gender and occupational category. The light occupational category was observed most frequently in all three study groups. This level is described as involving lifting of up to 20 lbs, frequent lifting of up to 10 lbs, prolonged walking or standing activities, or prolonged sitting with an element of pushing or pulling.[118] This observation was likely influenced by the fact that most subjects were recruited from the university community which involved primarily sedentary and light occupations. Activity level was addressed with respect to occupation but no information was obtained regarding sports and recreational activities. Therefore the groups may not be equivalent in this respect. The literature review did not support a relationship between leisure sports activity and low back pain.[70,72] Therefore, with the exception of BMI for the acute pain group, the study groups were equivalent with respect to the demographic parameters assessed.

The two pain groups were also described with respect to pain. These two groups were equivalent for all parameters studied; pain intensity, clinical diagnosis, vertebral level of pain, and mechanism of injury. Finneson[23] stated that lumbosacral strain is one of the most frequently used diagnoses related to low back pain. Klein et al[59] reported statistics from 1979 that encompassed all work-related injuries from 26 states. Eighty-seven percent of back injuries involved sprains or strains and this was the largest single category observed. Similarly, for this study, close to 50% of the participants in each group had musculoligamentous complaints, also the largest category observed. The decrease in incidence as compared to those observed by Klein et al[59] may be a reflection of slightly different study populations; they were restricted to work-related injuries whereas the present study included low back pain of any origin. Grieve[64] reported that the region of problem (middle versus junctional regions) between acute and chronic may differ. This study did not find regional differences but the classification groups were not particularly sensitive to this form of discrimination. Finally, insidious onset accounted for 55-60% of the low back pain observed in this study. Dillane et al[9] and Rowe[16] also reported very high incidence of insidious onset low back pain in their study populations. With respect to those with a specific injury, the mechanism of injury reported generally corresponded with those mentioned in the literature; lifting, twisting, pushing, and pulling.[8,59,75]

STANDING POSTURE

The results for the standing postural profiles revealed three unique profiles (table 5.1). Individuals with chronic low back pain had an increased lumbar lordosis as compared to the control group. Individuals with acute low back pain had an increased thoracic kyphosis and a forward head position as compared to the control group.

Only a few parameters can be directly compared to results of prior research due to the great variety of methods and landmarks used in recording posture. In general the results for the lumbar lordosis in normals (19°) were decreased as compared to previous research but were comparable to the photographic results of Burdett et al.[46] Previously recorded values for lordosis included 34° with the pantograph,[37] 35° with the kyphometer and inclinometer ($T_{11}T_{12}$ to S_1S_2),[39] 36° ($T_{11}T_{12}$ to S_1S_2) with the kyphometer,[109]

Table 5.1 Standing postural profiles.

	Group 1	Group 2	Group 3
Lumbar Lordosis	26°	23°	19°
Thoracic Kyphosis	45°	47°	40°
Head Position	51°	49°	54°
Shoulder Position	113°	108°	104°
Relative Shoulder Height	-1°	-1°	-1°
Pelvic Tilt	13°	11°	11°
Leg Length Discrepancy	0.6cm	0.4cm	0.4cm

Shading represents values significantly different from the normal group.

and 54° (L_1 to L_5)[104] and 49° ($T_{12}L_1$ to sacrum)[46] with X-ray analysis. Burdett et al[46] measured healthy individuals from the thoracolumbar junction to the sacrum using a photographic technique and reported a lumbar lordosis of 16°-22° which was comparable to the values obtained for the normal control group. There were no directly comparable results in the literature for thoracic kyphosis (40°). Previous research has produced a range of normal values dependent upon the method; 42° with the pantograph and an older population,[37] 32° (T_2T_3 to $T_{11}T_{12}$) with the kyphometer and inclinometer and a younger population,[39] 29° (T_2T_3 to $T_{11}T_{12}$) with the kyphometer,[104] and 35° (T_1 to T_{12}) with the inclinometer.[52] The results for head position were comparable to those found by Shiau and Chai[44] in the standing position (54° and 57° respectively). No values for standing shoulder position were found and the results for relative shoulder height could not be compared as they were calculated differently.[44] The pelvic tilt measurements (11°) were comparable to those found by Gajdosik et al[54] in males of a similar age group (8°). Leg length discrepancy values (0.4cm) were consistent with those found in the literature using the same method (0.3 cm)[114] and in standing (0.3 cm).[104] Therefore, the normal population used in this study was comparable to the normal populations reported in previous research for the standing postural parameters.

Those individuals with chronic low back pain were found to have a significantly increased lumbar lordosis as compared to the normal population, while those with acute low back pain were not significantly different but had a mean angle which lay between the other two groups. This finding of increased lordosis in the chronic group was in contrast to the findings of Hansson et al[105] in both chronic and acute groups, Pope et al[104] in moderate and severe low back pain, Day et al[40] in chronic low back pain, and Bergenudd et al[37] and During et al[18] in groups with unspecified pain duration, who all found no relationship between lumbar lordosis and low back pain. Magora[80] reported an increased incidence of hyperlordosis in low back pain sufferers but claimed that hypolordosis was a reliable indicator of severe low back pain. When the lordosis of study participants who reported greater than 20 mm of pain on the VAS was reviewed, there was no indication of a trend towards hypolordosis. The results found by Roncarati and McMullen,[65] Ohlen et al[39] in gymnasts, and Moore et al[38] in pregnancy were consistent with the findings in this study that an increase in lordosis was correlated with low back pain.

The acute pain group had an increased thoracic kyphosis as compared to the control group, whereas there was a non-significant trend towards an increased thoracic kyphosis in the chronic pain group. This is in contrast to previous research conducted by Magora[80] and Bergenudd et al[37] who both found no relationship between low back pain and thoracic posture. In both these cases, though, there was no indication of the duration of low back pain studied. Magora[80] stated that he found an increase in thoracic posture abnormalities in heavy industry workers. When the data in the present study was reviewed, it was found that for those exhibiting greater than 55° thoracic kyphosis there was a significantly different distribution with respect to occupation but the occurrence was more evenly distributed throughout all categories rather than being focused in the heavier occupations as predicted by Magora. Therefore the results of this research were not consistent with previous research[37,80] with respect to thoracic kyphosis.

The acute pain group exhibited a forward head position as compared to the normal group, while the chronic pain group had no significant change in posture. Shiau and Chai[44] found a similar change in position amongst individuals with head and neck pain. No data was found which investigated head and shoulder posture with respect to low back pain in a manner similar to this study. No significant postural changes were noted with respect to shoulder position or height in the three study groups. Several authors[35,41,43,103] have suggested that a forward head position is accompanied by rounded shoulders but these two postures were not well correlated in this study. Magee[17] proposed that a forward head position is often associated with an increased lumbar lordosis. This study also found no correlation between these two parameters.

There were no differences in pelvic tilt position between the study groups. This was consistent with the findings of During et al[18] but Roncarati and McMullen[65] found an increased anterior pelvic tilt in low back pain subjects. This was one variable where there was low power to find a difference between groups and further investigation is required to reach more powerful conclusions.

There were also no differences found between the groups with respect to leg length discrepancy. Only one study was reviewed that investigated absolute measurements of leg length inequality and an increase in leg length discrepancy in individuals with severe low back pain was found even though when looking at a discrepancy of greater than 0.05 cm there was no difference between groups.[104] Similarly, when groups were compared with respect to having a leg length discrepancy of 1.0 cm or greater, Biering-Sorensen,[69] Giles and Taylor,[33] and Roncarati and McMullen[65] all found an increased incidence of leg length discrepancy with low back pain. Therefore, the data was reviewed in a similar manner but there remained no significant difference between study groups with respect to having a leg length discrepancy of at least 1 cm.

The only parameters found to have a strong, significant correlation were lumbar lordosis and thoracic kyphosis. A weak, significant correlation was found between forward head position and thoracic kyphosis, and between lumbar lordosis and anterior pelvic tilt. Therefore, each aspect of the spinal curve had at least a weak, significant correlation with adjacent aspects of the curve.

Individuals with chronic low back pain presented with an increased lumbar lordosis as compared to the normal population with no significant variations in other aspects of their posture. Since 70% of the sample population consisted of individuals with musculoligamentous or mechanical problems the theories related to the muscular response to pain and ligament irritation are most appropriate. The experiments conducted by Hedtmann et al[90] suggested that individuals may adopt a flexed posture to decrease ligament strain and thus decrease irritation of the pain receptors. This pattern was not observed in the study population where 45% of the cases had a musculoligamentous diagnosis. It may follow, though, that these individuals had low back pain due to increased pain receptor irritation secondary to increased lordosis. Another potential explanation for the above findings relates to the muscular response to pain. Janda[95] suggested that the trunk extensors respond to pain by tightening which would pull the spine into increased lumbar lordosis. This extended position also protects the intervertebral discs from injury.[84,91] In those with chronic pain, these changes would have persisted over time and adaptive changes would be expected. Both theories account for the local changes found in this study.

The participants who presented with acute pain had a posture which exhibited an increased thoracic kyphosis and a forward head position. No literature reported an increased thoracic kyphosis associated with low back pain but there was also no indication of the duration of low back pain studied. Therefore, the results of this study may be indicative of postural changes found only in acute low back pain but not chronic low back pain. The changes associated with acute low back pain were focused in the upper back and neck regions. There was a tendency towards an increased lumbar lordosis which did not reach significance. A possible explanation for this finding is that with the onset of pain all aspects of the spinal curve initially respond to the pain; supported by the correlations found between adjacent aspects of the curve. A second theory is based on the forward head posture explanation advanced by Rocabado and Iglarsh.[35] Individuals with acute low back pain may have had a pre-existing forward head position which resulted in flexion of the thoracic spine and signs and symptoms in the lumbar spine and pelvis.

In this study individuals with a diagnosed scoliosis were excluded from the study. This may account for the discrepancy between the present data and the literature findings with respect to leg length discrepancy which is biomechanically related to scoliotic deformities.

The linear discriminant analysis, using the parameters that showed significant differences between the groups, identified BMI, lumbar lordosis and head position or BMI, head position and thoracic kyphosis as the parameters most important in the prediction of the low back pain group. The influence of thoracic kyphosis was confounded by its correlation with lumbar lordosis; it did not add any more predictive power than that obtained with lumbar lordosis but was strongly correlated with the discriminant function. This analysis was only able to correctly classify 52.5% of the cases which was slightly higher than the classification rate by chance alone (33%). When all variables were included in the analysis leg length discrepancy was added to the prediction equations. This analysis improved the classification rate to 66.1%. A limitation of this analysis was the high number of variables included in the analysis for a study group of only 59 cases. Therefore, some postural parameters are important in the prediction of the low back pain group but there are other unidentified variables that are important and are required to improve the classification rate.

SITTING POSTURE

The results for the sitting postural profiles revealed two unique profiles (table 5.2). Individuals with acute low back pain had an increased thoracic kyphosis as compared to the control group. No other significant differences were found between groups to differentiate between the chronic and control groups.

Table 5.2 Sitting postural profiles.

	Group 1	Group 2	Group 3
Lumbar Lordosis	4°	6°	0°
Thoracic Kyphosis	36°	40°	32°
Head Position	48°	47°	49°
Shoulder Position	114°	115°	108°
Relative Shoulder Height	-2°	-1°	-1°

Shading represents values significantly different from the normal group.

As with the standing posture only a few parameters can be directly compared to previous research. No values for measurements of lumbar lordosis and thoracic kyphosis were found for the sitting position using similar techniques. Previous research has shown that the lumbar curve decreases in sitting compared to standing,[25,26] which was consistent with the lumbar curve data obtained; 19° to 0° for normals, 26° to 4° for group 1 and 23° to 6° for group 2. Head position results (49°) were comparable to those found by Braun (53°)[43] and Braun and Amundson (52°).[41] Shoulder position results (108°) were similar to those found by Braun (111°)[43] but slightly higher than those found by Braun and Amundson (99°).[41] Considering the high standard deviation reported for these measures this was not likely a significantly different result. Finally, since the relative shoulder height was calculated differently from that found in the literature[44] it was not comparable. Therefore, as much as can be determined, the normal control group used in this study was comparable to the normals found in other studies.

No previous research was found that investigated the sitting posture with respect to low back pain in a manner similar to this study so no direct comparisons are available. In sitting the only postural parameter which was significantly different between groups was an increased thoracic kyphosis in the acute pain group. There is more muscle activity in the upper lumbar and thoracic regions in sitting as compared to increased muscle activity in lower lumbar regions in standing.[26,85] This is a potential reason for the finding that there was no longer any significant difference in lumbar lordosis between groups while the thoracic kyphosis changes remained. Since sitting is a much more stable posture than standing, fewer postural aberrations were expected particularly when there were few individuals in the study population with disc disease which could result in increased pain in sitting. The sitting posture did not differ from standing with respect to correlations between head position and shoulder position or head position and lumbar lordosis; neither group had a significant correlation.

Each aspect of the spinal curve was influenced by adjacent aspects of the curve with at least a weak, significant correlation. This was consistent with the findings for the standing postural profile.

There was a strong, significant correlation between the sitting and standing parameters for thoracic kyphosis, head position, shoulder position, and relative shoulder height. The correlation between standing and sitting lumbar lordosis was weaker but remained significant. This could have been influenced by the sitting surface used[22,25,27,28] and the position thus adopted by the subjects which was standardized but was still potentially variable.

The linear discriminant analysis, using the parameters which showed significance, BMI and thoracic kyphosis, indicated that the two parameters had an equal contribution to the prediction of study group. As with the standing posture, this analysis had a classification rate of only 55.9%. When all the variables were included in the analysis relative shoulder height was added to the prediction equations but its addition did not improve the classification rate. Therefore, as found with the standing posture, some postural parameters were important in the prediction of the low back pain group but other factors must also have an important role in prediction of low back pain. Thoracic kyphosis was an important factor in both sitting and standing postures, while head position and lumbar lordosis were primarily important predictors in the standing posture. Body mass index was a non-posture parameter that was shown to be an indicator of the low back pain group in both sitting and standing postures. The study groups were equivalent with respect to the other non-posture variables so they were not used in this analysis.

ADDITIONAL ANALYSES

The univariate and multivariate analyses were also calculated using the study groups (25 chronic, 19 acute, 25 control) prior to group size equalization. The results of these analyses were not different from the findings as reported. Therefore, the equalization did not alter the overall study findings.

The results reported are based on the results of multiple ANOVA tests for each postural profile. There are two different methods of correcting for repeated tests; a Bonferroni correction procedure and multivariate statistics such as linear discriminant analysis.[130] Since the Bonferroni correction is a very stringent correction when there is a small number of tests (7 standing, 5 sitting), multivariate statistics were chosen as the method of dealing with multiple tests. When the linear discriminant analyses were computed, the predictor variables identified were the same as the variables with significance using the ANOVA, lending support to the results of the ANOVA.

An analysis was also made to investigate low back pain with respect to clinical diagnosis rather than acute versus chronic. Those individuals with low back pain were categorized by clinical diagnosis. Significant differences were found by ANOVA testing in standing head position but a Tukey post-hoc analysis did not find a difference. Inspection of the data indicated a markedly forward head position for disc disease but this was based on a group size of only 5 cases. No significant differences were found between groups by an ANOVA test for the sitting posture. The linear discriminant analysis for standing used head position, leg length discrepancy and BMI as predictors but the classification rate was only 43.6%. Similarly, for the sitting posture the classification rate was only 46.2%, when BMI, head position, relative shoulder height and age were used as predictors. The classification rate by chance alone was 14%. This analysis was limited by the unequal group sizes and the small number of cases in some of the groups. Using study groups based on clinical diagnosis rather than acute versus chronic pain did not increase the value of postural parameters as predictors.

Another analysis was made to investigate the use of postural parameters in predicting low back pain in general as compared to the normal population. This analysis yielded a classification rate of 74.8% using BMI, lumbar lordosis, head position and leg length discrepancy as predictors of standing posture. A second analysis yielded a classification rate of 69.5% using BMI, thoracic kyphosis and shoulder position as predictors of sitting posture. For these analyses the classification rate by chance alone was 50%. Therefore, these postural parameters did not differentiate between low back pain in general and a control group any better than between the three study groups.

Throughout all the various analyses carried out for the standing posture BMI, head position, lumbar lordosis and leg length discrepancy were most often included in the discriminant function equation. Thoracic kyphosis was not included but this was a result of its correlation with lumbar lordosis. For the sitting posture BMI and thoracic kyphosis appeared in most of the various discriminant function equations with few extra additions. Therefore, those parameters deemed important predictors remained the same regardless of the method for discriminating groups; chronic versus acute versus control, clinical diagnosis categories, or low back pain versus control.

Finally, a subjective postural analysis was done. Six cases from each study group were randomly selected for analysis. The lateral standing posture was reviewed in rapid succession for each of the three groups. The only trend noted was that those from the chronic pain group appeared to have more exaggerated postural changes while those from the other two groups generally exhibited a straighter spine. There was no group specific consistency in the postural aberrations noted. Similarly, the lateral sitting posture was reviewed for each group in rapid succession. Overall, it was noted that a flatter spine was exhibited than that noted in the standing posture. No group specific trends were noted in sitting posture.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

Three major conclusions were reached based on the results of the preceding research project.

1. Discrete postural profiles existed for chronic pain, acute pain and normal control groups in the standing posture. The chronic pain group exhibited an increased lumbar lordosis as compared to the control group. The acute pain group exhibited an increased thoracic kyphosis and a forward head position as compared to the control group.
2. A discrete postural profile existed for the acute pain group in the sitting posture. The acute pain group had an increased thoracic kyphosis as compared to the control group. No further factors were found to discriminate between the chronic and control groups.
3. The postural parameters studied in this project were able to identify discrete postural profiles but they only had moderate value in the prediction of study group. Therefore other unidentified factors, postural and/or non-postural, are also important in the prediction of low back pain.

RECOMMENDATIONS

1. Posture is a factor that differs significantly in

individuals with low back pain but there are other factors yet to be identified that contribute to the prediction of low back pain. These unidentified factors may be postural parameters not included in this research and further investigation is required to identify them.

2. There is minimal normative data in the literature and further research, with larger samples, is required to accurately describe the normal posture.
3. This study showed that postural parameters are significantly different between low back pain groups. Additional investigation is required to determine whether treatment of posture can have an effect on low back pain.

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APPENDIX A

PILOT STUDY RESULTS

Prior to the commencement of data collection a pilot study was undertaken to check the feasibility of the data collection procedure and to clarify several issues identified at the proposal defense. The sample size for the pilot study was very small thus limiting the interpretation of the statistical results.

A) Photograph distortion: The measurement scale was photographed four separate times and the scale measured over nine different regions of the photograph. The average standard deviation was 0.05 cm. The results are listed in Table A.1.

B) Effect of visual fixation: Two photographs were taken of each subject in sitting and standing where the subject was requested to focus on a spot in their visual field for one photograph and did not use visual fixation for the other. In standing, only the measurement of pelvic tilt showed a significant difference with and without visual fixation (Table A.2). In sitting, none of the measurements showed a significant difference (Table A.3).

Table A.1 Results of repeated measurements of the measurement scale to investigate photograph distortion. Means (cm) and standard deviations (Std Dev) are reported for measures of the same part of the scale on different photographs (Columns 1-4) and for measures of the various 20 cm blocks on the same photograph (Rows).

	1	2	3	4	Mean	Std Dev
Vert 1	4.6	4.6	4.7	4.5	4.60	0.08
Vert 40	9.3	9.3	9.3	9.4	9.33	0.05
Vert 3	4.6	4.6	4.7	4.6	4.63	0.05
Vert 4	4.6	4.7	4.8	4.7	4.70	0.08
Horiz 1	4.6	4.6	4.7	4.6	4.63	0.05
Horiz 2	4.7	4.7	4.7	4.8	4.72	0.05
Horiz 3	4.7	4.7	4.7	4.8	4.72	0.05
Horiz 4	4.7	4.7	4.7	4.6	4.68	0.05
Horiz 5	4.7	4.7	4.7	4.8	4.72	0.05
Mean	4.65	4.66	4.70	4.68		
Std Dev	0.05	0.05	0.05	0.10		

Table A.2 Effect of visual fixation in the standing position. The Pearson correlation coefficient and it's p value and the T test p values are reported for each of the postural parameters.

	Correlation	p=	T test p=	Sig	N
Lordosis	0.98	.003	.314	no sig diff	5
Kyphosis	0.97	.027	.664	no sig diff	4
Head Pos	0.64	.362	.595	no sig diff	4
Sh Pos	0.99	.011	.189	no sig diff	4
Sh Ht	0.76	.139	.591	no sig diff	5
Pelvis	0.79	.113	.048	* sig diff	5

Table A.3 Effect of visual fixation in the sitting position. The Pearson correlation coefficient and it's p value and the T test p values are reported for each of the postural parameters.

	Correlation	p=	T test p=	Sig	N
Lordosis	0.99	.003	.703	no sig diff	4
Kyphosis			.170	no sig diff	2
Head Pos			.500	no sig diff	2
Sh Pos			.295	no sig diff	2
Sh Ht	0.71	.289	.098	no sig diff	4

C) Effect of changes in plane: Subjects were measured in a position perpendicular or parallel to the camera and in a position at a slight angle to the camera. The measurement of shoulder position was affected significantly in both sitting and standing, and the measurement of relative shoulder height was significantly different in sitting when there was a change in the angle of the subject to the camera. These results are outlined in Table A.4 and Table A.5.

D) Reliability of measurements: Several photographs were measured and then remeasured at another time. The only measure which showed a significant difference in the measures between trials was lumbar lordosis in sitting. When investigated further there was only a 2.6° difference in the means of these two measures clinically. These results are reported in Tables A.6 and A.7.

When the same subject was photographed repeatedly from the lateral aspect, the results showed that the most variable measure was shoulder position but the measure had a standard deviation of less than 3° (Table A.8).

Table A.4 Effect of changes in plane in the standing position. The Pearson correlation coefficient and it's p value and the T test p values are reported for each of the postural parameters.

	Correlation	p=	T test p=	Sig	N
Lordosis	0.61	.271	.273	no sig diff	5
Kyphosis	0.77	.126	.755	no sig diff	5
Head Pos	-0.03	.964	.077	no sig diff	5
Sh Pos	0.95	.013	.000	* sig diff	5
Sh Ht	-0.61	.271	.378	no sig diff	5
Pelvis	0.17	.789	.469	no sig diff	5

Table A.5 Effect of changes in plane in the sitting position. The Pearson correlation coefficient and it's p value and the T test p values are reported for each of the postural parameters.

	Correlation	p=	T test p=	Sig	N
Lordosis	0.99	.012	.524	no sig diff	4
Kyphosis			.410	no sig diff	2
Head Pos			.111	no sig diff	2
Sh Pos			.021	* sig diff	2
Sh Ht	0.87	.130	.005	* sig diff	4

Table A.6 Reliability of the measurements in the standing position. The Pearson correlation coefficient and it's p value and the T test p values are reported for each of the postural parameters.

	Correlation	p=	T test p=	Sig	N
Lordosis	0.99	.008	.895	no sig diff	4
Kyphosis	0.98	.020	.731	no sig diff	4
Head Pos	-0.25	.840	.560	no sig diff	3
Sh Pos	0.89	.298	.150	no sig diff	3
Sh Ht	0.97	.032	.182	no sig diff	4

Table A.7 Reliability of the measurements in the sitting position. The Pearson correlation coefficient and it's p value and the T test p values are reported for each of the postural parameters.

	Correlation	p=	T test p=	Sig	N
Lordosis	0.97	.006	.037	* sig diff	5
Kyphosis	0.96	.008	.547	no sig diff	5
Head Pos	0.94	.020	.395	no sig diff	5
Sh Pos	0.99	.002	.160	no sig diff	5
Sh Ht	0.94	.019	.541	no sig diff	5

Table A.8 Repeated photographs in the standing position. Means (°) and standard deviations (Std Dev) are reported for lumbar lordosis, thoracic kyphosis, head position and shoulder position.

	Mean	Std Dev	N
Lordosis	30.2	1.5	6
Kyphosis	49.9	1.5	6
Head Pos	53.4	0.6	6
Shoulder Pos	140.8	2.8	6

E) Effect of marker replacement: Subjects were photographed in each position and then the markers were removed and replaced prior to a second photographic session. The only position in which there was a significant difference between measures was for lumbar lordosis in sitting. The chance of having the subject assume a different sitting position was high and therefore the second measurement was not necessarily of the same position. The results are reported in Tables A.9 and A.10.

One problem encountered during the photographic procedure was the blockage of the C_7 marker by long hair. This was remedied by making sure that long hair was pulled back and the length of the C_7 marker was known so that the point of skin contact could be calculated as necessary. The only other problem was difficulty in identifying the tragus of the ear on some slides, therefore the tragus of the ear was also marked with a dot for more accurate identification.

The following conclusions were drawn from the results of the pilot study. Photographic distortion was not a significant problem. Visual fixation may have an effect on posture and therefore the same protocol should be instituted for use with all subjects. Since a change in plane can effect head and shoulder measurements, semi-permanent tape lines were placed on the floor to ensure consistent subject and camera positioning. The only area of concern regarding the reliability of measurements with and without marker replacement was sitting lumbar lordosis. Due to the high probability of variation in sitting positions, standard instructions were developed to be used with all subjects with respect to the sitting position to adopt.

Table A.9 Effect of marker replacement in standing. The Pearson correlation coefficient and it's p value and the T test p values are reported for each of the postural parameters.

	Correlation	p=	T test p=	Sig	N
Lordosis	0.34	.579	.171	no sig diff	5
Kyphosis	0.86	.060	.361	no sig diff	5
Head Pos	0.87	.129	.339	no sig diff	4
Sh Pos	0.97	.027	.246	no sig diff	4
Sh Ht	0.44	.456	.519	no sig diff	5
Pelvis	0.78	.117	.921	no sig diff	5

Table A.10 Effect of marker replacement in sitting. The Pearson correlation coefficient and it's p value and the T test p values are reported for each of the postural parameters.

	Correlation	p=	T test p=	Sig	N
Lordosis	0.99	.009	.019	* sig diff	4
Kyphosis			.234	no sig diff	2
Head Pos			.205	no sig diff	2
Sh Pos			.234	no sig diff	2
Sh Ht	-0.82	.182	.293	no sig diff	4

APPENDIX B

INFORMATION SHEET FOR STUDY PARTICIPANTS

Information for Study Participants

I am conducting a study of posture occurring in individuals who are experiencing chronic or acute low back pain. If you have low back pain you may be eligible to participate in this study.

The study involves a one-time visit for assessment of your posture. All assessments will take place at Corbett Hall, University of Alberta at a mutually convenient time. Assessments will take approximately 45 minutes. Assessment will involve an interview with respect to general information (such as age, sex, occupation, injury), body measurements necessary for postural analysis and a number of photographs in standing and sitting postures. Markers will be taped directly to your skin in order to identify certain body points on the photographs. Therefore, in order for markers to be placed and measurements made you will be requested to wear only shorts or loose pants with no top (bras or bikini tops acceptable).

There are no known risks involved with this type of assessment. The measurements to be made will have little or no effect on your back pain. Your participation will help to clarify the complex issue surrounding low back pain and posture.

If you are willing to participate in this project or wish further information, please contact me at ________.

Thank you,

Heather Christie BMR(PT)
Master's Candidate

APPENDIX C

INFORMATION SHEET FOR FACILITIES

Information for Facilities

I am conducting a study of posture occurring in individuals who are experiencing chronic or acute low back pain. If you have patients with low back pain they may be eligible to participate in this study.

Participants in all groups will be in the 20-45 year age group. The following exclusion criteria will be used: diagnosis of 1) spondylolisthesis, 2) spondylolysis, 3) myofascial pain syndrome, 4) sacroiliac joint problems, 5) osteoporosis, 6) scoliotic deformities, 7) pregnancy, 8) metabolic diseases and 9) neoplasm. In addition, individuals with a history of congenital deformities, spinal surgery, or recent general surgery (last 12 months) will be excluded.

The diagnostic categories to be included in the study are: degenerative disc disease with or without herniation, mechanical back pain (facet joint syndrome, muscular injury, ligamentous injury), or osteoarthritis of the back or neck.

If you have questions regarding this study please do not hesitate to contact me at ______. If you have eligible patients please provide them with the information sheets supplied to you.

Thank you,

Heather Christie BMR(PT)

APPENDIX D

SAMPLE SIZE CALCULATIONS

Sample Size Calculation[117]

With an alpha level of 0.05 and a study power of 0.80 (beta = 0.20).

$$n = \frac{L}{F^2} + k + 1$$

where $F^2 = \frac{r^2}{1-r^2} = \frac{0.20}{0.80} = 0.25$

(r^2 = variance declared significant = 0.20)

where k = # of variables = 9

where L = 15.65

$$n = \frac{15.65}{.25} + 9 + 1 = 72.6$$

Therefore, the appropriate sample size for 7 independent variables with the inclusion of 2 additional variables is 72.6. The target for this study will thus be 75 subjects (25 per group).

Revised Sample Size Calculation[117]

With an alpha level of 0.05 and a study power of 0.80 (beta = 0.20).

$$n = \frac{L}{F^2} + k + 1$$

where $F^2 = \frac{r^2}{1-r^2} = \frac{0.20}{0.80} = 0.25$

(r^2 = variance declared significant = 0.20)

where k = # of variables = 5

where L = 12.83

$$n = \frac{12.83}{.25} + 5 + 1 = 57.3$$

where k = # of variables = 6

where L = 13.62

$$n = \frac{13.62}{.25} + 6 + 1 = 61.5$$

Therefore, a sample size of 59 is appropriate for the use of 5-6 independent variables in the linear discriminant analysis.

APPENDIX E

DATA COLLECTION SHEETS

Data Collection Sheet

Subject Number: Study Group:

Age:
Sex: male ____ female ____

Occupation:

Diagnosis:
Pain Duration:
Vertebral level: L1 __ L2 __ L3 __ L4 __ L5 __ Other___
Mechanism of injury:

Dominant hand: right ____ left ____

Height:
Weight:

Leg length: right _______ left _______

Calliper measurement:

Visual analog scale completed: ______

Slides taken:	Standing	Sitting
anterior	________	_______
posterior	________	
lateral	________	_______

Raw Data Collection Sheet

Subject Number: Study Group:

Age:
Sex:

BMI:

Occupational Category: sedentary ____ light ____ medium __

heavy ____ very heavy _____

Pain Intensity: ____ mm
Pain Duration:

Diagnosis:
Vertebral level:
Mechanism of injury:

	Standing	Sitting
Lumbar lordosis (<L):	________	_______
Thoracic kyphosis (<T):	________	_______
Head position (<H):	________	_______
Shoulder position (<S):	________	_______
Relative shoulder height (<R): (dominant hand ___)	________	_______

Pelvic tilt:

callipers (A) =

ASIS = PSIS = height (B) =

θ =

Leg length discrepancy = _____ cm

APPENDIX F

CONSENT FORM

Consent Form

Title: Postural Aberrations in Low Back Pain

Investigators: Heather Christie, BMR(PT)　Phone:_______
Dr. S. Kumar

Purpose: The purpose of this research project will be to investigate standing and sitting postures in individuals with low back pain in comparison with individuals having no pain. You will be interviewed regarding general information and your low back injury/pain. Following this, body measurements necessary for postural analysis will be made and five photographs in sitting and standing will be taken. There are no known risks associated with this assessment and the measurements will have little or no effect on your back pain or pathology. Your participation may contribute to a better understanding of the relationship between posture and low back pain.

Consent:

I, ____________________, agree to participate in the above named project.

I understand that my participation is voluntary. I may refuse to answer any questions and may withdraw from the study at any time without consequence. I have read and understand the information sheet provided. I have been given the opportunity to ask questions and they have been answered to my satisfaction.

I understand that all information will be treated confidentially and my name will not be associated with any reports or publications arising from this study. Any photographs will be adjusted so that I cannot be identified prior to public use.

____________________	____________________
Participant's signature	Investigator's signature
______________	______________
Date	Date

APPENDIX G

RAW DATA

Table G.1 Demographic data. Group (1 = chronic, 2 = acute, 3 = control), Age (years), Sex (F = female, M = male), BMI (kg/m^2) and Occupational Category are reported.

Subject	Group	Age	Sex	BMI	Occupational Category
1	1	38.9	F	19.6	Light
5	1	34.8	M	22.5	Light
6	1	18.9	F	20.8	Sedentary
8	1	21.1	M	23.6	Light
9	1	33.5	F	21.7	Light
11	1	29.1	M	23.0	Light
12	1	31.3	F	21.1	Light
13	1	18.4	F	26.3	Light
14	1	37.9	M	25.0	Sedentary
15	1	27.2	F	32.6	Sedentary
17	1	28.5	F	26.4	Medium
18	1	28.5	M	26.1	Sedentary
19	1	40.6	M	24.6	Light
22	1	32.7	M	24.4	Light
23	1	25.0	M	24.3	Sedentary
24	1	23.1	M	22.4	Sedentary
26	1	24.7	M	24.3	Light
27	1	26.0	M	28.4	Light
30	1	32.0	M	25.9	Light
31	1	26.6	F	30.9	Sedentary
2	2	45.1	F	27.6	Medium
3	2	33.8	M	25.7	Light
4	2	31.2	M	20.8	Medium
16	2	32.2	F	23.9	Light
25	2	46.7	M	24.3	Heavy
28	2	40.7	F	25.6	Sedentary

Subject	Group	Age	Sex	BMI	Occupational Category
33	2	23.5	M	28.7	Sedentary
37	2	26.2	M	27.5	Light
44	2	25.3	M	22.3	Light
45	2	21.7	M	23.7	Medium
50	2	21.6	F	23.9	Light
55	2	33.2	M	27.7	Light
60	2	30.6	F	21.5	Light
62	2	23.1	F	25.4	Medium
64	2	26.7	F	23.6	Light
65	2	29.2	M	33.9	Sedentary
66	2	40.1	M	27.9	Heavy
68	2	39.5	M	37.3	Medium
75	2	27.0	F	20.8	Light
29	3	21.1	F	22.1	Light
38	3	23.5	F	21.7	Sedentary
39	3	21.1	F	19.4	Light
40	3	20.8	F	17.9	Light
41	3	35.6	M	23.9	Sedentary
42	3	30.9	M	23.0	Light
43	3	21.6	F	25.8	Light
46	3	22.1	M	26.1	Very Heavy
47	3	24.1	M	24.0	Light
48	3	21.7	F	19.7	Light
49	3	18.4	F	22.3	Light
51	3	37.5	F	21.2	Sedentary
53	3	34.1	F	23.2	Light
56	3	28.6	M	27.9	Medium
57	3	28.9	M	22.3	Medium

Subject	Group	Age	Sex	BMI	Occupational Category
58	3	31.2	M	24.8	Light
59	3	29.5	F	23.3	Light
61	3	28.1	F	22.3	Sedentary
63	3	27.2	F	22.1	Light
67	3	37.0	F	23.3	Light

Table G.2 Raw data for pain group descriptive variables. Group (1=chronic, 2=control, 3=acute), Diagnosis (1=Musculoligamentous, 2=Facet joint syndrome, 3=Osteoarthritis, 4=Nerve root irritation, 5=Disc disease, 6=Vertebral fractures, 7=Mechanical problems), Pain intensity (mm), Pain duration (years), Vertebral level of pain (1=Upper lumbar L_1-L_3, 2=Lower lumbar L_3-L_5, 3=Total lumbar L_1-L_5, 4=Other), and Mechanism(mech) of injury (1=Insidious onset, 2=Twisting, 3=Twisting and bending, 4=Twisting and lifting, 5=lifting, 6=fall from height, 7=Stretching, 8=Post motor vehicle accident, 9=Whiplash, 10=Extension injury, 11=Repetitive trauma) are reported for subjects in the chronic and acute pain groups.

Subj	Group	Diagnosis	Pain Intensity	Pain Duration	Level of Pain	Mech of Injury
1	1	1	22	2.0	2	1
5	1	2	1	17.0	2	1
6	1	1	18	2.5	2	1
8	1	1	21	2.5	3	1
9	1	1	10	3.0	2	1
11	1	1	4	10.0	2	1
12	1	1	25	15.0	2	1
13	1	7	0	3.0	2	1
14	1	6	72	14.0	2	6
15	1	7	5	13.0	4	1
17	1	4	0	2.0	2	4
18	1	5	7	6.0	2	4
19	1	7	0	16.0	2	5
22	1	5	7	9.0	2	7
23	1	1	21	7.0	2	8
24	1	1	5	8.0	2	1
26	1	7	0	6.0	1	1
27	1	2	0	12.0	2	10
30	1	7	39	8.0	1	11
31	1	1	20	4.0	2	9

Subj	Group	Diagnosis	Pain Intensity	Pain Duration	Level of Pain	Mech of Injury
2	2	1	77	0.2	4	2
3	2	5	44	0.5	2	2
4	2	1	1	0.2	2	1
16	2	1	48	0.4	2	1
25	2	4	60	0.2	2	1
28	2	7	5	0.1	2	1
33	2	2	0	0.5	2	1
37	2	1	18	0	2	3
44	2	1	0	0.5	2	1
45	2	1	23	0.1	3	5
50	2	1	0	0	2	8
55	2	7	0	0.3	2	1
60	2	7	0	0.5	4	1
62	2	5	18	0.3	2	11
64	2	7	0	0.5	2	1
65	2	7	0	0.2	2	1
66	2	1	26	0	2	5
68	2	5	43	0.6	2	10
75	2	1	0	0.5	1	1

Table G.3 Raw data for standing postural parameters. Group (1=chronic, 2=acute, 3=control), Lumbar lordosis (L in °), Thoracic kyphosis (T in °), Head position (H in °), Shoulder position (S in °), Relative shoulder height (R in °), Pelvic tilt (Pelvis in °), and Leg length discrepancy (LL in cm) are reported.

Subject	Group	L	T	H	S	R	Pelvis	LL
1	1	42.5	53.0	52.5	150.0	-3.0	33.6	0
5	1	20.5	41.5	52.0	100.0	-4.0	11.3	1.0
6	1	22.5	42.0	42.5	113.5	1.0	16.0	0.5
8	1	27.5	46.0	47.5	127.0	-1.5	4.9	0
9	1	28.0	43.5	50.0	113.5	-2.0	12.2	0.5
11	1	31.0	38.5	60.5	124.0	1.5	4.0	1.0
12	1	21.5	44.5	47.0	89.5	-1.0	0	1.5
13	1	31.5	33.5	50.5	118.0	-2.0	21.8	0.5
14	1	24.0	48.5	57.5	102.5	0	14.5	1.5
15	1	35.0	65.0	47.0	127.5	0	-2.3	0
17	1	26.5	37.5	53.5	118.0	-4.5	4.7	0.5
18	1	20.5	47.5	43.0	130.0	0.5	23.5	0.5
19	1	17.5	34.5	54.0	121.0	-1.5	14.8	0.5
22	1	17.5	54.0	38.0	88.5	-1.5	18.0	1.0
23	1	15.0	30.0	60.0	90.0	-1.5	8.0	0.5
24	1	18.5	41.0	52.5	95.0	-1.5	12.7	1.5
26	1	23.5	43.0	54.5	130.0	-2.5	8.4	0.8
27	1	35.5	46.5	57.0	103.5	0	17.8	0.2
30	1	19.5	46.0	58.5	105.5	0	8.9	0
31	1	50.0	66.0	44.5	115.5	1.0	23.3	0.5
2	2	22.0	41.0	51.0	135.5	2.0	11.9	0.5
3	2	22.5	45.0	40.5	121.0	-1.5	13.3	0.5
4	2	24.0	58.5	52.0	90.0	1.5	15.7	1.5
16	2	31.0	43.0	52.5	144.0	-2.5	15.8	0
25	2	10.0	32.0	56.0	75.0	-1.0	14.5	1.0

Subject	Group	L	T	H	S	R	Pelvis	LL
28	2	24.5	41.0	54.5	104.0	1.5	-0.7	0.2
33	2	22.5	50.5	44.5	85.5	0.5	14.4	0.5
37	2	3.5	42.5	45.0	105.0	0	6.0	0.2
44	2	22.5	51.0	59.0	61.5	0	1.1	0
45	2	15.5	41.5	47.5	127.5	-2.5	10.8	0.8
50	2	26.5	49.0	52.0	86.0	-4.0	11.4	0.1
55	2	26.0	59.5	51.0	94.5	0	9.8	0.1
60	2	18.0	36.5	52.0	130.0	-2.0	0	0.1
62	2	31.5	56.5	49.5	122.0	-2.5	9.3	0
64	2	26.0	45.0	50.0	114.0	1.5	13.5	0
65	2	23.5	61.5	40.5	96.0	0	8.8	0.2
66	2	40.0	62.0	40.0	101.5	-1.0	18.0	0.3
68	2	22.5	51.5	44.0	155.5	-2.0	22.9	0.7
75	2	17.0	32.5	51.0	107.5	-3.0	15.8	0.2
29	3	32.5	39.0	53.0	102.0	0	2.6	1.5
38	3	26.0	34.5	52.0	107.5	-2.5	31.9	0.5
39	3	27.5	33.5	56.0	90.5	0	10.8	0.5
40	3	22.5	38.0	52.5	64.0	-0.5	10.0	1.0
41	3	8.5	30.0	52.0	87.0	-6.5	-9.2	0
42	3	18.0	27.0	53.0	117.0	0	8.5	0.3
43	3	12.0	41.5	52.5	88.0	-3.0	14.7	0
46	3	21.0	37.5	60.5	121.0	-4.5	11.5	0.2
47	3	27.0	43.0	56.0	104.0	0.5	15.7	0.3
48	3	10.5	25.0	59.0	127.5	-2.5	9.2	0.5
49	3	11.0	41.0	54.0	113.0	-2.0	14.7	0.2
51	3	28.5	56.5	49.5	111.0	-1.5	15.8	0.4
53	3	8.5	27.5	52.0	103.0	-1.5	5.2	0.3
56	3	37.5	61.0	55.0	122.0	1.5	10.1	0.2

Subject	Group	L	T	H	S	R	Pelvis	LL
57	3	12.0	41.0	54.5	112.0	-1.0	6.3	0.1
58	3	12.0	33.0	56.0	109.0	-1.5	5.1	0.2
59	3	8.0	46.0	48.5	106.0	-2.0	-2.9	1.0
61	3	30.0	55.5	50.5	83.5	-1.5	21.4	0.7
63	3	21.5	46.0	53.0	106.5	1.0	23.2	0.3
67	3	12.0	34.5	50.0	106.5	-0.5	9.0	0

Table G.4 Raw data for sitting postural parameters. Group (1=chronic, 2=acute, 3=control), Lumbar lordosis (L in °), Thoracic kyphosis (T in °), Head position (H in °), Shoulder position (S in °), and Relative shoulder height (R in °) are reported.

Subject	Group	L	T	H	S	R
1	1	0.5	49.5	48.5	141.0	-3.0
5	1	7.0	26.0	46.0	118.5	-3.5
6	1	4.0	32.0	38.5	110.0	-2.5
8	1	2.0	35.0	45.0	121.5	-2.5
9	1	-4.5	33.5	46.5	109.5	-2.5
11	1	9.0	26.0	59.0	103.5	0
12	1	-5.0	38.0	41.5	94.5	-1.0
13	1	3.5	25.0	50.5	115.5	-2.0
14	1	4.0	39.5	49.5	101.5	-1.5
15	1	15.5	59.5	50.0	124.5	-1.0
17	1	8.5	32.5	47.0	117.0	-4.0
18	1	9.5	41.0	41.0	122.0	1.0
19	1	5.5	25.0	51.0	115.5	-2.0
22	1	0	38.0	41.5	91.0	-4.0
23	1	-10.0	21.5	57.0	107.5	0
24	1	0	30.0	48.5	103.0	-3.5
26	1	12.5	43.0	45.5	119.5	-2.0
27	1	-4.5	26.5	60.0	127.0	-2.0
30	1	-15.5	35.5	47.0	126.0	-1.0
31	1	30.5	58.5	44.0	110.0	1.5
2	2	10.0	34.5	49.5	133.0	4.5
3	2	14.0	53.0	42.5	100.0	-3.5
4	2	6.5	47.5	53.5	119.0	1.5
16	2	21.0	41.0	47.0	119.5	0
25	2	3.0	33.0	55.0	108.5	-1.5

Subject	Group	L	T	H	S	R
28	2	11.5	40.5	57.5	112.0	3.0
33	2	3.5	41.5	45.5	106.0	0.5
37	2	-8.5	33.0	42.5	118.0	-1.0
44	2	-15.0	38.5	46.5	70.5	-1.5
45	2	0	32.0	42.5	131.5	-1.5
50	2	9.0	36.5	50.0	99.5	-2.0
55	2	1.5	43.5	52.0	95.0	-2.0
60	2	5.0	35.0	58.0	130.5	-1.0
62	2	14.5	52.0	47.0	111.5	-1.0
64	2	4.5	34.0	45.0	119.0	1.0
65	2	2.5	42.5	38.5	131.5	2.0
66	2	12.0	53.0	35.5	117.0	-1.5
68	2	9.0	44.5	38.0	157.0	-2.5
75	2	11.5	22.5	54.0	113.0	-4.0
29	3	-2.5	35.5	46.0	103.5	-1.5
38	3	6.0	32.0	50.5	88.5	-2.5
39	3	-10.5	19.5	52.0	96.5	0
40	3	2.5	42.0	46.0	86.0	0
41	3	-3.5	27.5	46.0	101.0	-6.5
42	3	1.0	27.0	53.0	124.5	0
43	3	0	33.5	45.0	97.0	-3.0
46	3	-10.5	21.0	52.0	128.0	0.5
47	3	7.0	31.0	52.0	107.5	-1.0
48	3	-1.0	19.5	55.5	118.0	0
49	3	-2.5	32.5	49.0	116.5	-2.5
51	3	1.0	38.5	48.0	133.0	0.5
53	3	-3.5	20.5	49.0	104.0	-3.5
56	3	17.5	46.0	54.5	114.5	1.5

Subject	Group	L	T	H	S	R
57	3	-3.5	34.5	43.0	104.5	-0.5
58	3	7.0	34.0	54.5	114.0	-3.0
59	3	0.5	34.5	46.0	108.5	-2.0
61	3	0.5	42.0	45.0	101.0	-2.0
63	3	-5.0	33.0	48.0	105.5	0
67	3	6.0	27.5	49.0	97.5	-2.0