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THE EFFECT OF WHIPLASH INJURY ON THE THORACIC SPINE

BY

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DEDICATJON

This work is dedicated with love and gratitude to all my family and friends who gave me the encouragement and support I needed to realize this goal.

ABSTRACT

Whiplash injury is a frequent cause of pain and dysfunction of the cervical spine. Although there is evidence to indicate involvement of the thoracic spine as well, the effect of whiplash injury on thoracic function has not been investigated.

The purpose of this study was to compare the pain and movement of the thoracic spine of whiplash injured and healthy persons matched for gender and age. Thirty subjects in each group were tested on one occasion only, for pain on the McGill Pain Questionnaire (MPQ), pain threshold of the cervical and thoracic extensor, and tibialis anterior muscles, range of motion (ROM) of flexion/extension, rotation, and side flexion of the thoracic spine, and passive intervertebral movement (PIVM) of thoracic segments 1-8. T-tests and analyses of variance (ANOVA) were used to compare groups on these variables.

The whiplash injured subjects presented with significantly greater pain, and a greater number of motion segments demonstrating abnormal mobility, compared to the healthy subjects. Pain threshold was significantly lower for the whiplash injured group across all three sites assessed. Pain threshold of the tibialis anterior muscle was significantly greater than that of the thoracic muscles, which in turn was significantly greater than pain threshold of the cervical muscles. ROM was not different between groups. ROM in the horizontal plane was significantly greater than ROM in the sagittal and coronal planes.

Additional analyses evaluated gender and point of impact differences, and the relationship of each of the four dependent variables. There were no gender differences for the MPQ and PIVM. Female whiplash subjects demonstrated significantly lower thoracic pain threshold than male and female comparison subjects, and lower tibialis anterior pain threshold than male whiplash, and male and female comparison

subjects. Female whiplash subjects also had significantly less ROM than male whiplash subjects. There were no significant differences between front and rear-end collisions for any of the tests. Pearson product moment correlations revealed generally significant, but weak association between the MPQ, pain threshold, ROM, and PIVM. The results indicate that whiplash injury does have an effect on the thoracic spine, and further study is suggested.

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THE PROBLEM

Introduction

To date, the focus on whiplash injury and the assessment and treatment of whiplash syndrome have been related to the cervical spine; the mechanics, pathology, and cervical symptomatology of whiplash injury are well documented. However, there is a scarcity of information available in the literature on the effect of whiplash injury on the thoracic spine. Although a number of authors acknowledge that the upper back and chest wall may be involved in whiplash syndrome, there have been no studies that specifically question the role of thoracic spine dysfunction in whiplash syndrome.

If one considers that a significant percentage of persons who have received treatment for their cervical problems continue to present with whiplash signs and symptoms greater than six months post-injury (Balla 1980; Braaf & Rosner 1958; Deans et al. 1987; Gay & Abbott 1953; Gargan & Bannister 1990; Greenfield & Ilfeld 1977; Hildingsson & Toolanen 1990; Hohl 1974; Macnab 1971; Radanov et al. 1991), it becomes apparent that there is a need for investigation of other factors that may be contributing to the persistence of the signs and symptoms. Greenfield and Ilfeld (1977) claimed that the best indicators of poor recovery of whiplash syndrome are upper thoracic and interscapular pain. There are a number of anatomical and biomechanical reasons why whiplash injury could affect the thoracic spine and contribute to whiplash syndrome.

Maiman & Pintar (1992) stated that when a load is applied through the pelvis, as in a motor vehicle accident, flexion-compression loading of the thoracic spine occurs. The bending moment which develops as a result of the spinal loading depends on the length of the spinal column, and the distance between the centrum of the column and a vertical line extended from the load point. The greater the amount of flexion that takes place, the greater the loading force on the spine, and the greater the potential injury to the thoracic spine.

Croft (1988) suggested that a slack shoulder harness may result in greater injury to the thoracic, cervical, and lumbar spines, by permitting greater forward momentum to occur relative to the seat back. In addition, the diagonal orientation of the seatbelt acts as a pivot point about which the trunk rotates when it contacts the strap. Croft (1988) stated that the rotational component may significantly increase the severity of the whiplash injury.

Many of the muscles and ligaments that are damaged in whiplash injury have extensive attachments to the thoracic spine. The splenius capitis and cervicis muscles, for example, were found to be the muscles most strained during the flexion phase of a whiplash injury (Deng & Goldsmith 1987; Luo & Goldsmith 1991). Another consideration is that the areas of greatest curvature of the cervical and the lumbar spines (C4/C5 and L3/L4 respectively) are the levels that demonstrate the greatest change in disc pressure during whiplash injury (Deng & Goldsmith 1987; Luo & Goldsmith 1991). It is possible that the T7/T8 level, being the apex of the thoracic spine might also be subject to a significant amount of stress (White & Panjabi 1990). The T7/T8 segment has also been identified as the level of transition of functional rotation between the upper body and the lower body (Gregerson & Lucas 1967), and so may further increase the amount of stress on the mid-thoracic spine during a whiplash injury. Dommisse (1974) identified the T4-T9 region as being a "critical vascular zone of the spinal cord". He suggested that the cord is at high risk for damage following trauma. Finally, the sympathetic trunk of the autonomic nervous system is anatomically related to the thoracic spine, being situated just anterior to the costovertebral joints.

In their study of the reaction of the human head, neck, and torso to sudden impact forces, Luo and Goldsmith (1991) stated that the forces acting on the thoracic region were found to be small compared to those acting on the head and low back. They concluded that only minor injuries to this area are likely. Despite this conclusion, authors (Braaf & Rosner 1958; Bring and Westman 1991; Gay & Abbott 1953; Greenfield & Ilfeld 1977; Hohl 1974; Macnab 1971; Maimaris et al. 1988) make numerous references to complaints of interscapular, upper back, and anterior chest pain following whiplash injury. Although these symptoms are often assumed to be referred pain from the cervical spine, they are just as likely to be local or referred symptoms from the thoracic spine. Bower (1986) stated that pathological lesions following whiplash injury can include the thoracic area in addition to the cervical and lumbar spines, and he suggested that scapular pain and anterior chest pain can be produced by injury of thoracic joints, muscles, or discs.

Feinstein's (1977) studies on referred pain support the above statement. Stimulation of the paravertebral muscles of the segmental levels C7-T5 resulted in pain and tenderness around the scapular region, while stimulation of segments T4-T9 referred pain to the posterior, lateral, and anterior aspects of the chest wall. Autonomic reactions were commonly demonstrated with thoracic segmental stimulation, but were relatively rare with stimulation of the cervical and lumbar segments. The autonomic reactions included sweating, bradycardia, pallor, and feelings of nausea and faintness. All of these symptoms have been associated with whiplash syndrome (Braaf & Rosner 1958).

More direct citations of thoracic involvement have been made by Gargan and Bannister (1990) who stated that 42% of their sample had thoracic or lumbar backache at follow-up assessment (8-12 years post-injury), and Hildingsson and Toolanen (1990) who reported that 12% of their group had tenderness of the thoracic vertebrae at re-assessment (6 months to 3 1/2 years post injury). Neither of these studies provided specific information with regard to whether thoracic function was affected, or which area of the thoracic spine was involved. Bring and Westman (1991) indicated that more than half of their subjects (N=22) complained of pain and tenderness in the chest and ribs. Ten of the subjects also demonstrated a "jump reaction" to palpation of the upper thoracic spine.

Objectives of the Study

At the present time it is not known whether whiplash injury does in fact affect thoracic function, or what the signs and symptoms of thoracic whiplash syndrome are. The primary objective of this study was to determine if there are differences in the measures of upper and middle thoracic spine function in whiplash injured persons, compared to the findings in non-whiplash injured persons. Thoracic spine function was measured with regard to four variables: pain, paravertebral muscle tenderness, active range of motion with passive overpressure (ROM), and passive intervertebral joint mobility (PIVM).

It was necessary to assess non-injured persons, in addition to whiplash-injured persons, because normative data on thoracic spine function is virtually non-existent. The results of testing injured and non-injured subjects could then be compared to determine if there was a significant thoracic spine dysfunction in the injured group.

Research Hypothesis

The research hypothesis of this study was that there would be differences between the whiplash injured group and the non-injured group with regard to each of the four dependent variables being measured. It was expected that, compared to the non-injured group, persons who sustained a whiplash injury would have:

a. greater pain in the upper and middle back, and/or along the anterior or lateral aspects of the chest wall.

b. greater muscle tenderness of the paravertebral muscles of the neck, and upper and middle thoracic spine (T1-T8), but equal tenderness of the tibialis anterior muscles.

c. less ROM of combined flexion and extension, combined right and left axial rotation, and combined right and left side flexion of the T1-T8 levels.

d. a greater number of upper and middle thoracic motion segments demonstrating abnormal PIVM.

Significance of the Study

Little is known about the effect of whiplash injury on the thoracic spine, and its contribution to the presentation of whiplash syndrome. The present study, which assessed the effect of whiplash injury on the upper and middle thoracic spine, will provide new information to increase the knowledge base of whiplash injury, and will potentially benefit the medical care of persons who sustain whiplash injury.

Operational Definitions

Range of motion (ROM): Volitional movement of the thoracic spine in the sagittal, frontal, and horizontal planes, with the application of passive overpressure at the end of voluntary active movement. ROM is a test of functional mobility of the joints and soft tissues of the region being assessed.

Cohort (whiplash group): The group of subjects who were involved in a rear-end or front-end collision following the onset of this study, and subsequently evaluated with regard to measures of thoracic spine function.

Comparison group: The group of subjects who did not sustain a whiplash injury, and whose measures of thoracic function were compared to those of the cohort.

Motion segment: A 3-joint complex existing between two adjacent vertebrae. It consists of:

i) the cartilaginous joint between two consecutive vertebral bodies including the intervening intervertebral disc.

ii) the two synovial zygapophyseal joints formed by the inferior and superior articular facets of two consecutive vertebrae.

iii) the associated soft tissues (joint capsules, muscles, ligaments, nerves, dura, etc.) existing between the lower half of the superior vertebrae and the upper half of the subjacent vertebrae.

Pain threshold: The minimum pressure or force that produces discomfort (Fischer 1986a; Ohrbach & Gale 1989a, 1989b; Reeves et al. 1986). Pain threshold measurements (PTM) were used in this study to quantitatively document cervical and thoracic paravertebral, and tibialis anterior muscle tenderness.

Passive accessory movement: Passively induced glide of a specific joint. The accessory movement is part of the physiological movement of the joint, occurring perpendicular to the axis of the physiological motion, and parallel to the plane of the joint.

Passive intervertebral joint movement (PIVM): Passively induced physiological movement of a specific bone or body segment. Involves gross movement of the bone, as well as the associated accessory motion. The physiological movements assessed in this study included upper and middle thoracic flexion, extension, side flexion, and rotation.

Thoracic dysfunction: Greater thoracic pain and upper and middle thoracic paravertebral muscle tenderness, less ROM, and a greater number of upper and middle thoracic spine motion segments exhibiting abnormal PIVM, relative to the comparison group.

Thoracic pain: Pain occurring in the truncal region from the base of the neck to the inferior costal border posteriorly, and/or along the lateral or anterior aspects of the chest wall.

Whiplash injury: The mechanism of injury. For the purposes of this study, the term whiplash injury refers to a flexion/extension injury of the spine incurred in a rear-end or front-end motor vehicle collision.

Whiplash syndrome: The multitude of signs and symptoms that present as a result of a whiplash injury.

Delimitations

This study was delimited to:

1. Testing persons of the greater Edmonton area who had been involved in a rear-end or front-end collision within the previous three months, or who had not sustained a whiplash injury.
2. Male and female subjects between 16 and 46 years of age.
3. The evaluation of upper and middle thoracic function by measuring:
   a) thoracic pain using the McGill Pain Questionnaire (Melzack 1975).
   b) paravertebral muscle tenderness using a pressure threshold meter.
   c) ROM in the sagittal, frontal, and horizontal planes using OB (Myrin) goniometers.
   d) PIVM of flexion, extension, side flexion, rotation, and posterior/anterior accessory glides using Maitland's (1986) manual assessment techniques of

physiological and accessory joint motion.

Limitations

This study was limited by:

1. The validity and reliability of the measurement instruments used to evaluate thoracic function.
2. The intra-rater reliability of the tester in using the measurement instruments to evaluate pain threshold, ROM, and PIVM of the upper and middle thoracic spine.
3. The inability to blind the principal investigator with regard to whether subjects were members of the whiplash or comparison group.
4. The variability of treatment (medical, physiotherapy, chiropractic, medications, etc.) received by the whiplash subjects following the whiplash injury, and prior to their participation in the present study.

CHAPTER TWO
REVIEW OF THE LITERATURE

This chapter addresses four main topics of concern to this study: whiplash injury, the thoracic spine, measurement of pain, and measurement of spinal mobility. The discussion of each of these topics is limited to its relevance to the present study.

Whiplash injury is discussed with regard to the mechanics, pathology, and symptomatology of this condition. The section on the thoracic spine briefly describes the relevant anatomy and biomechanics of the region. In the pain measurement section a commonly accepted definition of pain is presented, and the MPQ and the pressure threshold meter are discussed as tools of pain measurement. Finally, a variety of methods used to measure spinal mobility are mentioned, followed by a more detailed discussion of the OB (Myrin) goniometer and manual therapy.

Whiplash Injury

Whiplash injury to the spine is a major concern of any society in which motor vehicles are a primary mode of transportation. In Alberta in 1991 there were 98,535 reported motor vehicle accidents (Alberta Transportation and Utilities 1993). Accidents categorized as non-fatal injury collisions numbered 13,646 (13.8%), and resulted in 19,646 injured persons. Of the non-fatal injury collisions in Alberta, 9965 (73%) occurred in an urban environment; 21% involved rear-end impacts, 59.2% were the result of frontal impacts, and 18.2% were side-impact and roll-overs.

The significance of the above figures is appreciated when the potential costs to the health care system, the medico-legal system, and potential costs of lost work time are considered, not to mention loss of quality of life as a result of functional disability. Although specific figures for Canada are not available in the reported literature, a report to the United States Congress in October, 1989 entitled "Cost of Injury in the United States" detailed the following information (Faigin 1991). In the United States in 1985, motor vehicle accidents were the leading cause of fatal injuries, the second leading cause of non-fatal injuries, and the single most costly type of injury. Injuries from motor vehicle accidents were estimated to cost almost $49 billion total. Cost estimates included medical costs, emergency services, nursing home care, rehabilitation, home modifications, insurance administration costs, and losses in productivity due to mortality and morbidity. When loss of quality of life benefits were taken into account, estimates of cost per injured person ranged from $55,000 for a moderately severe non-fatal injury, to greater than $2,000,000 for a fatally injured person.

The Mechanics of Whiplash Injury. The majority of motor vehicle accidents involve front-end impacts, but it is widely accepted that the majority (46-90%) of cases of whiplash syndrome arise from rear-end collisions (Balla 1980; Deans et al. 1987; Gargan & Bannister 1990; Hildingsson & Toolanen 1990; Hohl 1974; Maimaris et al. 1988; Norris & Watt 1983; Randanov et al. 1991). Macnab (1971) defined whiplash injury in terms of a rear-end collision only. However, several authors have acknowledged the development of whiplash syndrome from other mechanisms as well. Severy et al. (1955), and Deng and Goldsmith (1987) described in detail the two most common mechanisms of whiplash injury; sudden acceleration followed by deceleration when the force of impact is from the rear, and sudden deceleration/acceleration when the force of impact is from the front.

On impact from the rear the front car is accelerated forward. After a short delay the occupant's torso, which is in contact with the car seat, accelerates forward underneath the relatively stationary head and neck. The head and neck are generally not in contact with the vehicle unless the head restraint is being used properly. The sudden changes in rate of movement subject the spine to significant axial loading forces; the greater the change in gravity forces, the greater the loading force (Willen et al. 1984). The acceleration forces are transmitted from the torso through the neck, and when the neck muscles become fully stretched the head hyperextends. As the acceleration of the vehicle decreases and the inertia of the head is overcome, the head then accelerates forward relative to the shoulders and trunk, rebounding into flexion before returning to a neutral position. When the point of the impact is from the front the sequence of events is reversed (Bocchi & Orso 1983).

Flexion of the head is limited by the chin coming into contact with the anterior chest wall. In persons with normal neck mobility this motion is within normal physiological neck range of motion. Extension of the head on the neck is limited by the occiput contacting the posterior chest wall. This movement is beyond the normal physiological range of motion; therefore the potential for tissue damage in the neck is much greater with the extension phase of whiplash injury than with the flexion phase (Bocchi & Orso 1983; Gay & Abbott 1953; Macnab 1971; Severy et al. 1955).

Other factors which have been found to influence the severity of the whiplash injury include the size and type of the cars involved, the speed of contact between the two cars, use of seatbelts and the type of seatbelt used, use of head restraints, position in the car, and human body variations (Deng & Goldsmith 1987; Luo & Goldmsith 1991; Severy et al. 1955).

<u>The Pathology of Whiplash Syndrome</u>. Macnab (1964) examined

the pathologic changes in monkeys due to hyperextension of the head and neck induced by a whiplash injury. He determined that the following lesions could occur during the extension phase of the trauma as a result of tension on the anterior structures, and compression of the posterior structures of the neck: minor to severe muscle tears; retropharyngeal haematoma; damage to the cervical plexus; tearing of the anterior longitudinal ligament; separation of the disc from the vertebra; damage to the posterior cervical joints (capsular sprains or tears, fractures, dislocations); and disc herniation. Various types of vertebral fractures may also result from hyperextension injuries (Kettner & Guebert 1991).

During the flexion phase the posterior structures are subjected to tension forces, and the anterior structures to compression forces. Posterior neck muscles may be strained, vertebral bodies compressed and fractured, posterior spinal ligaments strained or torn, posterior joint capsules strained or torn, the tips of the spinous processes avulsed (Bocchi & Orso 1983; Kettner & Guebert 1991), intervertebral discs disrupted, and facet joints subluxed bilaterally (Kettner & Guebert 1991).

Maiman et al. (1986), subjected intact cadaver and spinal column specimens to flexion-compression loads similar to the type of load force that occurs during the flexion phase of a whiplash injury. Their studies consistently demonstrated the following damage to thoracic spine structures: disruption of the posterior elements, followed by vertebral fractures, and then injury to the posterior disc and posterior longitudinal ligament.

Twomey and Taylor (1993) examined the cervical spines of 16 subjects who were involved in fatal motor vehicle accidents. The types of injuries noted were: clefts in the cartilage plates and the annulus fibrosus of the vertebral disc; disc ruptures with posterior herniation; blood within the outer layers of the annulus fibrosus; and haemarthrosis and capsular/synovial tears of the facet joints. None of the control specimens in their study demonstrated the same pathological changes.

Pennie and Agambar (1991) stated that the variability of factors in any motor vehicle accident makes it impossible to anticipate which segmental levels of the spine, and which related structures are going to be injured.

The Symptomatology of Whiplash Syndrome. Assessment of persons following whiplash injury generally includes an interview to determine the patient's medical history, the details of the accident, and the patient's symptoms. The physical examination usually consists of assessment of active range of motion, manual palpation for tenderness and muscle spasm, a basic neurological examination, and x-rays of the spine. It most often focuses on the cervical region, but occasionally includes the lower back. The thoracic spine is generally overlooked.

The onset of symptoms varies. However, 87-94% of persons who develop whiplash syndrome experience signs and symptoms within 24 hours of the accident (Braff & Rosner 1958; Deans et al. 1987; Greenfield & Ilfeld 1977; Hildingsson & Toolanen 1990; Maimaris et al. 1988).

Due to the fact that pathological lesions may occur at multiple levels of the spine, and that a variety of structures may be damaged in these different regions, there are a multitude of signs and symptoms associated with whiplash injuries (Bower 1986). The most common complaint of persons who are subjected to a whiplash injury is neck pain. Deans et al. (1987) determined that 85% of the 137 patients they examined after motor vehicle accidents complained of neck pain, compared to a 7.2% prevalence of neck pain in the control group. Unfortunately, neck pain was the only variable compared between the two groups. No other studies have compared the prevalence of acute whiplash signs and symptoms between injured and control subjects.

Other common findings following whiplash injury are: radiating pain to the shoulders and down the arms; radiating pain to the interscapular region and chest wall; occipital headaches that may radiate to the temporal, vertex, and retro-orbital areas; numbness and paraesthesia of the ulnar border of the hand; blurring of vision; tinnitus; dizziness; decreased neck range of motion; and cervical muscle spasm and tenderness (Bocchi & Orso 1983; Braaf & Rosner 1958; Gay & Abbott 1953; Hildingsson & Toolanen 1990; Hohl 1974; Macnab 1971; Norris & Watt 1983). Gay and Abbott (1953) and Braaf and Rosner (1958) stated that signs and symptoms of jaw injury and low back injury are also common, and that psychosocial problems are frequently observed. Insomnia, irritability, and poor concentration are just a few of the psychogenic symptoms that may develop (Balla 1980; Braaf & Rosner 1958; Gay and Abbott 1953; Radanov et al. 1991).

Behavioral changes such as decreased participation in hobbies and recreational activities have been reported in 67-73% of persons with whiplash syndrome (Balla 1980; Maimaris et al. 1988; Norris & Watt 1983). Time off work ranged from no time off at all to inability to return to work. Balla (1980) found that the majority of his subjects were away from work for less than two months.

Whether or not there is any significant difference between males and females developing whiplash syndrome remains to be determined. Bring and Westman (1991), Bocchi & Orso (1983), Gay and Abbott (1953), and Macnab (1971) stated that females are more likely to develop signs and symptoms. Deans et al. (1987) and Larder et al. (1985) observed that although females tended to complain of neck pain and be diagnosed with neck injury more than males, the differences were not statistically significant.

"Late whiplash syndrome" has been defined by Balla

(1980) as a group of symptoms and disabilities which are present longer than six months after a whiplash injury. However, Maimaris et al. (1988) determined that signs and symptoms persisting for more than two months are indicative of prolonged disability. Their study of 102 whiplash injured patients demonstrated that two-thirds of their sample was asymptomatic at follow-up (two years post-injury), and 88% of these persons were symptom-free within two months of the accident.

"Late whiplash syndrome" is characterized by headache, neckache and stiffness, depression, and anxiety. Other signs and symptoms commonly associated with chronic whiplash syndrome include paraesthesia of the upper extremities, low back pain, dizziness, auditory problems, dysphagia, visual problems, decreased neck range of motion, muscle tenderness, and restricted participation in sports and recreational activities (Balla 1980; Bring & Westman 1991; Maimaris et al. 1988; Watkinson et al. 1991).

Worth (1991) utilized a functional x-ray, geometric measurement technique, and computer digitizer to assess cervical spinal mobility of chronic whiplash subjects and control subjects. Segmental mobility in the sagittal plane was evaluated by measuring cephalo-caudad and anterior-posterior translation of each cervical motion segment. The results indicated a significant difference of C1/2 and C3/4 mobility between the whiplash injured and control groups, even though plane x-rays were read as "normal".

Balla (1980) assessed the relationship between neck pain and stiffness, headache, arm pain, and cervical x-ray abnormalities, in chronic whiplash injured persons. There were very poor to moderate correlations ($r=.064-.585$) between most of these variables. However, a good correlation ($r=.773$) between neck pain and neck stiffness was indicated.

The reported percentage of persons with chronic whiplash syndrome varies between 20% and 45% of those who present with acute whiplash syndrome (Bocchi & Orso 1983; Braaf & Rosner 1958; Deans et al. 1987; Hohl 1974; Macnab 1971; Maimaris et al. 1988; Radanov et al. 1991). However, Hildingsson and Toolanen (1990), and Hodgson and Grundy (1989) reported that 58% and 62% of their subjects, respectively, continued to have problems years after their accident. Gargan and Bannister (1990) reported that 88% of their sample had persisting symptoms, although only 12% had severe problems.

Davis et al. (1991) and Twomey and Taylor (1993) suggested that chronic pain and dysfunction of the cervical spine following a whiplash injury may be due, in part, to multi-level trauma of the cervical discs which may be slow to heal. The delayed healing may lead to early degenerative changes. However, Hodgson and Grundy (1989) stated that the persisting signs and symptoms in the majority of whiplash injured subjects in their study did not change over time. Therefore, they concluded that secondary degenerative changes did not play a significant role in the chronicity of whiplash syndrome. They suggested that if they did, then symptoms would worsen over time.

Prognostic indicators of poor recovery have not yet been determined, but Greenfield and Ilfeld (1977) suggested that the best indicator of poor recovery of whiplash syndrome is the presence of upper thoracic and interscapular pain at initial assessment. They further suggested that these symptoms may be indicative of injury to structures of the upper thoracic spine or cervical vertebral discs.

<u>Anatomy and Biomechanics of the Thoracic Spine</u>

Spinal research has focused primarily on the cervical and lumbar regions, with comparatively little research being directed toward the thoracic spine. O'Gorman and Jull (1987) and Bogduk and Valencia (1988), suggested that the relative lack of attention to the thoracic spine is due to less frequent diagnosis of thoracic dysfunction and pain, relative to diagnoses of lumbar and cervical pain. However, thoracic pain syndromes are not uncommon in clinical practice (Lee 1993), and are becoming recognized with increasing frequency (Bogduk 1985).

The relative lack of information on the thoracic spine has resulted in clinicians examining and treating the thoracic spine based on suppositions and assumptions derived from studies of the lumbar and cervical spines (Bogduk & Valencia 1988). It is presumptuous to think that the thoracic spine is the same structurally and functionally as the cervical and lumbar regions, and that it can be examined and treated in the same manner. The research that has been done on the thoracic spine has demonstrated that there are significant differences in both the anatomy and biomechanics of the area compared to other regions of the spine.

In an attempt to learn more about this region it has been necessary to simplify the overall picture. Few studies have examined the thoracic spine and rib cage as an intact single unit, and even fewer investigations have been done in vivo. Therefore, it is important that caution be exercised when interpreting the results of studies, and when applying findings to the clinical environment.

The following discussion of thoracic anatomy was intended as a brief review of the major structures which comprise the thorax, and which may be injured as a result of whiplash trauma involving the thoracic spine.

The bony thorax consists of the sternum anteriorly, twelve ribs bilaterally, and twelve thoracic vertebrae posteriorly. Articulations include the intervertebral, zygapophyseal, costovertebral, costotransverse, costochondral, sternochondral, and interchondral joints. Although there are similarities in structure throughout the thoracic spine, differences are evident between the upper, middle, and lower regions (Gray 1977; Parke 1982; White & Panjabi 1990). These anatomical differences result in variable biomechanics (osteokinematics and arthrokinematics) between the different areas, and potentially could result in variable responses to whiplash injury.

The stability of the thoracic spine is due in large part to the well-developed neuromuscular system (White & Panjabi 1990). The numerous muscles attaching to the thoracic spine and rib cage are listed in Table 2.1. Not all of the muscles listed have their primary function in the thorax. However, each of them has a significant attachment in the area, and can therefore influence the mobility and stability of the region. Maiman and Pintar (1992) agreed that the muscles of the thorax improve stability during physiologic movements, but they stated that their protective role during trauma has not been well established.

In addition to muscles, numerous ligaments (Table 2.2) contribute significantly to stabilization of the area. The function of a specific ligament may be different during various movements of the spine, and even during a given movement, as the axis of rotation changes (Panjabi & White 1980. Panjabi and White (1980) stated that the functions of the ligaments are to both allow and limit movement between adjacent vertebrae. The mobility is necessary to attain the static and dynamic postures required in daily activities. The restriction of movement within certain physiological limits is essential for the protection of the spinal cord in normal activities and traumatic situations, such as a whiplash injury.

The vascular supply to the structures of the thoracic spine and rib cage is by means of the internal thoracic and segmental spinal vessels, and branches of these vessels. Dommisse (1974) made an important observation with regard to the vascular supply in the thoracic spine. The diameter of the spinal canal at the fourth through the ninth thoracic

Table 2.1. Muscles having an attachment to the thorax (Gray 1977).

FUNCTIONAL MUSCLE GROUPS	MUSCLES
Functional neck muscles	Sternocleidomastoid, sternohyoid, sternothyroid, longus colli, scalenes, splenius
Functional shoulder girdle muscles	Trapezius, latissimus dorsi, rhomboid major & minor, pectoralis major & minor, serratus anterior
Functional trunk and rib cage muscles	Posterior superior & inferior serratus, iliocostalis, longissimus, spinalis, semispinalis, multifidus, interspinales, intertransversarri, rotatores, intercostals, transversus thoracis, subcostals, levatores costarum, thoracic diaphragm
Functional abdominal muscles	Internal & external abdominal obliques, rectus abdominus, transversus abdominus

Table 2.2. Ligaments of the joints of the thorax (Gray 1977).

JOINT	LIGAMENTS
Sternocostal	Anterior/posterior radiate; intra-articular; costoxiphoid; interchondral; joint capsule
Costotransverse	Superior; interosseous; lateral; joint capsule
Costovertebral	Anterior/posterior radiate; intra-articular; joint capsule
Spinal	Anterior/posterior longitudinal (ALL/PLL); ligamentum flavum; intertransverse; interspinal; supraspinal; joint capsules

levels is narrower than in the rest of the spine; the smallest measurement is at the T6 level. This region is recognized as being a critical vascular zone, potentially at high risk for damage due to vascular insufficiency following trauma to the area.

The innervation of the thoracic spinal column, the rib cage, and the associated soft tissues has not been the subject of much study. There is still much unknown with regard to the nerve supply of the specific structures of the region, and with regard to the types of nerve endings present in those structures that are known to be innervated (Bogduk 1985). It is assumed that the structures which are innervated can be sources of pain (Bogduk 1985, Lowcock 1991).

Innervation of the thorax involves the branches of the ventral and dorsal rami of the thoracic spinal nerves, the sinuvertebral nerves, and the sympathetic component of the autonomic nervous system (Bogduk 1985; Gray 1977, Groen et al. 1990; Wyke 1975). The ventral rami form the intercostal, thoracoabdominal, and subcostal nerves. The nerves contribute fibers to, and receive fibers from the sympathetic chain via the white and gray rami communicantes. These nerves are responsible for innervating the respiratory muscles of the chest wall and the abdominal muscles. They also give off cutaneous branches dorsally, laterally, and anteriorly.

The dorsal rami innervate the musculature of the dorsum of the trunk, and provide cutaneous branches to the back (Bogduk & Valencia 1988; Gray 1977). Maigne et al. (1991) have determined that the zygapophyseal joints, at levels T1-T5, receive sensory fibers from the dorsal ramus prior to its division into medial and lateral branches.

Wyke (1975) studied the innervation of the costovertebral and costotransverse joints. He determined that the costovertebral joints are innervated by branches arising from the ventral rami of the thoracic spinal nerves, just distal to the intervertebral foramen, or sometimes directly from the spinal nerve itself. The costotransverse joints are innervated by a branch off the dorsal ramus of the spinal nerve, near its division into the dorsal and ventral rami. The articulations are also supplied by segmentally related branches from the intercostal nerves, and medial branches of the dorsal rami.

Groen et al. (1990) suggested that the nerve supply of the entire vertebral column in man is almost solely related to the sympathetic trunk and its branches, although somatic fibers may contribute via the sympathetic pathways. They stated that branches from the sympathetic trunks, the rami communicantes, the perivascular nerve plexuses of the segmental arteries at all levels, and the nerve plexuses of the costovertebral joints contribute to the ALL nerve plexus which covers the anterior vertebral column. The PLL plexus receives branches only from the sinuvertebral nerves. Branches of these nerve plexuses then supply the vertebral bodies, discs, ALL and PLL. In addition branches of the sinuvertebral nerve were found to innervate the anterior dura, segmental arteries, epidural blood vessels, vertebral bodies, and the discs.

The Functional Spinal Unit (FSU). In the thoracic spine the FSU consists of a typical motion segment, plus its costovertebral and costotransverse articulations (White & Panjabi 1990). The FSU has six degrees of freedom (Grieve 1984; White & Panjabi 1990). Movement may occur as rotation about, or translation along, the three cardinal axes (coronal, sagittal, horizontal). Functional movement commonly occurs as a combination of these motions. Movement of a region is the sum total of mobility contributed by each motion segment within the specified region.

The direction and magnitude of movement is influenced by a multitude of factors (Grieve 1984, 1986; Parke 1982; White & Panjabi 1990): articular morphology; ligamentous and muscle tissue; deformation of the bone itself and the cartilage covering it; the various connective tissues adjacent to the motion segment; proportion of disc height to vertebral body height; disc and articular facet pathology; spinal curves; and the presence of the rib cage.

Flexion motion of a FSU involves anterior translation, and slight distraction of the upper vertebrae on the lower vertebrae (Panjabi et al. 1976), and superior gliding of the inferior facets of the upper vertebrae on the superior facets of the vertebrae below (Parke 1982). Movement of the ribs involves a superior glide at the costotransverse joints, in association with anterior rotation of the ribs (Lee 1993).

Flexion movement is limited by tension of the posterior ligaments, muscles, and annular fibers, compression of the anterior annulus, and impaction of the articular processes (Panjabi et al. 1981). The posterior ligaments include the supraspinous, interspinous, facet joint capsules, ligamentum flavum, and the costotransverse ligaments.

The events that occur during extension of the FSU are opposite to those described for flexion. The movement is restricted by tension of the anterior muscles, ligaments, and disc, and compression of the posterior aspect of the disc. The anterior ligaments include the ALL, PLL, and the costovertebral ligaments (Panjabi et al 1981). White and Hirsch (1971) suggested that at the extremes of range, contact of the inferior facets on the laminae below, and of adjacent spinous processes also limits extension.

Lateral flexion of a motion segment, at the zygapophyseal joints, involves superolateral gliding of the inferior articular facet relative to the superior articular facet on the contralateral (opposite) side to which the movement is occurring. On the ipsilateral (same) side, the inferior articular facet glides inferomedially relative to the superior facet (Lee 1993; Parke 1982). Ipsilateral lateral translation and contralateral rotation of the superior vertebrae on the inferior vertebrae also occur (Panjabi et al. 1976).

Lee (1993) proposed that the following rib mechanics occur with side flexion of the upper and middle thoracic spine. The ipsilateral ribs approximate, and the necks of the ribs rotate anteriorly. At the same time, the contralateral ribs separate, and the necks of the ribs rotate posteriorly. At the costotransverse joints the anterior and posterior rotations are associated with superior and inferior gliding, respectively, of the ribs.

Side flexion movement is limited by tension in the contralateral soft tissue structures of the spine and rib cage, tension in the ligaments of the costovertebral and costotransverse joints, and impaction of the ipsilateral articular processes of the vertebrae (Valencia 1988).

According to Panjabi et al. (1976), thoracic rotation is associated with contralateral lateral translation and side flexion of the superior vertebrae. Lee (1993), however, stated that clinically the coupling movement of contralateral side flexion is not seen in the upper and middle thoracic spine. She suggested that ipsilateral side flexion occurs, and that the discrepancy between clinical observation and the work of Panjabi et al. (1976) might be due to the latter's use of FSUs rather than intact thoracic cages in vivo. Rotation of the thoracic spine involves the same glides of the zygapophyseal joints as for side flexion (Lee 1993).

During trunk rotation the ribs deform such that the concavity of the ribs increases on the ipsilateral side, and decreases on the contralateral side (Schultz et al. 1974). The costochondral angle decreases on the ipsilateral side, and increases on the contralateral side (Kapandji 1974).

More specifically (Lee 1993), the necks of the ribs on the contralateral side rotate anteriorly, and those on the ipsilateral side rotate posteriorly. The movements are associated with posterolateral and anteromedial gliding, respectively, of the ribs at the costotransverse joints.

Rotation motion is restricted by tension of the contralateral ligamentum flavum (White & Hirsch 1971), the facet joint capsules, costovertebral ligaments, costotransverse ligaments, and annulus fibrosus fibers, and ipsilateral articular process compression (Valencia 1988).

White (1969) summarized his findings with regard to the mobility of the thoracic spine in the statement, "The main generalization that characterizes this region of the spine situated in the thorax is that it moves very little." In conflict with White's (1969) observation, O'Gorman and Jull (1987) suggested that there is considerable movement of the thoracic spine in all directions.

Table 2.3 provides average values of segmental movement in the different regions of the thoracic spine, as determined by cadaveric studies (White 1969; White & Panjabi 1990). The table indicates that the movements of flexion/extension and side flexion increase progressively from proximal to distal, while rotation is greatest proximally, and decreases significantly in the lower thoracic spine. Of the combined flexion/extension ROM values given, approximately 30% to 40% of the movement was due to extension.

One of the primary reasons the biomechanics of the thoracic spine are thought to be different than the cervical and lumbar regions, is the presence of the rib cage. The intimate structural relationship between the two results in them functioning as a single unit. Changes in the function of the thoracic spine influence the rib cage, and changes in the function of the rib cage affect the thoracic spine (Greenman 1989).

Table 2.3. Average values of segmental ROM for regions of the thoracic spine.

Region of T-Spine	Combined Flexion/ Extension (degrees)	One-way Side Flexion (degrees)	One-way Rotation (degrees)
Upper	4	6	8-9
Middle	6	6	7
Lower	12	8-9	2

Individual components of the rib cage are quite flexible, but the rib cage as a whole significantly enhances the mechanical stability of the thoracic spine (Andriacchi et al. 1974; Valencia 1988; White & Panjabi 1990). This stiffening effect is due to the additional ligamentous structures of the costovertebral and costotransverse joints, the sternal component, and also to the effect that the rib cage has on increasing the moment of inertia of the thoracic spine (Valencia 1988; White & Panjabi 1990). Andriacchi et al. (1974), using a three dimensional mathematical model of the rib cage and thoracolumbar spine, examined the mechanical interactions between the two. The results of their study demonstrated that with an intact rib cage, the stiffness of the thoracic spine was increased for movement about all three axes.

Pain

Defining Pain. The most commonly accepted definition of pain is that proposed by the International Association for the Study of Pain (IASP) (Feurstein 1989). The IASP Subcommittee on Taxonomy defined pain as: "An unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage." (Merskey et al. 1979). The definition was expanded upon by the Subcommittee in an appended 'note' (Appendix A).

The definition suggests that actual tissue damage is not essential to the pain experience. It implies that there are two major components to the pain experience; a physical sensory component, and a psychological component.

It was once thought that pain was simply a sensory experience associated with tissue damage; therefore pain measurement addressed only the variation in intensity of this quality (Melzack & Wall 1988; Tursky et al. 1982). The intensity of the pain was thought to be proportional to the extent of tissue damage. Transmission of the noxious stimulus was thought to occur via a direct pathway that extended from peripheral pain receptors, to a localized pain centre in the brain (Melzack 1983; Tursky et al. 1982).

It is now recognized that pain is a very complex experience that is influenced by numerous factors intrinsic and extrinsic to the individual (Reading 1989). It is also realized that the pathways for the transmission of the painful stimulus are very complicated. The nature of the different dimensions of pain varies according to the type of noxious stimulus the individual is experiencing, and the time course of the pain experience, that is, acute pain versus chronic pain (McCreary et al. 1981; Melzack & Wall 1988; Sternbach 1989).

Melzack and Wall (1988) suggested that there are three major dimensions of pain: sensory-discriminative, motivational-affective, and cognitive-evaluative. The affective and evaluative dimensions comprise the psychological component of pain, interpreting and giving meaning to the pain experience, and motivating pain behaviour. The sensory dimension encompasses the anatomical, physiological, and chemical factors that contribute to the sensation of pain. Pain sensation may vary in intensity, quality, duration, and location (Echternach 1987; Gracely et al. 1978; Kremer & Atkinson 1981; Melzack 1983). It is important to recognize the significant contribution of both the psychological and physical components. Neither should be emphasized to the extent that the other component is overlooked in the assessment of a patient's pain (Melzack & Wall 1988).

Measurement of Pain. Pain that affects functional activity is one of the primary reasons that individuals solicit the aid of medical professionals (Echternach 1987). The subjective nature of the pain phenomena necessitates inclusion of the person's self-report of pain as an integral part of the assessment and treatment planning protocol. Self-described reports are important to identify the location, severity, and quality of the pain, the activities that aggravate and alleviate the pain, and so on. However, verbal reports can be biased by an individual's personality, past experiences, expectations of the future, cultural factors, etc. (Melzack & Wall 1988; Sternbach 1986). Thus, it is the subjective nature of pain that also necessitates the inclusion of objective and reliable pain measurement techniques in the assessment of patients (Echternach 1987; Elton et al. 1979).

The realization that pain is a very complicated phenomenon, has resulted in the effort to develop a pain assessment tool that will satisfactorily measure all of the components of pain. To date, however, no single pain assessment instrument adequately meets this goal (Kremer & Atkinson 1981). It is therefore necessary to use a number of different instruments, each of which measures specific characteristics, to completely assess a patient's pain experience.

Several of the tools developed to quantitatively measure pain include: pain drawings (Margoles 1983; Margolis et al. 1986; Savedra et al. 1989; Toomey et al. 1983; Toomey et al. 1991); the Pain Perception Profile (Tursky et al. 1982); the Card-sort Method (Reading & Newton 1978); verbal rating scales (Duncan et al. 1989; Jensen et al. 1989; Ohnhaus & Adler 1975; Scott & Huskisson 1976); visual analogue scales (Dixon & Bird 1981; Duncan et al. 1989; Jensen et al. 1989; Ohnhaus & Adler 1975; Price et al. 1983; Revill et al. 1976; Scott & Huskisson 1976, 1979; Sriwatanakul et al. 1983); the 11-point Box Scale (Jensen et al. 1989); and the 101-point Numerical Rating Scale (Jensen et al. 1989). The two measurement tools chosen to assess pain in this study, the MPQ and PTM, are described in greater detail below.

McGill Pain Questionnaire. The MPQ (Melzack 1975) (Appendix B) has received wide acceptance as one of the most comprehensive pain assessment tools to date. It was developed to quantitatively measure the intensity of different qualities of pain. The questionnaire is divided into five parts: a top sheet that records various medical information about the patient, such as diagnosis of condition, and medications; a body diagram to indicate spatial distribution of pain; a checklist of three categories to describe the temporal properties of pain; a 5-point rating scale to indicate overall present pain intensity (PPI); and a checklist of 78 descriptive pain words (PRI).

The descriptive pain words were chosen from a list of 102 words that had been previously classified, rank ordered, and assigned weighted scale units according to intensity (Melzack & Torgerson 1971). The descriptive words are arranged in twenty subclasses of two to six words which are qualitatively the same, but differ slightly in meaning and intensity. The words are rank ordered according to their intensity. Sixteen of the twenty subclasses represent the three major dimensions of pain: sensory dimension (temporal, spatial, pressure, and thermal characteristics); affective dimension (tension, fear, and autonomic characteristics); and evaluative dimension (subjective overall intensity).

The remaining four subclasses are made up of miscellaneous words.

The instructions for completion of the questionnaire, as suggested by Melzack (1975), stipulate that the patients are to complete the questionnaire with regard to their pain at the time that the questionnaire is being completed, not pain experienced in the past. Graham et al. (1980) agreed with Melzack (1975) that the MPQ is best used as a measure of present pain rather than past pain. However, Hunter et al. (1979) found that pain recall within five days was very accurate, and therefore concluded that the MPQ could be used reliably to assess pain within this time period.

Melzack (1975) also suggested that the MPQ be administered verbally by the tester. However, Graham et al. (1980) examined two groups (N=18) of cancer patients, and did not find any significant difference between the results of tests administered orally, and those administered by written form. They suggested the written form is preferable to oral administration, because it minimizes potential tester bias resulting from verbal emphasis of specific words, and body language cues.

Three primary outcome measures of the MPQ were initially proposed by Melzack (1975): the scale value of the PPI rating; the total number of words chosen (NWC) from the twenty subclasses; and summation of either the rank values (R) or the scale values (S) of the words chosen from the twenty subclasses ie. Pain Rating Index (PRI R or S). The NWC and the PRI scores may by summed over all twenty subclasses, or individual scores for each of the three major dimensions can be calculated.

Melzack et al. (1985) suggested that most testers using the MPQ choose the PRI(R) method of scoring over the more complex PRI(S) method, but in doing so lose some of the information provided by the MPQ. They proposed a fourth outcome measure, the weighted-rank method, as a compromise between the PRI(R) and PRI(S) scoring methods. Each of the twenty descriptive categories was weighted based on the scale values of its words, as determined by Melzack and Torgerson (1971). The rank value of each word was then multiplied by the category's weighted correction factor to determine the word's weighted rank-value.

Melzack et al. (1985) used the PRI(R) and weighted-rank scores to compare low-back pain patients who were or were not on compensation. The PRI(R) scoring method did not show a significant difference between the two groups, but the weighted-rank method did. Melzack et al. (1985) concluded that the new scoring method increases the power of the MPQ by increasing the sensitivity and accuracy of scoring.

Since its development, the MPQ has been extensively used in research and clinical settings, and the reliability of the tool has been fairly well established (Reading 1982). A test-retest reliability of r=.70 was calculated by Melzack (1975) in the testing of cancer patients (N=10). Graham et al. (1980) calculated a test-retest reliability ranging from 66-88.4% mean consistency over four administrations of the tool. Elton et al. (1979) determined that both the interval and ordinal scoring methods were reliable (r=.93) for test-retest within a session. Test-retest on ratio scaling of sensory and affective verbal pain descriptors for between groups, between sessions, and intra-sessions was determined by Gracely et al. (1978) to range between r=.89-.99.

Internal consistency for the subscales, and the test as a whole, was established by Melzack (1975) to range between r=.82-.96. Hunter et al. (1979) concurred with Melzack's (1975) assessment that internal consistency of the sensory and affective subscales of the questionnaire is fair, but they also noted that internal consistency of the evaluative subscale cannot be determined because there is only one category for this factor.

Convergent validity of the MPQ has been assessed in studies comparing the MPQ with the Beck Depression Inventory (Doan & Wadden 1989), the Minnesota Multiphasic Personality Inventory scale (McCreary et al. 1981), the Brief Symptom Inventory, and the Sickness Impact Profile (Kremer & Atkinson 1981). Divergent validity of the independent nature of the three dimensions of the MPQ was substantiated by Gracely et al. (1978), and McCreary et al. (1981). However, factor analysis of the MPQ has produced contradictory results. The findings of Prieto et al. (1980) and Lowe et al. (1991), supported the three dimension concept upon which the MPQ is based, but Reading (1982) suggested that more than three factors are evident, particularly in acute pain.

Discriminative validity of the tool has been supported by Dubuisson and Melzack (1976), who used the MPQ to correctly classify 77% of 95 cases with regard to previously diagnosed pain syndromes. Melzack et al. (1982), in a study of 138 acute pain patients determined that the MPQ was also able to discriminate between acute and chronic pain patients. Chronic pain tended to be associated with significantly higher affective scores, but there was no difference in the frequency of sensory descriptors between the two groups.

Pain Threshold. Manual palpation is commonly used in the clinical setting to assess tenderness, but it is very difficult to quantify the findings using this assessment technique (List et al. 1991). An alternative to using manual palpation to assess tenderness, or sensitivity to pain, is to use a pressure threshold meter (Appendix C). This instrument is also known as a dolorimeter or pressure algometer.

Pain threshold has been defined as the minimum pressure or force that produces discomfort (Fischer 1986a; Melzack 1983; Ohrbach & Gale 1989b; Reeves et al. 1986; Wolff 1980). The patient is instructed to indicate as soon as the pressure becomes uncomfortable, not painful. A lower PTM indicates a lower sensitivity to pain threshold.

Fischer (1987b) suggested that pain threshold measurement (PTM) for the assessment of tenderness in pathologically sensitive regions is preferred over measurement of pain tolerance (the maximum force a person can tolerate). He stated that because pain threshold induces only mild discomfort, it is a more accurate, more reproducible, and more informative measure of tenderness than pain tolerance. The latter has been used to assess other dimensions of pain (Fischer 1987b).

A limited amount of normative data of PTM has been collected (Fischer 1986a). To date, studies indicate that there is significant variability in "normal" threshold measurements of the same site between healthy individuals. However, there is significant correlation (r-.738-.934) (Gerecz-Simon 1989), and no significant difference between sites bilaterally in healthy persons (Fischer 1987a; Hogeweg et al. 1992). Fischer (1988) and Hogeweg et al. (1992) suggested that when assessing patient populations, values obtained on the affected side be compared to values from the same site on the unaffected side of the patient, to determine whether the change is meaningful. Based on his clinical experience, Fischer (1988) stated that a difference in muscle pain threshold values of greater than 2 kg between sides indicates pathological tenderness.

PTM is influenced by numerous factors that should be controlled during testing, or at least be taken into consideration when analysing the results of studies, and making conclusions based on those results. Some of the factors that have been identified as affecting pain threshold values are:

i) Daily activity level, weather changes, and psychological tension (Fischer 1987a; Gerecz-Simon et al. 1989).

ii) Gender. Generally, females have a lower pain threshold than males (Fischer 1987a; Gerecz-Simon et al. 1989; Hogeweg et al. 1992; Ohrbach & Gale 1989a; Takala 1990). However, Jensen et al. (1986) did not find a significant difference between male and female values. The reason for the discrepant findings is not clear. Jensen et al. (1989) suggested that in consideration of the large variation between individuals, their sample size (N=24) may have been too small to demonstrate a gender difference. However, some of the above studies also had small sample sizes. Perhaps the different results were due to the site (temporalis muscle) and population assessed (healthy subjects). Ohrbach and Gale (1989a) also tested the temporalis muscle, but on a patient population.

iii) Type of tissue. Tendon, for example, has been found to have a higher threshold than muscle (Ohrbach & Gale 1989b), and muscle a higher threshold than bone (Fischer 1986b, 1987a; Gerecz-Simon et al. 1989).

iv) Site. Fischer (1987a) found that lower body muscles were less sensitive than upper body muscles. However, Gerecz-Simon et al. (1989) studied 36 healthy and 90 arthritic subjects (54 females and 72 males), and found no significant difference between upper and lower limb measurements. It should be noted that these two studies evaluated different sites. This suggests that the sensitivity of upper vs lower body muscles may depend on the muscles assessed.

v) Patient population. Gerecz-Simon et al. (1989) found that ankylosing spondylitis patients had significantly higher threshold values than osteoarthritic patients, who had higher thresholds than normal subjects. The latter, in turn, had higher values than rheumatoid arthritis patients.

vi) Rate of pressure application. List et al. (1991) stated that because the instrument is applied manually, deviation from a constant pressure rate will occur. They found that pain threshold increased as the rate of pressure application increased. They suggested that the rate of pressure application be .5 kg/cm^2/second, because at this rate the variation for repeated measures was .5 kg/cm^2. Within this range, reliability of the measures was acceptable. However, Fischer (1986a) suggested that pressure be applied at a constant rate of 1 kg/cm^2/second. He did not offer any rationale for this rate, other than to suggest that it allowed the tester to increase pressure evenly by counting seconds.

vii) Area of application. Jensen et al. (1986) noted that pressure threshold decreased as the area of application increased. The surface area of the tip of the pressure threshold meter most often reported in the literature was either .5 cm^2 or 1 cm^2.

viii) Time between repeated measures of the same site. Hogeweg et al. (1992) claimed that a large part of variance in measures was due to short time intervals between measures, but they did not mention what time intervals they tested. They suggested that repeated measures within short time periods could be influenced by modulation of sensation due to previous pressure. Jensen et al. (1986) also found an increase in threshold values with repeated measures. However, other authors (List et al. 1991; Ohrbach & Gale 1989a; Reeves et al. 1986) have not found significant changes in PTM with repeated measures. Takala (1990) suggested that because there is a high variability of repeated measures of a given point, the mean of several measures be calculated to minimize the variance. Ohrbach and Gale (1989b) indicated that the mean of two measures of a given site was a better estimate of pain threshold than either the first or second value alone. They used the 95% confidence interval from five trials of fifteen sites for ten subjects as the criterion measure. Means of each trial, or combination of trials, was then compared to the criterion measure. The means of trials one and two were within the 95% confidence interval 100% of the time.

All of the above variables can potentially affect the measurement of pain threshold. However, if there is careful adherence to a good standardized methodology, PTM is a reliable and valid measure of tenderness (Fischer 1987a; Hogeweg et al. 1992; Ohrbach & Gale 1989a).

Takala (1990) assessed pain threshold of the upper trapezius and levator scapulae muscles in 93 males and 70 females, between 24 and 60 years of age. He calculated an intra-rater reliability of r=.71-.92, and an inter-rater reliability of r=.69-.79. These findings are comparable to those noted by Reeves et al. (1986) in a study of fifteen head and neck pain patients (eleven men and four women ranging in age from 24-60 years). Intra-rater reliability ranged from r=.69-.97, and inter-rater reliability from r=.71-.89 (when the points to be tested were marked). Hogeweg et al. (1992) assessed various sites in 28 healthy adults aged 21-41 years (fourteen males and fourteen females). They did not find any significant difference between tests performed on different days, or between testers in measurement of paravertebral points. However, they did find significant inter-tester difference in the measurement of peripheral joints. They stated that the differences only ranged from .8080-1.4154 kg/cm^2, and they questioned the clinical significance of this variability. (Clinical significance implies that an observed difference would be meaningful in the practical setting. It would be important with regard to the assessment, treatment, and/or prognosis of a patient's condition.)

Jaeger and Reeves (1986) found a mean difference of 1.0 kg/cm^2 between pre and post treatment fibromyalgic patients to be statistically significant (p=.01). Gerecz-Simon et al. (1989) and Ohrbach and Gale (1989a) determined that mean differences of .66-1.21 kg/cm^2 between control and patient populations were significantly differently.

Comparison of measures between patient populations and healthy control populations suggests that intra-rater and inter-rater reliability varies depending on the population. Ohrbach and Gale (1989a, 1989b) calculated within session and between session test-retest values of r=.795-.9135 and r=.55-.93 respectively for patient populations. Scores of r=.897 and r=.87 were calculated for the control population. Their findings suggested that test-retest reliability of PTM is very good, and that variability of measures between testing sessions is due to the variable nature of pain, rather than tester variability.

The validity of PTM has also been established. The application of pressure has been found to replicate clinical complaints of pain, and PTM has been able to distinguish between subjects with and without pain (Ohrbach & Gale 1989a; Reeves et al. 1986). Jensen et al.'s (1986) findings also supported construct validity of PTM. Pain threshold of the temporal region of nine healthy adults increased following administration of an analgesic medication, but did not change when a placebo was administered.

Spinal Range of Motion

Spinal mobility can be addressed at three different levels: functional or global, regional, and at a specific motion segment. Movement at the regional level is a composite of the movement of individual motion segments, while functional movement is a composite of the movement occurring at different regions. In the literature, measurement of spinal motion has focused on regional and segmental ROM of the lumbar spine, with relatively few studies examining cervical and thoracic movement.

Spinal ROM is commonly assessed in the clinical setting, and the results used to determine a diagnosis or a treatment protocol, and to monitor effectiveness of treatment. To facilitate measurement of this variable, numerous methods of measuring regional spinal motion have been devised. The majority of them measure lumbar movement in the sagittal plane (flexion/extension ROM), although some have been adapted to measure ROM in the different spinal regions and planes.

Segmental mobility has been assessed, in the research setting, using x-rays and CT scans for in vivo measurements, and cadaveric specimens subjected to various types of loads and load forces. Although manual palpation techniques are the more common method of clinical assessment of segmental mobility, radiographic measures have also been used in the clinical setting. Radiographic imaging is considered to be the "gold standard" for measuring spinal motion, because it is an in vivo measurement, and is a relatively direct measurement compared to the other techniques. Therefore, studies interested in demonstrating validity of another measurement method have compared the data from the new method to radiographic data.

Table 2.4 presents some of the measurement tools utilized to assess spinal ROM. Table 2.5 presents regional values of "normal" thoracic spine ROM.

The variability in methods of assessing spinal mobility makes it difficult to compare the results of studies, and to generalize them to the clinical setting. Numerous procedural factors can affect the measurement values obtained: population assessed (Archer et al. 1974; Dvorak et al. 1991; Hart et al. 1974; Sturrock et al. 1973); instrument utilized; positioning and stabilization of the subject (Mellin et al. 1991); active versus passive ROM (Dvorak et al. 1988); experience and skill of the examiner (Boline et al. 1988; Gonella et al. 1982), and so on.

Table 2.4. Measurement tools used to assess spinal ROM.

MEASUREMENT TOOL	SPINAL REGION	STUDIES UTILIZING TOOL
Radiography	CV jts	Dvorak et al. 1988; Panjabi et al. 1988
	C-spine	Lysell 1969; Pennal et al. 1972; Portek et al. 1983; Dvorak et al. 1988, 1993; Worth 1991
	L-spine	Macrae & Wright 1969; Pearcy et al. 1985; Dvorak et al. 1991; Panjabi et al. 1992
Photographs/ Slides	T-spine	Wing et al. 1992
	L-spine	Troup et al. 1968; Burdett et al. 1986
Tape Measure		
Fingertip to floor	L-spine	Reynolds 1975; Moran et al. 1979; Merritt et al. 1986; Gill et al. 1988
Modified Schober's	T-spine L-spine	Macrae & Wright 1969; Moll & Wright 1969; Reynolds 1975; Moran et al. 1979; Portek et al. 1983; Rae et al. 1984; Burdett et al. 1986; Haley et al. 1986; Merritt et al. 1986; Beattie et al. 1987; Gill et al. 1988; Wing et al. 1992
Moll & Wright's	T-spine & L-spine	Moll & Wright 1969; Moll et al.1972; Reynolds 1975; Moran et al. 1979; Portek et al. 1983; Haley et al. 1986; Merritt et al. 1986
Flexicurve	L-spine	Salisbury & Porter 1987; Burton & Tillotson 1988
Flexirule/ Hydrogoniometer	L-spine	Anderson & Sweetman 1975

MEASUREMENT TOOL	SPINAL REGION	STUDIES UTILIZING TOOL
Inclinometer	C-spine T-spine L-spine	Loebl 1973; Lowery et al. 1992 Loebl 1967, 1973; Reynolds 1975; O'Gorman & Jull 1987 Loebl 1967, 1973; Reynolds 1975; Portek et al. 1983; Mayer et al. 1984; Keeley et al. 1986; Merritt et al. 1986; Gill et al. 1988; Boline et al. 1992; Lowery et al. 1992
Leighton Flexometer	C-spine & Trunk	Leighton 1966
Kyphometer	L-spine	Salisbury & Porter 1987
Spondylometer	T-spine & L-spine L-spine	Dunham 1949; Hart et al. 1974; Sturrock et al. 1973; Reynolds 1975 Twomey & Taylor 1979; Taylor & Twomey 1980
Rotameter	T-spine L-spine	O'Gorman & Jull 1987 Twomey & Taylor 1979; Taylor & Twomey 1980
OB (Myrin) Goniometer	C-spine T-spine & L-spine	Mealy et al. 1986 Mellin 1986, 1987; Mellin et al. 1991; O'Gorman & Jull 1987; Poussa et al. 1989; Mellin et al. 1991; Mellin & Poussa 1992
Rangiometer	C-spine	Zachman et al. 1989
Manual Palpation	C-spine T-spine L-spine	Johnston et al. 1982a, 1982b; Jull et al. 1988 Johnston et al. 1982a; Love & Brodeur 1987 Cassidy & Potter 1979; Gonella et al. 1982; Johnston et al. 1982a; Bergstrom & Courtis 1986; Jull & Bullock 1987a, 1987b; Boline et al. 1988; Mootz et al. 1989; Keating et al. 1990

Abbreviation Key: CV jts = craniovertebral joints
C/T/L-spine = cervical, thoracic, lumbar spine

Table 2.5. Normative data of thoracic spine ROM.

STUDY	MEAN RANGE OF MOTION (SD) (degrees)	INSTRUMENT	SUBJECTS
Gregerson & Lucas (1967)	R(2way) = 74	Steinman pins; transducer	N = 7 M 20-26 yrs
White (1969)	F/E = 34.4 SF(1way) = 52 R(1way) = 41.1	Compression apparatus & differential transformer	N = 10 Cadavers Mean age 50.9 yrs
Mellin (1986)	F = 15 (8) E = 17 (14) SF(1way) = 15-22 (6)	OB goniometer	N = 25 M & F Mean age 31.3 yrs
Mellin (1987)	R(2way) = 93.6 (20.4)	OB goniometer	N = 39 M & F Mean age 37.1 yrs
O'Gorman & Jull (1987)	F = 15.85-32.98 (8.29-9.02) E = 11.85-37.43 (7.04-10.52) SF(1way) = 19.5-37.45 (5.92-8.86) R(1way) = 25.85-60.28 (6.05-12.59)	Inclino-meter OB goniometer Rotameter	N = 120 F 22-99 yrs
Poussa et al. (1989)	F/E = 58.7 (15.2) SF(2way) = 66.3(12.2) R(2way) = 31.2 (10.0)	OB goniometer	N = 30 F Mean age 14.0 yrs
Mellin et al. (1991)	F=51.2-54.1(6.0-6.3) E = 13.4-17.3 (12.9-19.0) SF(1way) = 28.2-30.1 (7.9-8.6)	OB goniometer	N = 27 M & F 24-58 yrs
Mellin & Poussa (1992)	F=62.2-70.3 (5.9-8.8) E= 1.7-13 (10.8-15.5) SF(2way) = 65.86-82.6 (8.2-12.2) R(2way) =31.8-47.1 (8.1-16.8)	OB goniometer	N = 294 M & F 8-16 yrs

Abbreviation Key:
F = flexion E = extension SF = side flexion R = rotation
F/E = combined flexion/extension
1way=unilateral (left/right) 2way = combined left and right
N = number M = males F = females yrs = years of age

In addition to the above procedural factors, there are a number of anatomical, biomechanical, and physiological factors that affect measurement of spinal mobility: regional anatomical differences (Mootz et al. 1989); plane of movement (Jull & Bullock 1987b); presence of anatomical anomalies or pathology (Mayer et al. 1984; Pearcy et al. 1985; Poussa et al. 1989); age (Jull & Bullock 1987a; Mellin & Poussa 1992; Moran et al. 1979; O'Gorman & Jull 1987; Taylor & Twomey 1980); gender (Burton & Tillotson 1988; Mellin & Poussa 1992; Moll & Wright 1969; Taylor & Twomey 1980); and diurnal variation (Wing et al. 1992).

Of the methods of measuring spinal mobility developed thus far, no one method is capable of measuring both regional and segmental mobility of the physiological movements in the three different planes. The method of choice is dependent on a number of variables, such as, objectives of the study, instruments available for use, reliability and validity of the instruments, and population being assessed.

For the purposes of the present study, the OB (Myrin) goniometer was chosen to assess regional thoracic (T1-T8) ROM, and manual assessment techniques were chosen to assess segmental passive joint mobility. Each of these measurement tools is discussed in greater detail below.

OB (Myrin) Goniometer. The major advantage of using the OB (Myrin) goniometer (Appendix D), is that it allows measurement of spinal ROM in all three planes without having to reposition the subject. Other advantages to this tool are that it is small in size, it has a rotating dial allowing zeroing of the scale, and the scale is printed in both directions.

Several studies have used the OB (Myrin) goniometer to assess spinal ROM (Mealy et al. 1986; Mellin 1986, 1987;

Mellin et al. 1991; Mellin & Poussa 1992; O'Gorman & Jull 1987; Poussa et al. 1989). The majority of these studies evaluated thoracic ROM. However, Mealy et al. (1986) used the OB goniometer to assess cervical movement of whiplash injured subjects (N=61).

The issues of instrument reliability and validity have been addressed by some of the studies noted above. Mellin (1986), in a study assessing thoracic and lumbar postural curvatures and ROM, calculated intra-rater reliabilities ranging from r=.57-.85 for side flexion movement, r=.86-.93 for flexion, and r=.93-.98 for extension. Inter-rater reliabilities for each of these movements were r=.75-.91, r=.95-.97, and r=.89 respectively. Coefficients of variance values ranged from .59-18.7%. Good to high intra-rater reliability for thoracic side flexion, flexion, and extension was also reported by Mellin et al. (1991) in a study that assessed spinal ROM in various subject positions. Pearson correlation values ranged from r=.76-.92 depending on the position of the subject, and the plane of movement being assessed. O'Gorman and Jull's (1987) study of 120 "normal" females reported good intra-rater reliability for measurement of thoracic side flexion ROM. There was no significant difference of values between three trials, and a high percentage of intersubject variation relative to total variance, indicated minimal measurement error. Validity of the OB goniometer was assessed relative to a clinometer; no significant difference between the two instruments was found.

Reliability values for measurement of thoracic spine rotation using the OB goniometer have also been determined (Mellin 1987). Intra and inter-rater reliability ranged from r=.70-.90; the mean correlation value was r=.79 and the standard deviation .11. Mellin (1987) suggested that the OB goniometer was a valid tool for measuring thoracic rotation, because the values obtained with the OB goniometer were comparable to those obtained with an inclinometer (Loebl 1973), and with Steinman pins (Gregerson and Lucas 1967). However, the inclinometer was not validated with regard to assessment of thoracic spinal ROM. Although the Steinman pin technique was a direct measurement of thoracic spine motion, and may be considered a valid measurement, only seven subjects participated in the study.

Manual Palpation. Assessment of spinal mobility using manual palpation techniques has been advocated over time by numerous persons (Grieve 1984; Maitland 1986; Mennel 1964; Stoddard 1983). Russell (1983) suggested that palpation of joint movement is one of the most common assessment tools used to make diagnoses, determine treatments, and monitor progress. Widely used by various professions (chiropractors, physiotherapists, osteopaths, physicians), manual assessment techniques evaluate both the quantity and quality of physiological (gross or inter-segmental) and accessory spinal joint movement.

It is believed by the proponents of manual techniques that findings of altered joint mobility indicate significant regional or segmental dysfunction (Johnston et al. 1982b; Panzer 1992). Manual assessment is also believed to provide information with regard to the type of pathological changes occurring in the spine (Boline et al. 1988; Cassidy & Potter 1979; Keating 1989). However, to date there is little literature to support the belief that alterations of joint mobility are associated with other components of joint dysfunction (Keating 1989), or clinical symptoms (Maher & Latimer 1992; Mootz et al. 1989).

Panzer (1992) stated that manual assessment techniques are commonly accepted as having face validity, but the consensus of the literature is that there is a definite need to further evaluate the reliability and validity of these techniques (Alley 1983; Keating 1989; Keating et al. 1990;

Matyas & Bach 1985; Panzer 1992; Russell 1983). The majority of studies that have addressed this issue have examined intra and/or inter-rater reliability. Only one study addressed validity (Jull et al. 1988).

Jull et al. (1988) examined the validity of manual therapy to diagnose symptomatic zygapophyseal joints of the cervical spine, relative to radiologically-controlled diagnostic blocks. Twenty subjects were assessed. The examiner correctly identified the affected joint levels indicated by the diagnostic block in all fifteen symptomatic subjects, as well as correctly identifying the five subjects who were asymptomatic. Sensitivity and specificity of the manual assessment techniques used by the examiner were 100% each.

Bergstrom and Courtis (1986) reported intra and inter-rater reliability of assessing segmental lumbar spinal mobility as percentages of examiner agreement; values were 95.4% $\pm$ 3.2% and 81.8% $\pm$ 4.6% respectively. Jull and Bullock (1987a) reported very high intra and inter-rater reliability; r=.81-.98 (87.5% agreement), and r=.82-.94 (86% agreement) respectively. Gonella et al. (1982), and Love and Brodeur (1987) suggested that intra-rater reliability is good with manual assessment, but inter-rater reliability is poor. In contrast to the intra-rater values reported above, Mootz et al. (1989) did not report good values; Kappa coefficient values of fair to moderate rating were calculated for only two levels of the lumbar spine assessment. However, their findings of poor inter-rater reliability were in agreement with the other studies. Two additional studies examined reliability between examiners (Boline et al. 1988; Keating et al. 1990), and again both studies confirmed that inter-rater assessment is not reliable.

Overall, studies have indicated that intra-rater reliability is moderate to good, but inter-rater is poor.

Several suggestions have been put forth to explain the latter:

i). Subject variability. Some persons are more difficult to palpate than others (Gonella et al. 1982; Maher & Latimer 1992).

ii). Segmental variability. Some intervertebral motion segments are more difficult to palpate than others (Gonella et al. 1982; Mootz et al. 1989).

iii). Lack of standardization of palpatory techniques (Gonella et al. 1982; Panzer 1992; Russell 1983).

iv). Lack of standardized criteria as to what constitutes 'normal' and 'abnormal' joint mobility (Bergstrom & Courtis 1986; Gonella et al. 1982; Love & Brodeur 1987; Mootz et al.1989). Love and Brodeur (1987) suggested that examiners tend to define their own standards against which they evaluate subjects.

v). Isolation of motion palpation findings of single tests from the rest of the clinical examination (Keating et al. 1990; Russell 1983). Keating et al. (1990) reported improved reliability values when the sum score of all variables of "abnormal" were considered, rather than scores of individual tests.

<u>Summary</u>

Whiplash injury occurs frequently in our society. Extensive pathological changes, and numerous signs and symptoms of the cervical spine following injury have been documented. Pain, muscle tenderness, ROM, and passive joint mobility of the cervical spine are variables commonly assessed after a whiplash injury.

Unfortunately, a significant percentage of persons who present with acute whiplash syndrome develop chronic signs and symptoms, despite the focus on cervical spine assessment and treatment. The literature makes references to the presence of thoracic pain and muscle tenderness following whiplash trauma. There are several biomechanical and anatomical reasons why the thoracic spine could be affected by whiplash trauma. However, whether or not whiplash injury has an effect on the measures of thoracic pain, pain threshold, ROM, and PIVM has not been evaluated.

CHAPTER THREE
METHODS AND PROCEDURES

Research Design

The research followed a concurrent design involving both a cohort and a comparison group. A flowchart of the study protocol is illustrated in Figure 3.1. Prior to the onset of the study proper, a pilot study (Appendix E) was conducted to determine the investigator's intra-rater reliability for measuring muscle tenderness, ROM, and PIVM, using a pressure threshold meter, OB (Myrin) goniometers, and Maitland's (1986) manual assessment techniques respectively. Assessment of whiplash and matched comparison subjects was completed within three months of the cohort subject sustaining a whiplash injury.

The independent variables of concern to this study were:

a) involvement in a whiplash injury or not.

b) body region being measured with regard to pain threshold (upper and middle thoracic spine; cervical spine; anterior lower leg).

c) plane of movement of the range of motion measures (flexion/extension in the sagittal plane; rotation in the horizontal plane; side flexion in the coronal plane).

The dependent variables of interest were:

a) thoracic pain. Pain in the thoracic spine and/or the anterior and lateral aspects of the chest wall was measured using the McGill Pain Questionnaire (MPQ).

b) tenderness of the upper and middle thoracic paravertebral muscles. Cervical tenderness and tibialis anterior muscle tenderness were also assessed. Tenderness was quantitatively documented by measuring pain threshold using a

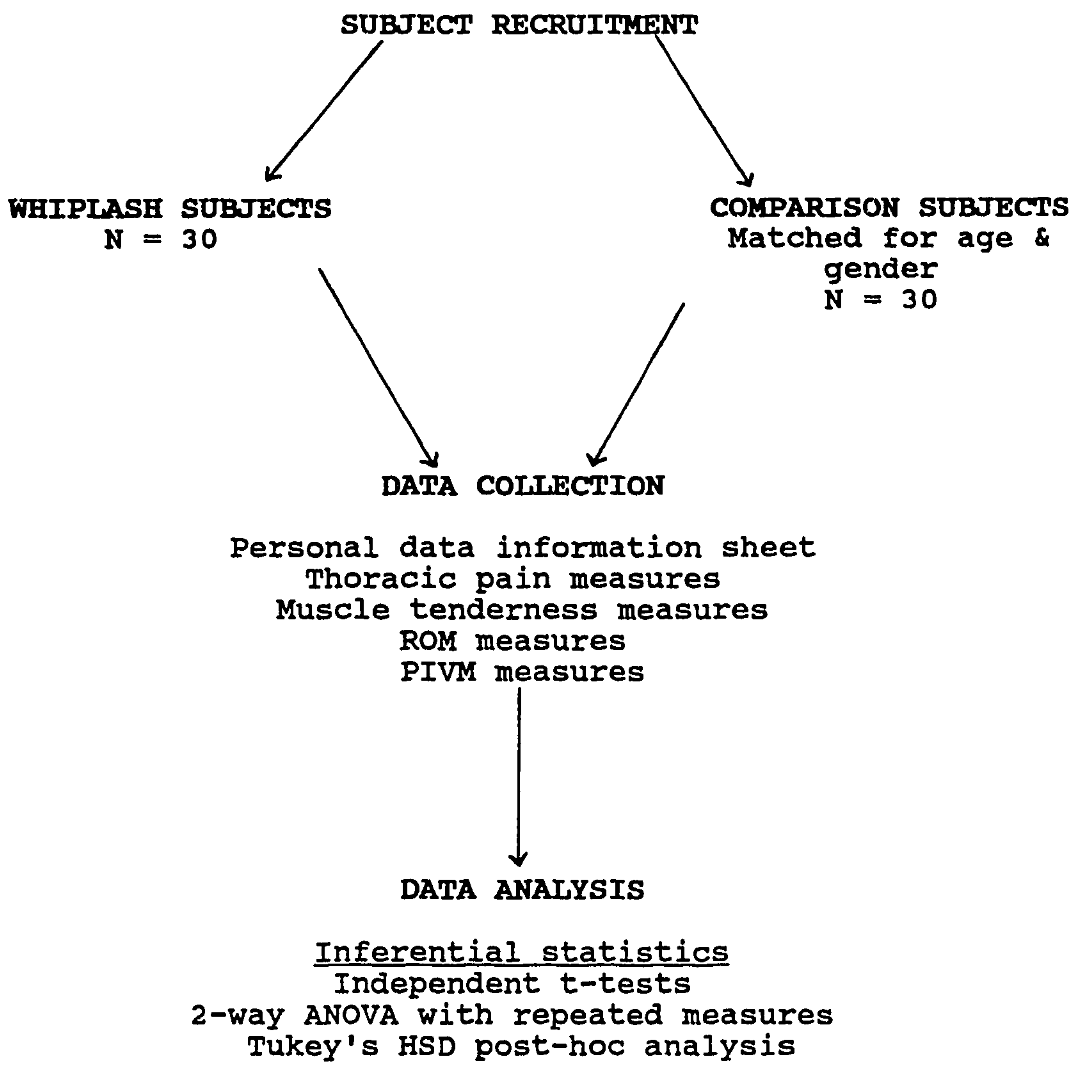

Fig. 3.1: Flow chart of study protocol

pressure threshold meter (dolorimeter).

c) ROM of flexion, extension, axial rotation, and side flexion of the upper and middle thoracic spine. ROM was assessed using two OB (Myrin) goniometers.

d) PIVM of the upper and middle thoracic motion segments. PIVM was evaluated using Maitland's (1986) manual assessment techniques of physiological and accessory joint motion.

The measures obtained for each of the four dependent variables were analyzed separately using raw scores.

Subjects

Power analysis calculations (Cohen & Cohen 1983) indicated that a minimum sample size of 30 subjects per group would be necessary to demonstrate a significant difference if one existed. The calculations allowed for a ten degree difference (SD = 11.83-16.53) in ROM measures, 1 kg/cm^2 difference (SD = .7-2.39) for PTM, and two abnormal motion segments (SD = 1.5) for PIVM measures. The calculations were based on a .05 level of significance, and a beta error of .20.

A number of businesses in Edmonton, Sherwood Park, Leduc, St. Albert, Spruce Grove, Stony Plain, Grande Prairie, Ft. McMurray, Whitecourt, Red Deer, Wetaskiwin, and Vermillion were approached to enlist their participation in the study with respect to subject recruitment. Physiotherapy clinics, chiropractic clinics, walk-in medical clinics, insurance companies, autobody repair shops, and taxicab companies were approached. In addition, advertisements were placed in Edmonton newspapers, on a community television channel, the University of Alberta radio station, and on notice boards of the University of Alberta campus and Grant MacEwan Community College campuses. A $20.00 honorarium was offered to subjects to help pay for transportation and parking costs, and to compensate them for their time commitment.

Volunteer subjects of the whiplash group (N=30) were subsequently recruited from a number of greater Edmonton physiotherapy clinics, autobody repair shops, newspaper advertisements, and university poster boards. They were sampled by convenience, that is, the first 30 volunteers who met the inclusion/exclusion criteria were recruited into the study. Participants of the comparison group (N=30) were matched for gender and age (± 2 years) with the whiplash subjects, to ensure comparability of these factors. Comparison subjects were recruited from the University of Alberta student and staff population, as well as from the community at large. They were also sampled by convenience; the first 30 volunteers who met the inclusion/exclusion criteria were recruited into the study.

The inclusion criteria were that:

a) Participants be either male or female.
b) Participants be between 16-46 years of age.
c) Participants of the whiplash group be involved in a front-end or rear-end collision within the previous three months.

The exclusion criteria were:

a) Sustainment of a head or chest injury due to direct impact in the motor vehicle accident.
b) Sustainment of one or more fractures or dislocations of the vertebrae due to direct or indirect trauma during the accident.
c) A history of neck, back, or chronic shoulder problems for which the person sought medical, physiotherapeutic, or chiropractic treatment, or which necessitated absence from work, or limited normal daily activities or recreation.
d) A history of metabolic, bone, or visceral disease.

Procedure

Once a subject was determined to be eligible for the study, an appointment for the testing session was arranged. Prior to the onset of data collection, the principal investigator ensured that each subject understood the testing procedure and that any questions regarding the study were answered. [illegible]jects were then required to sign an informed con[illegible] (Appendix F). Testing of subjects involved comp[illegible] of a personal data information sheet (Appendix [illegible], [illegible]tion of the MPQ, measurement of muscle tenderness, R[illegible], and PIVM in that order.

All testing took place in the Faculty of Rehabilitation Medicine at Corbett Hall on the University of Alberta campus. The testing session took an average of 45 minutes to complete.

Thoracic Pain Measurement. Thoracic pain was measured using parts two to five of the MPQ (Melzack 1975) (Appendix B). A quantitative measure of pain was obtained by using the PRI(R) scoring method. The rank values of the words chosen by the subject were added up to obtain a total score, and a score for each of the three categories.

Muscle Tenderness Measurement. Muscle tenderness was quantitatively documented by measuring pain threshold using a pressure threshold meter (Pain Diagnostics & Thermography, 17 Wooley Lane East, Great Neck, New York) (Appendix C). The following locations were tested bilaterally: C2, C4, C6 levels, 2 cm lateral to the midline of the spinous process; at each vertebral level T1-T8, 2 cm lateral to the midline; 2 points on the tibialis anterior muscle belly located 7 and 10 cm distal to the tibial tubercle, 2 cm lateral to the crest of the tibia. A single score for each of the three body regions (cervical spine, thoracic spine, anterior lower leg) was determined by calculating the mean of all the trial scores obtained for each region.

Range of Motion Measurement. Two OB goniometers (Olle Blomqvist Rehab-Produkter AB, Olaus Petrigatan 10-Fack, 10051 Stockholm) (Appendix D), were used to measure the range of motion of the upper and middle thoracic spine (T1-T8) for each of the three cardinal planes of movement: sagittal plane (combined flexion and extension); horizontal plane (combined right and left rotation); coronal plane (combined right and left side flexion).

Subjects were positioned in sitting on a stool so that their feet were flat on the floor. One adhesive pad was placed directly over the T1 spinous process, and a second pad directly over the T8 spinous process. The goniometers were attached to the pads directly for measurement of side flexion, and indirectly via right angled plates for measurement of flexion, extension, and rotation. When measuring movements in the horizontal plane, the compass housing was rotated so that the compass needle pointed to zero when the subject was in the starting position. When measuring movement in the sagittal or frontal planes, the housing was rotated so that the inclination needle pointed to zero when the subject was in the starting position.

For the measurement of flexion, subjects let their arms hang by their sides as they tucked their chin to their chest, and slumped forward as far as possible. For extension, they tipped their head backward, and arched their upper back backward as far as possible. Subjects performed rotation by turning as far as possible to the right and then left, with their hands on opposite shoulders. Side flexion ROM was performed with the arms hanging by the sides as the subjects bent sideways as far as possible to the right, and then left. Passive overpressure was applied by the tester at the end range of each of the active movements, to ensure that the end of available range of motion had been attained.

Subjects were asked to repeat each movement two times. The first movement served as a "warm-up" to ensure that the subjects understood the instructions given. The subjects were asked to hold the end range of the movement of the second trial while the measurements of angular motion were recorded from the goniometers.

Regional range of movement of T1-T8 was calculated by determining the difference between the angular motion indicated by the two goniometers. The measurements of flexion and extension, right and left rotation, and right and left side flexion, were summed to obtain a combined score for ROM in the sagittal, horizontal, and frontal planes respectively.

Passive Intervertebral Joint Mobility Measurement. Maitland's (1986) manual assessment techniques of physiological and accessory joint motion were used to assess upper and middle thoracic passive intervertebral joint mobility. These techniques provide information about joint range of motion, as well as the quality of resistance throughout the range of movement, and the endfeel of the movement (the quality of resistance to movement at the end of available range of movement).

PIVM of each motion segment T1/T2 through T8/T9 was assessed for each of the following movements: flexion, extension, bilateral side flexion, bilateral rotation, and if indicated, posterior/anterior accessory glides. Subject positioning and application of the assessment technique varied depending on the level of the motion segment and the specific movement being assessed (Appendix H).

The PIVM of each movement at each motion segment was scored on a 5-point rating scale (Appendix I) ranging from locked to hypermobile, and subsequently categorized as having either normal or abnormal mobility (Grade 3 = normal; Grades 0, 1, 2, 4 = abnormal). The number of motion segments in the T1-T8 region categorized as having abnormal mobility were summed to obtain a single score of abnormal joint mobility for the upper and middle thoracic spine. There are a total of eight motion segments in this region.

Data Analysis

The data collected by the Personal Data Information Sheet was summarized using descriptive statistics to provide information on the age and gender of participants, the percentage of persons involved in litigation, and so on. Descriptive statistics were also used to summarize the information provided by the temporal properties, and present pain intensity index of the MPQ. The common patterns of spatial distribution of pain as indicated by the MPQ body diagram were qualitatively described.

Independent t-tests (Huck et al. 1974; Pagano 1990) were used to examine differences between groups for the PRI of the MPQ, and the number of abnormal motion segments determined by the PIVM assessment.

Two way ANOVAs with repeated measures (Huck et al. 1974; Pagano 1990) on one factor were conducted for each of the dependent variables, pain threshold (group vs body region) and ROM (group vs plane of movement). When the ANOVAs revealed a significant difference, Tukey's HSD multiple comparison test (Pagano, 1990) was used to conduct post-hoc analyses. The adjusted Bonferroni method was utilized to control Type I error associated with multiple statistical comparisons (Ottenbacher 1991). The two multiple tests for each of the above statistical procedures were rank ordered by their importance to the research question, so that the more important tests were evaluated with greater power ($p < .05$) than the second ranked test ($p < .025$).

SPSSPC and SPSSX (SPSSX, SPSS Inc, 444 N Michigan Ave, Chicago Illinois 60611) statistical software was used to analyze the data.

Ethical Considerations

Study participants were informed of the nature of the study by verbal explanations provided by the investigator. They were also provided with written information on the informed consent form (Appendix F), which they were asked to read and sign prior to testing. Participants of the whiplash group were informed of the possibility of a slight, temporary increase in whiplash signs and symptoms following the examination. They were told that they should contact the principal investigator if the increase in signs and symptoms persisted for more than 24 hours. Subject participation involved a single test session of approximately 45 minutes duration, rather than the 1 1/2 hours estimated on the consent form.

Participant confidentiality was maintained throughout the study. Physiotherapists were required to obtain verbal consent from potential subjects before passing along names and phone numbers to the investigator, or interested persons were encouraged to contact the investigator directly. All data sheets were coded, and only the principal investigator had access to the information sheet which cross-referenced names and addresses of subjects with their code number.

Prior to the onset of data collection this study was approved by the "Student Projects Ethical Research Review Committee" of the Department of Physical Therapy, University of Alberta.

CHAPTER FOUR
RESULTS

The results of this study are outlined below. A description of the study subjects is followed by a descriptive analysis of the PDIS data. The results of the MPQ, PTM, ROM, and PIVM assessments are each described in turn. Finally, the results of some additional analyses are presented. The additional analyses were conducted to evaluate differences between gender and point of impact, and the association between the dependent variables.

Subjects

The characteristics of the whiplash and comparison groups are listed in Table 4.1. The raw data for the two groups is presented in Appendix J (Tables J.1 - J.3).

Table 4.1. Characteristics of the whiplash and comparison groups.

GROUP	WHIPLASH (N=30)	COMPARISON (N=30)
GENDER	Females (N=18) Males (N=12)	Females (N=18) Males (N=12)
AGE (years)	Range 17-46 Mean 28.80 SD 9.23	Range 18-47 Mean 28.83 SD 9.12
BODY MASS INDEX	Range 18.42-38.60 Mean 23.98 SD 4.28	Range 18.85-28.72 Mean 23.35 SD 2.38

Abbreviation key: SD = standard deviation

T-test analyses of age and BMI data (Table 4.2), showed that there were no statistically significant differences between the whiplash and comparison subjects with respect to these variables.

Table 4.2 T-test resúlts for age and BMI of the whiplash and comparison subjects.

VARIABLE	t VALUE	PROBABILITY
AGE	-.01	.989
BMI	.71	.479

*significant difference ($p \leq .05$)

Abbreviation Key:
BMI = body mass index

Personal Data Information Sheet

Table 4.3 presents descriptive statistics of factors related to the motor vehicle accidents of the whiplash group.

McGill Pain Questionnaire

Eleven of the 30 whiplash subjects participating in the study stated that they no longer had any pain related to their whiplash injury. Of the 19 remaining whiplash subjects, 53% (10) claimed that they had constant pain in the thoracic region, and 47% (9) indicated their pain was periodic in nature. At the time of assessment, 18 (60%) of the cohort subjects were experiencing pain. Table 4.4 shows the percentage of persons choosing each level of the "Present Pain Intensity Index" of the MPQ. The majority of subjects (83%) chose the less intense levels of the index.

Only one comparison subject stated that she had thoracic pain at the time of assessment. She described the pain as being constant in nature, and of mild intensity.

The spatial distribution of thoracic pain experienced by the whiplash subjects (and the single comparison subject), was illustrated by the body drawing component of the MPQ. A typical pattern of pain distribution was not apparent, although many of the drawings demonstrated pain around the scapular area bilaterally. Eleven of the 18

Table 4.3. Descriptive statistics of factors related to the motor vehicle accidents of whiplash subjects.

VARIABLE	DESCRIPTIVE VALUE
Point of impact	43% (N=13) front-end 57% (N=17) rear-end
Position in vehicle	70% (N=21) driver 30% (N=9) passenger
Number of days post-accident	Range: 5-90 days Mean: 35 days SD: 24 days
Use of seatbelt	90% (N=27) yes 10% (N=3) no
Use of headrest	10% (N=3) yes 90% (N=27) no
Medical attention	67% (N=20) yes 33% (N=10) no
Physiotherapy treatment	40% (N=12) yes 60% (N=18) no
Chiropractic treatment	10% (N=3) yes 90% (N=27) no
Litigation pending	40% (N=12) yes 50% (N=15) no 10% (N=3) maybe

Table 4.4. Percentage of whiplash subjects (N=30) choosing each level of the "Present Pain Intensity" index of the MPQ.

0 No pain	1 Mild	2 Discom-forting	3 Distres-sing	4 Horrible	5 Excru-ciating
40% (12)	10% (3)	33% (10)	7% (2)	3% (1)	7% (2)

whiplash subjects indicated that their pain extended below the inferior angles of the scapulae. Only one subject noted the presence of anterior chest pain (around the manubrial-sternal junction), and two persons indicated that their pain radiated bilaterally to the lateral aspect of the middle and lower thorax. Central back pain extending the whole length of the spine was shown by four persons.

From Figure 4.1, it can be seen that PRI(R) mean scores of the whiplash group were greater than those of the comparison group, for each of the individual categories and the total score. T-test analysis of the PRI(R) total scores showed that there was a significant difference ($p=.000 < .05$) between the whiplash and comparison groups.

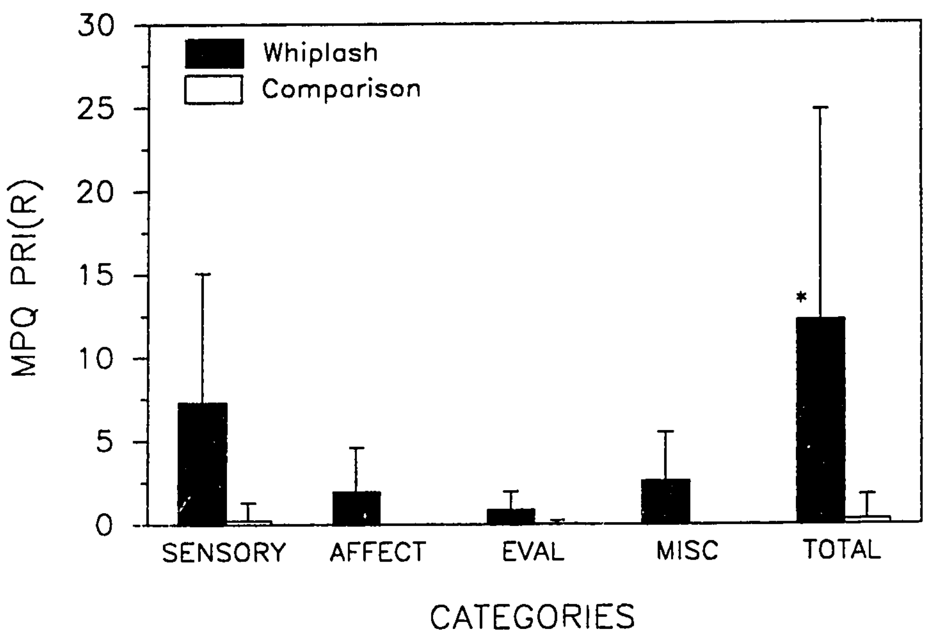

Figure 4.1. Means and SD of the PRI(R) for whiplash and comparison groups. Sensory, affective, evaluative, and miscellaneous categories, and total score. *Whiplash group significantly ($p \leq .05$) different from comparison group.

Pain Threshold Measurement

The means and standard deviations for PTM of the cervical and thoracic spines, and the tibialis anterior muscle are presented in Figure 4.2. Significant group ($p=.001 < .05$) and site ($p=.000 < .05$) effects were revealed by the 2-way ANOVA.

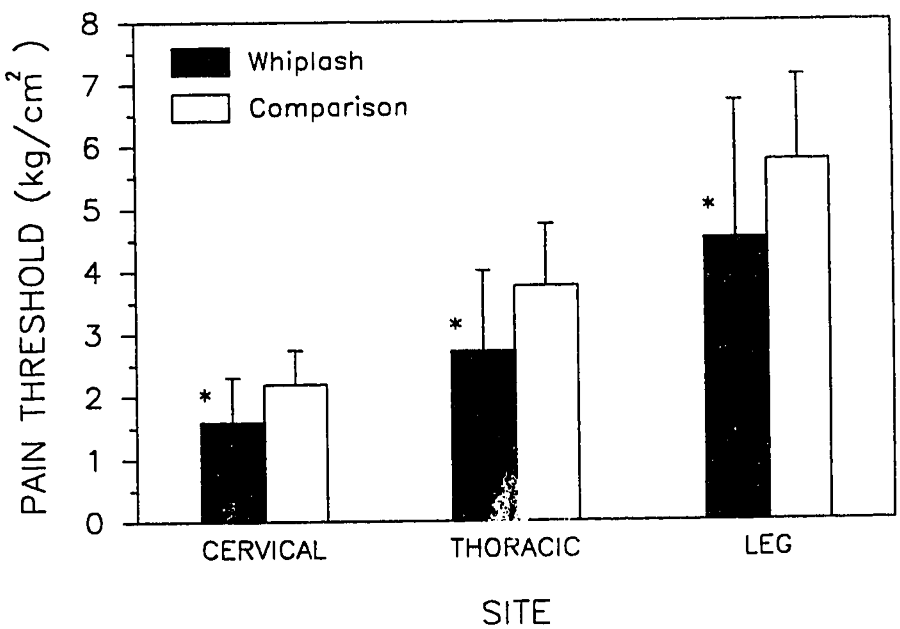

Figure 4.2. Means and SD for PTM of whiplash and comparison groups. *Significantly ($p \leq .05$) different from comparison group. Leg PTM > thoracic PTM > cervical PTM ($p \leq .05$)

Range of Motion

Comparisons between the whiplash and comparison groups for ROM measures of the three planes of movement are illustrated in Figure 4.3. The 2-way ANOVA demonstrated a significant difference ($p=.000 < .025$) between planes of movement.

Passive Intervertebral Joint Mobility

The number of abnormal PIVMs for the whiplash and

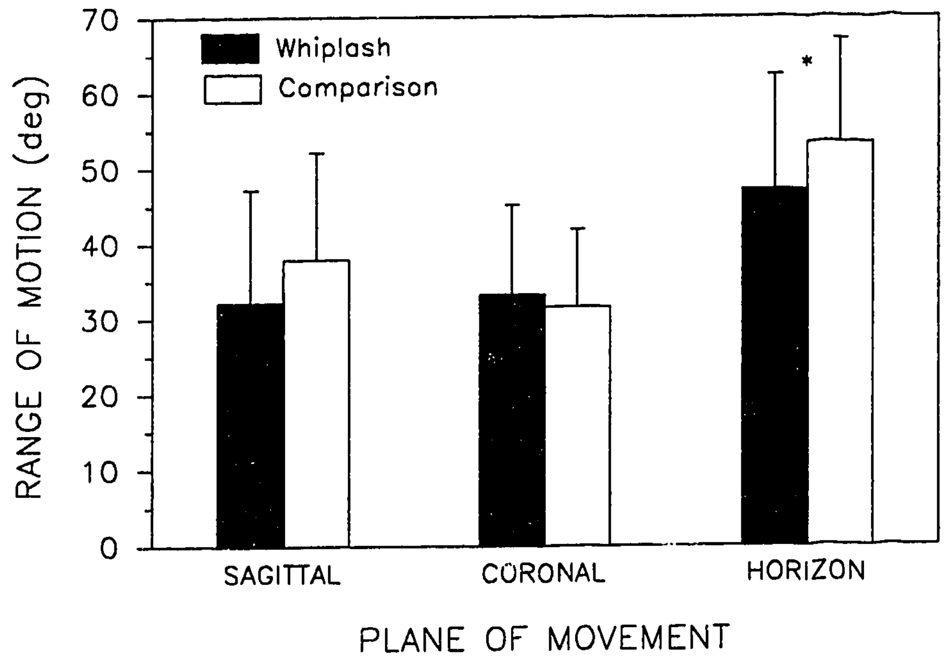

Figure 4.3. Means and SD for ROM measures of whiplash and comparison groups. *Horizontal ROM significantly ($p \leq .05 < .025$) different from ROM in the sagittal and coronal planes.

comparison groups are illustrated in Figure 4.4. The difference between groups was highly significant ($p = .000 < .025$).

Additional Results

In addition to the statistical procedures described in "Chapter Three - Methods and Procedures", a number of other analyses were run to help explain the findings of the main analyses. All Tables and Figures illustrating the results generated from these additional analyses are contained in Appendix K.

Gender differences. To determine if there were gender differences in response to the MPQ, an independent t-test was run for the whiplash group only. The comparison group

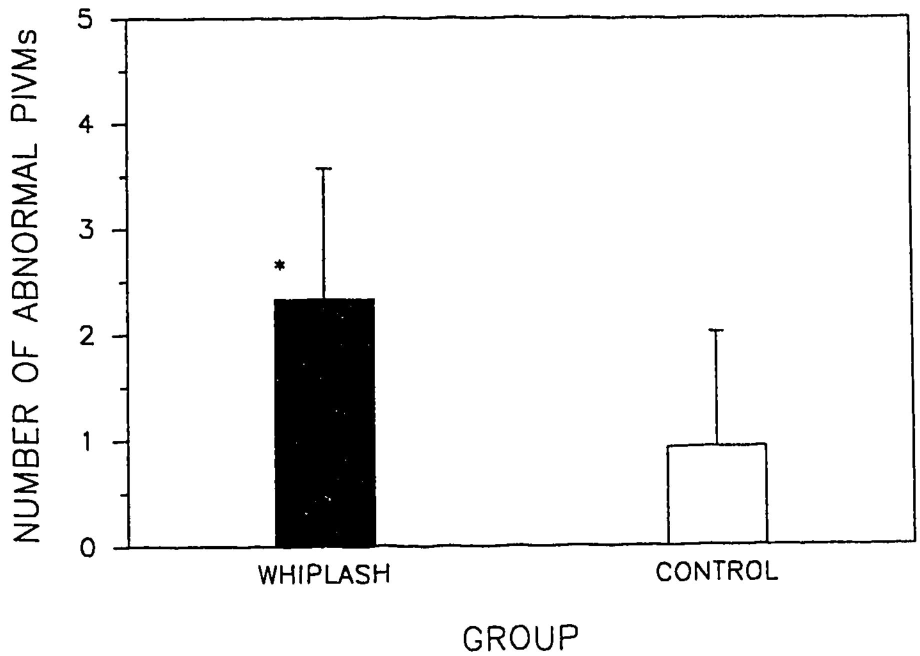

Figure 4.4. Means and SD for PIVM of whiplash and comparison groups. *Significantly ($p \leq .025$) different from control (comparison) group.

was not included in the gender analysis, because only one comparison subject completed the MPQ. The data of the whiplash group are illustrated in Figure K.1. The t-test showed there was no significant difference ($p=.574 > .05$) between males and females.

A 2-way ANOVA compared gender and group on the number of abnormal PIVMs. The results are illustrated in Figure K.2. There was no significant gender difference ($p=.790 > .05$), but there was a significant group difference ($p=.000 < .05$).

Three-way ANOVAs were run to determine if males and females of the whiplash and comparison groups demonstrated significantly different pain threshold and ROM scores. The analysis of PTM revealed significant main effects (gender, group, and site of PTM), 2-way interactions (gender by group, gender by site of PTM), and a significant ($p=.020 < .05$) 3-way interaction (site of PTM by gender and group).

The results are illustrated in Figure K.3. The ROM analyses, on the other hand, demonstrated significant main effects for gender and plane of movement, and a significant interaction effect for gender by group ($p=.046 < .05$) (Figure K.4).

Point of Impact. Point of impact was considered as an independent variable, to determine if there were differences in the measures of thoracic function between persons involved in front-end and rear-end collisions. The data generated by the MPQ and the PIVM assessments were analyzed using t-tests. The data generated by the assessment of pain threshold and ROM were analyzed using 2-way ANOVAs. The results are illustrated in Figures K.5-K.8. There were no significant differences between front and rear-end collisions for any of the dependent variables assessed.

Correlation of Thoracic Function Measures. Pearson product moment correlations were calculated to assess the relationships between the dependent variables evaluated in the study. The results are presented in a correlation matrix (Table K.1).

CHAPTER FIVE
DISCUSSION

The emphasis in the literature regarding whiplash injury and whiplash syndrome, has been related to the cervical spine. In light of the large percentage of persons whose problems persist for extended periods of time, despite treatment of the cervical spine, further study of the effects of whiplash injury are warranted. This study addressed the effect of whiplash injury on the thoracic spine with regard to four variables: pain, pain threshold, ROM, and PIVM.

The main results of the study indicated that pain, and the number of motion segments exhibiting abnormal mobility, were greater in the whiplash group relative to the comparison group. ROM of the region (T1-T8) was not significantly affected by the trauma. Pain threshold was lower across all sites following whiplash injury, relative to the comparison group.

Discussion of the subjects will be followed by discussion of the results of the MPQ, pain threshold, ROM, PIVM, and the additional analyses conducted (differences in gender and point of impact, and correlation of the dependent variables).

Subjects

Gender, age, and BMI have been implicated as factors affecting the dependent variables of interest in this study. Gender and age were controlled for by matching the whiplash and comparison subjects on these variables. BMI was determined to be comparable between the whiplash and comparison subjects. Therefore, it is unlikely that these variables had any effect on the between groups results.

Thirteen of the whiplash injured subjects were recruited from the University of Alberta student population, and seventeen from the community at large. The majority of comparison subjects (N=25) were recruited from the University of Alberta student and staff population. Therefore, the two groups were recruited from a similar 'occupational' population.

Data were collected on occupations, but not recreational activity levels. Whether occupational and recreational activities affect thoracic spine function has not been addressed. Also, few studies have addressed the role of occupational and recreational activities as factors affecting whiplash syndrome. Balla (1980) suggested that there was a greater incidence of "late whiplash syndrome" in males of upper middle occupational categories compared to lower categories, but statistical significance was not determined.

Lifestyle activities of whiplash and comparison subjects were not controlled for in this study. Although many of the subjects of the two groups were recruited from a similar 'occupational' population, extracurricular activities may have been very different. It is possible that differences between groups with respect to this variable may have affected the results.

Variability of whiplash subjects with regard to the severity of accidents, number of days post-accident, and treatment received or not, may also have affected the results by influencing the extent of tissue damage, or tissue healing. Some of the subjects were still in the acute phase of tissue healing, some in the chronic phase (N=5 greater than two months post-accident), and still others claimed that their signs and symptoms had completely resolved. Some subjects did not seek medical treatment following the accident, while others continued to receive treatment. Twelve persons had been referred for physiotherapy treatment, and another three sought chiropractic treatment. The treatment programs themselves were also variable.

Improper use of head restraints and seatbelts have been implicated as factors affecting the severity of injury resulting from whiplash trauma. Head restraints were designed as a safety measure to minimize head displacement in the event of a whiplash injury (Croft 1988a). However, if used improperly they are not effective, and may in fact contribute to a more severe injury. Only three subjects indicated that they were using their headrest at the time of their accident.

It has been suggested that seatbelts may cause injury to the anterior chest wall, however, only one subject complained of anterior chest pain, and the location of the pain was not related to positioning of the shoulder harness. Although information on the use of seatbelts and head restraints was collected, this study was not designed to statistically analyze the data.

Information on litigation involvement was also collected, but not statistically analyzed. The only conclusion that can be drawn from the data regarding this variable, is that the majority of persons who indicated that they were experiencing thoracic pain, were also involved in litigation processes (67%). None of the painfree subjects were involved in lawsuits related to their accident.

Norris and Watt (1983) and Maimaris et al. (1988) stated similar findings. Norris and Watt (1983) indicated that only 50% of persons with mild signs and symptoms, but all persons with severe problems sought legal compensation. Maimaris et al. (1988) found that 57% of symptomatic subjects and only 18% of asymptomatic subjects were claiming compensation.

Some authors (Gotten 1956; Hodge 1971) have suggested that involvement in the litigation process and the potential for monetary compensation, may influence the presentation and progression of whiplash signs and symptoms. They suggested that persons who claim compensation present with more severe symptoms that improve after settlement of the claim. However, there is little evidence to support this view. Several authors (Braaf & Rosner 1958; Gargan & Bannister 1990; Hodgson & Grundy 1989; Hohl 1974; Maimaris et al. 1988; Mcnab 1964; Norris & Watt 1983; Pennie and Agambar 1991) have found that although persons with more severe and persisting problems are more likely to seek compensation, litigation has no affect on the outcome of the patient's condition.

Representativeness of the whiplash group was evaluated by comparing it with the Alberta Traffic Collision Statistics report of 1991 motor vehicle accidents (Alberta Transportation & Utilities 1993). The report indicated that 15-24 year old persons had the highest percentage (31.2%) of motor vehicle accident casualty rates compared to all other age groups. If the age range is restricted to 15-44 years, as it was in this study, then 15-24 year olds comprised 45% of the casualty rates. 53% of whiplash subjects in the present study were between 15-24 years of age. Although the study subjects were comparable with Alberta statistics regarding age, the study subjects were not representative of provincial gender statistics. Males were more often (2:1) involved in casualty collisions than females. However, 60% of subjects who volunteered to participate in this study were female.

According to Alberta statistics, 59.2% of accidents in 1991 involved front-end collisions, 21% rear-end collisions, and 19.8% side collisions; 81% occurred in/near an urban centre; and 62% of injured vehicular occupants were drivers. In comparison, 43% of accidents sampled in this study were front-end collisions, and 57% rear-end; 100% of accidents occurred in/near an urban area; and 70% of subjects were driving at the time of the accident.

Overall the whiplash group assessed in this study was fairly representative of persons injured in motor vehicle accidents in Alberta. Therefore, the results of this study may be generalized to the population with some caution.

McGill Pain Questionnaire

The hypothesis that thoracic pain would be greater in the whiplash injured group relative to the comparison group was upheld. The finding of a significant difference between the groups was expected, based on clinical experience. Although no studies specific to the prevalence of thoracic pain following whiplash injury have been reported, its presence had been noted in numerous studies. The results of this study support the suggestion that thoracic pain is a component of whiplash syndrome.

The prevalence of thoracic pain in the comparison group was only 3% (N=1). Considering the sample assessed was comprised primarily of students, it was expected that a greater number of subjects would have pain in the upper and middle back, as a result of a prolonged sitting posture. As the literature has not reported any studies that have assessed the prevalence or incidence of thoracic pain in healthy persons, this needs to be addressed by further study.

The results of the PRI(R), in addition to showing a significant difference between groups, indicated that the whiplash injured subjects characterized their thoracic pain more in terms of the sensory dimension, than the evaluative, or affective dimensions. This suggested that although there was an emotional and behavioral component to the pain experienced following a whiplash injury, the physical sensation was the primary pain factor. There are a number of reasons why the pain may have been described more in sensory terms. The most obvious reason is that there are twice as many sensory descriptor categories on the MPQ for subjects to choose, than evaluative or affective categories.

Also, the majority of injuries were not very severe, so that subjects were able to continue their normal daily activities.

The MPQ has not been used previously to assess whiplash injured persons, or to assess thoracic pain conditions. However, it has been used extensively to measure low back pain. Prieto et al. (1980) identified a sensory descriptive factor that accounted for the majority of variance (77%) in the description of chronic low back pain. Evaluative, affective-sensory, and affective factors made up the remaining variance. Although whiplash subjects also tended to describe their pain more in sensory terms further study would be required to determine if thoracic back pain following whiplash injury was similar to chronic low back pain resulting from different mechanisms.

Leavitt et al. (1978), in contrast, found that the factor accounting for most of the variance in the description of back pain, was comprised of words from the affective categories of the MPQ. Sensory descriptors comprised most of the other factors revealed by their study. Leavitt et al. (1978) did not describe the diagnoses, or the duration of back pain of their subjects.

The majority of whiplash subjects participating in this study were still in the acute phase of their injury. Sixty per cent were less than 1 month, and 80% less than two months post-accident. The results of the PRI(R) supported the findings of previous studies comparing acute and chronic pain patients. Reading (1982) suggested that acute episiotomy pain patients chose sensory descriptors to a greater extent than chronic pelvic pain patients. The latter chose affective descriptors with greater frequency. Melzack et al. (1982) came to the same conclusions in their study of emergency clinic subjects who were suffering acute injuries. They also found that the sensory component of pain was the primary factor of acute pain description.

The spatial distribution of thoracic pain illustrated by the pain drawings of whiplash subjects, did not demonstrate a "typical" pattern overall. Comparison of the pain drawings to referred pain charts (Dwyer et al. 1990; Feinstein 1977), indicated that the pain illustrated was probably referred from both cervical and thoracic segments. C3-C7 zygapophyseal joints and interspinous tissues have been shown to refer pain to an area extending from the cervico-thoracic junction, distally to the inferior angles of the scapulae, and bilaterally to the shoulders. T1-T8 interspinous tissues have been shown to refer pain to an area extending from the superior angles of the scapulae, to the lower borders of the chest wall. The majority of whiplash injured subjects in this study who were experiencing pain at the time of assessment, indicated that they had pain in this thoracic referral region. Only seven of the 18 subjects claimed their back pain was restricted to the area proximal to the inferior angles of the scapulae.

Clinically, it is important that reports of subjective pain in the thoracic region be correlated with more objective assessment findings to determine where the pain originates from. Soft tissue tension testing (specific active, passive, and resisted movement tests and ligament stress tests) and specific biomechanical assessment (PIVM) of the cervical and thoracic segments should be conducted to determine what reproduces the pain.

The specific structures of the thoracic region that are responsible for the pain can only be speculated upon. Few studies have been conducted regarding pathology of the thoracic area following whiplash injury, therefore it is not known for certain what structures are damaged. Maiman et al. (1986) stated that the body and various soft tissues of the thoracic motion segments could be damaged in a whiplash injury. The respiratory and thoracic extensor muscles, zygapophyseal joints, intervertebral discs, and vertebral bodies are known to be innervated. Although it is assumed that any structure that is innervated is also potentially pain sensitive, further study of thoracic spine innervation is necessary before conclusive statements can be made.

There were two possible sources of error in the administration of the MPQ that could have affected the results, and the subsequent interpretation of results. Subjects were instructed to complete the questionnaire only with regard to the thoracic pain that they were experiencing at that point in time. The instructions were based on the assumption that pain in a specified area can be described independently of pain felt elsewhere in the body, and that present pain can be described to the exclusion of the memory of pain. Whether this is truly possible is not known, and even if it is possible, there was no way to ensure that subjects complied with the instructions.

Pain Threshold Measurement

The results of this study revealed a significant difference between groups, and between sites on the measure of pain threshold. The hypothesis, that there would be a group difference of cervical and thoracic pain threshold, but not of the tibialis anterior muscle, was not upheld.

Lower PTMs were not specific to the body areas that were subjected to whiplash trauma, rather the results showed a generalized decrease in pain threshold of the whiplash group relative to the comparison group. O'Driscoll and Jayson (1974) compared pain threshold at a single point on the centre of the forehead in patients with osteoarthrosis (OA) of the hip and healthy control subjects. They found that the OA hip patients had significantly lower PTM than the control subjects. Langemark et al. (1989) found that patients with chronic headache had decreased PTM not only in the temporalis and occipital muscles, but also in the hands. Gerecz-Simon et al. (1989) observed the same occurrence in rheumatoid patients. They concluded that decreases in pain threshold were not localized to areas commonly affected by rheumatoid arthritis, but that patients demonstrated decreased pain threshold across all sites assessed (three bony points and three muscle points). However, their study also found that osteoarthritic and ankylosing spondylitis patients had generally higher pain thresholds than normals, across the six sites evaluated.

This phenomenon can be explained by the concept of a central pain control mechanism. It is commonly acknowledged that pain perception is modified at the spinal cord and higher central nervous system levels, as transmission ascends from the periphery. In addition, descending pathways are also known to modify pain. Some of these pathways have been shown to be inhibitory to pain, while others have demonstrated excitatory responses.

For example, ascending pathways of nociception are known to excite the ascending reticular activating system, which leads to excitation of the cerebral cortex as a whole, and an increased level of consciousness (Watson 1981b). Brain regions that are known to influence descending systems include the cerebral cortex, periaqueductal gray matter in the brain stem, and serotonergic neurons of the raphe magnus nucleus (Bishop 1980). As well, Yezierski et al. (1983) found that stimulation of the sensorimotor cortex in primates was shown to have an inhibitory, and/or an excitatory effect on nociceptive neurons in the spinothalamic tract.

Whether the generalized response is excitatory or inhibitory may depend on the patient's condition or disease process. A diffuse excitatory response could account for a general decrease in pain threshold following a whiplash injury.

There have been no previous studies on PTMs of whiplash subjects relative to comparison subjects. However, other studies have found group differences between a variety of patient populations and healthy controls (Gerecz-Simon et al. 1989; Scudds et al. 1988; Tunks et al. 1988). Scudds et al. (1988) and Tunks et al. (1988) determined that pain threshold was significantly different between fibromyalgic patients and control subjects. Gerecz-Simon et al. (1989) showed significant differences between rheumatoid arthritis, osteoarthritis, and ankylosing spondylitis patients, and control subjects.

The mean pain threshold values of the comparison group in this study were in accordance with Hogeweg et al. (1992). The pain threshold value of healthy subjects (fourteen males, fourteen females) in their study, at the C6 level was 2.86 kg/cm^2 (.79), and the average mean value of the T1, T3, and T6 levels was 4.31 kg/cm^2 (1.37). The mean values obtained in this study were 2.39 kg/cm^2 (.55) and 3.76 kg/cm^2 (.99), for the cervical (C2, C4, C6) and thoracic (T1-T8) areas respectively.

The site difference pattern demonstrated in this study, was also in accordance with the findings of previous studies (Fischer 1986a; Hogeweg et al. 1992; Simms et al. 1988). PTM values of the spine increased progressively in a cranial to caudal direction, and tibialis anterior muscle values were found to be greater than the spinal measurements. These findings indicated that the cervical region was more sensitive than the thoracic region, which in turn was more sensitive than the tibialis anterior muscle. These results may be due to a difference in the density of pain/pressure receptors in these areas (Ohrbach & Gale 1989b; Watson 1981a), or it is possible that differences in tissue compliance affect PTM (Ohrbach & Gale 1989b).

Error in the assessment of pain threshold may have occurred due to landmarking error, variation in the rate of application of pressure, and non-compliance of the subjects with respect to indicating the onset of discomfort.

Attempts were made to minimize these potential sources of error through practice, and by ensuring that subjects understood the test protocol. Pilot study results indicated that test-retest reliability of the tester was very good.

A ceiling effect was not a problem in this study. Only one of the male whiplash subjects reached the ceiling in the measurement of the tibialis anterior muscles. Although this may have increased the mean PTM of the whiplash group slightly, it did not have an effect on the overall results, as a significant difference between groups was still demonstrated.

<u>Range of Motion</u>

The hypothesis, that ROM would be less for the whiplash group relative to the comparison group, was not upheld. The finding of no significant group difference is explained in part by the large between-subject variability of ROM in all three planes of movement. With such great variability in ROM measures, the differences between group measures would have had to be greater than they were to demonstrate a significant difference. It was expected that a 10^{o} difference between group means would be clinically significant. The differences observed were not close to this criterion measure.

The finding of a significant difference between planes of movement was expected. Thoracic rotation was significantly greater than side flexion, and flexion/extension ROM. Previous studies (Gregerson & Lucas 1967; Mellin 1986, 1987; O'Gormann & Jull 1987; White 1969; White & Panjabi 1990) also have shown that rotation in the thoracic spine is greater than movement in either of the other two planes. Flexion/extension and side flexion movements have been shown to have similar ranges.

The primary reason for differences in ROM in the different planes of movement, is the orientation of the zygapophyseal joints. In the thoracic spine the joints are oriented in a coronal plane. This orientation facilitates rotation, but limits the amount of flexion/extension and side flexion that can occur. In comparison, the zygapophyseal joints of the lumbar spine are oriented in the sagittal plane. This orientation facilitates flexion and extension, but restricts rotation ROM.

There have not been any studies reported in the literature with regard to thoracic ROM of persons who have sustained a whiplash injury. However, thoracic ROM values of the comparison group can be compared to previous studies. Thoracic flexion/extension and rotation ROM values found in this study were in accordance with Gregerson and Lucas (1967), White (1969), and White and Panjabi (1990). Side flexion ROM, on the other hand, was not comparable. The majority of other studies reporting thoracic mobility have assessed ROM of the total thoracic spine (T1-T12), making it difficult to directly compare with this study, which only measured T1-T8 levels. However, the ROM values found in this study were less than the values found in those previous studies (Mellin 1986; Mellin 1987; Mellin & Poussa 1992; Mellin et al. 1991; O'Gorman & Jull 1987; Poussa et al. 1989). This finding was as expected, considering that their measures included more motion segments. In constrast, flexion/extension values obtained by Mellin (1986), and rotation ROM values obtained by Poussa et al. (1989), and Mellin and Poussa (1992), were less than or equal to the values found in this study. The latter two studies were conducted on adolescent populations.

Validity of the OB goniometer as an assessment tool of thoracic movement in the sagittal and horizontal planes was confirmed in this study. The results obtained with the OB goniometer were comparable with those obtained in cadaver studies (White 1969; White & Panjabi 1990), and relatively direct in vivo measures (Gregerson & Lucas 1967).

Possible sources of error in this study regarding ROM assessment included: landmarking for the placement of the goniometers; orientation of the goniometer (the indicator needles caught if the instrument was not at 90° to the plane of movement); movement of the skin relative to the bony landmarks during assessment; and tester bias in determination of endfeel with the application of passive overpressure, and in reading the instruments.

Potential error was minimized by practising the measurement techniques prior to the onset of data collection. Very good test-retest reliability was demonstrated by the pilot study. Skin movement was not controlled for, and therefore may have affected the results.

<u>Passive Intervertebral Joint Mobility</u>

As hypothesized, the whiplash group had a significantly greater number of upper and middle thoracic motion segments demonstrating abnormal mobility, relative to the comparison group. The results are not surprising, considering the extent of damage to spinal related structures that has been proposed (Bocchi & Orso 1983; Kettner & Guebert 1991; Macnab 1964; Maiman et al. 1986; Twomey & Taylor 1993). These same structures are responsible for initiating, guiding, and limiting the movement of the spine. If the tissues are injured, it is likely that movement will be affected (increased or decreased depending on the injury).

Worth (1991) found significant differences in C1/2 and C2/3 flexion/extension segmental mobility in whiplash subjects, compared to healthy control subjects. He stated that his findings supported the claims of manual therapists, that abnormal joint mobility often exists despite conclusions of "normal" movement based on plane x-rays. Worth (1991) further suggested that the functional x-ray/geometric technique used in his study could be used to validate manual palpation techniques. Dvorak et al. (1993)

also assessed cervical segmental mobility of chronic whiplash subjects using radiographs and a computer digitizer. They noted that whiplash subjects had decreased anterior translation at the C6/7 level, relative to healthy subjects. Subjects also displayed a trend to hypermobility of anterior and cephalo-caudad translation, and rotation of the upper cervical segments.

There have not been any studies reported in the literature with respect to measurement of segmental mobility of the thoracic spine in healthy or whiplash injured persons. The outcome measure for the assessment of PIVM in this study, was the number of segments exhibiting abnormal mobility. The study was not designed to statistically differentiate between the types of abnormal movement demonstrated, or the specific levels of abnormal movement. It would be interesting, and clinically relevant to assess these variables in future studies.

The findings of this study indicated that some abnormal mobility is "normal". Comparison subjects had an average of one segment that did not demonstrate normal movement. Whiplash subjects, in comparison, had an average of almost 2.5 segments exhibiting abnormal movement. The standard deviation for both groups was just greater than one segment.

There are a few sources of error in assessing PIVM that may have affected the results of this study. Potential landmarking errors, and tester bias regarding the subjective nature of assessing endfeel, were minimized by practising the techniques prior to the onset of data collection. However, tester bias related to knowing which group subjects belonged to was not controlled for. The final source of error was subject variability relative to ease/difficulty of palpation. It is more difficult to palpate segmental spinal movement of some persons compared to others, for a variety of reasons. The subject's ability to relax, and thickness and extensibility of the soft tissue overlying the spinal joints are two of the reasons. It was not possible to control for this variable.

<u>Discussion of Additional Results</u>

This study was not designed to evaluate gender, point of impact, or the relationship between the dependent variables. As a result, the groups had unequal numbers of subjects, and some of the sample sizes were small. These factors must be considered in the following interpretation of results.

<u>Gender differences</u>. The literature presents contradictory information with respect to the response of males and females to whiplash injury. Bring and Westman (1991) and Hohl (1974), stated that there were gender differences related to chronicity of whiplash signs and symptoms. Hohl (1974) found that females did not recover from their symptoms (headache, neck pain and stiffness, etc.) as frequently as males, and Bring and Westman (1991) found that females reported significantly more severe symptoms (migraine-like headaches, eye, ear, and face symptoms, etc.) than males. On the other hand, Deans et al. (1987) and Hohl (1975) did not find significant differences in reported pain between males and females who had sustained whiplash injury.

Results of this study indicated that there were no gender differences for the MPQ and PIVM evaluations. This suggested that males and females responded the same to whiplash injury regarding subjective pain reports and passive mobility of thoracic motion segments.

None of the literature reviewed for this study addressed gender differences with respect to the MPQ. The only studies reported in the literature comparing gender on PIVM, evaluated lumbar mobility in painfree subjects; Jull and Bullock (1987a, 1987b) found no differences between males and females.

The finding of a three-way interaction effect (gender by group by site) for PTM, and a two-way interaction effect (gender by group) for ROM, indicated that the response of males and females in the two groups was different. The results suggested that females responded differently to whiplash injury than males with regard to pain threshold and ROM. Croft (1988b) suggested that the female neck may be more vulnerable to injury due to whiplash trauma, because women have smaller muscles in the cervical and thoracic regions than males. Muscles play a protective role by restricting ROM, so that heavier musculature might limit the amount of tissue damage.

It was interesting that there was no significant gender difference of the comparison subjects for PTM. Although Jensen et al. (1986) also found no difference between males and females, several studies (Fischer 1987a; Ohrbach & Gale 1989a; Takala 1990) have found a male/female difference. The results of this study suggested that whether there is a gender difference or not, may depend on the population (patient vs healthy subjects), and site assessed.

The finding that male and female comparison subjects did not differ on ROM measures was in accordance with Lowery et al. (1992). However, they assessed sagittal and coronal movement of the lumbar spine. The vast majority of other studies (almost all on the lumbar spine), have found some differences in ROM between males and females depending on age, plane of movement, and population assessed (Archer et al. 1974; Haley et al. 1986; Mellin & Poussa 1992, Moll & Wright 1969; Taylor & Twomey 1980).

<u>Point of impact</u>. There were no statistically significant differences between subjects involved in front-end and rear-end collisions on the measures of pain, pain threshold, ROM, and PIVM. However, mean rotation ROM of the rear-end collision group was 11° greater than rotation ROM of the

front-end collision group. It was expected that this difference would be clinically important, but a larger sample size would be needed to demonstrate a statistical difference.

In contrast to this observation, the literature commonly stated that rear-end collisions result in greater tissue damage, and more severe signs and symptoms. However, very few studies have compared front and rear-end collisions, and the findings of these studies are contradictory. Worth (1991) claimed that both front-end and rear-end accident subjects had significantly less cervical mobility than healthy control subjects, but those who sustained rear-end impacts were more affected. Deans et al. (1987) found that self-reported neck pain was significantly more common following rear-end collisions than front-end. Pennie and Agambar (1991) suggested that rear-end collision patients were more likely to have anterior neck pain, but other signs and symptoms did not differ between groups. They did not determine if their results were significant. Larder et al. (1985) and Maimaris et al. (1988), suggested that neck injuries occurred regardless of the point of impact. Maimaris et al. (1988) further suggested that the type of collision had minimal or no effect on the outcome.

<u>Correlation of thoracic function variables</u>. The correlations between the dependent variables were found to be generally significant, but weak. Several other interesting observations were also made about the relationships of the variables.

Cervical and thoracic PTMs demonstrated a very strong relationship, suggesting that these regions were affected by whiplash injury in a similar way. The association of tibialis anterior muscle pain threshold with cervical and thoracic measures was weaker, but still good. These findings were as expected, and were in accordance with the findings of Gerecz-Simon et al. (1989). They also found a strong correlation of pain threshold values between sites. Harris and Rollman (1983) found significant correlations of PTM across different stressors. They suggested that the variables contributing to pain threshold are consistent within an individual.

The weak correlation between different pain measures (the MPQ and PTM), was also supported by the literature. A fair correlation of the MPQ with a visual analogue scale (VAS) was demonstrated by Elton et al. (1979) for patients with various chronic pain conditions. Jaeger and Reeves (1986) concluded that there was little or no relationship between pain threshold and the VAS for myofascial patients. Lautenschlager et al. (1991) also found poor correlation between PTM, a VAS, and pain intensity reported in body drawings by fibromyalgic patients.

ROM values for the three planes of movement were not significantly correlated, perhaps indicating that each movement occurs relatively independently of movement in the other planes. The finding of no correlation between ROM and the MPQ supported the conclusion of Mellin et al. (1991), that spinal ROM is poorly correlated with low back pain. That side flexion and rotation ROM were not significantly correlated with any of the other variables assessed, raised the question of how, or if these movements contribute significantly to thoracic function. On the other hand, flexion/extension ROM was significantly correlated with both PTM and PIVM. It was not clear why flexion/extension was associated with PIVM, but the other movements were not.

Keating (1989) stated that there was minimal information to support the relationship between passive joint mobility of the lumbar spine, and other factors that are thought to affect joint function. The present study demonstrated significant correlations between PIVM and the MPQ, and PTM of the cervical and thoracic paravertebral muscles. It was not expected that PTM of the tibialis anterior muscle would be correlated with passive joint mobility of the thoracic spine.

Clinical Relevance

Functional performance of a given body region is assumed to be affected by a number of factors, including the four dependent variables evaluated in this study. Pain, pain threshold (muscle tenderness), ROM, and PIVM are commonly evaluated in the clinical assessment of whiplash injured patients. The results of evaluating these, and other variables, are used to determine the severity of injury and functional impairment, treatment regime, progression of treatment, and prognosis.

The results of this study suggest that clinicians re-evaluate the use and interpretation of some traditional assessment techniques used to evaluate whiplash injured patients. Assessment of these patients commonly focuses on the cervical region, but the results of this study demonstrated that the thoracic spine may also be affected by whiplash injury. Certainly, further investigation of the effect of whiplash injury on the thoracic spine is indicated.

The results of this study also suggested that the assessments of muscle tenderness and ROM might not provide the information they are thought to provide. The possibility that gender and point of impact may influence examination results, must also be taken into consideration when assessing whiplash injured subjects.

Pain and PIVM demonstrated highly significant differences between the whiplash and comparison groups. However, the finding of minimal pain, and of one or two spinal segments that have abnormal movement, may be "normal" for that individual and have no relevance to the problems that the patient is presenting with. On the other hand, PRI(R) scores of greater than four may be significant. Also, pain drawings may be helpful in localizing the spatial distribution of a patient's pain, and in identifying affected spinal segments that may be referring pain to that area (Aprill et al. 1990).

A significant group difference on PTM was demonstrated in this study. Although PTMs may be used to differentiate whiplash injured patients from healthy persons, they cannot be relied upon to localize areas injured as a result of whiplash trauma. The group difference of PTM was across all sites assessed, including the tibialis anterior muscle. The latter site had not been injured in any of the whiplash subjects participating in this study. The conclusion from the PTM analysis was that following a whiplash injury, pain threshold may be generally lower throughout the body due to facilitation of central pain mechanisms.

ROM of the thoracic spine did not differentiate between the whiplash and comparison subjects. Assessment of ROM of whiplash patients may not provide the clinician with any significant information with respect to severity of injury. Variability of "normal" ROM is so great, it would be very difficult to evaluate the severity of injury due to whiplash trauma by a patient's ROM values.

Despite the limitations outlined above, the measurement tools used in this study, may be used to evaluate changes of these variables in a patient over time. However, the clinician would have to determine that intra-tester reliability was good (significantly high intra-class correlations and small standard errors of measurement).

The finding of generally significant, but weak correlations of the four variables evaluated in this study, indicated that additional factors must contribute significantly to these variables. This suggests that clinical assessment of whiplash injured patients must be comprehensive in nature. It should include a number of different tests, depending on the factors that are determined to be important.

Future studies must identify the variables that affect thoracic function, and then validate clinical measurement tools to ensure that they reliably measure the variables that they are intended to measure. The effect of whiplash injury on the thoracic spine could then be evaluated more completely, and the clinical implications would be more meaningful.

CHAPTER SIX
SUMMARY AND CONCLUSIONS

Summary

The purpose of this study was to determine if there were differences between whiplash injured persons and non-injured persons, with respect to upper and middle thoracic pain, paravertebral muscle tenderness, ROM, and PIVM.

Prior to the onset of the main study, a pilot study was conducted to assess intra-tester reliability of the tester for the measurement tools used in the study.

Sixty subjects (30 whiplash, 30 comparison) participated in the main study. Eighteen females and twelve males, between the ages of 17 and 47 years, comprised each group. Comparison subjects were matched for gender and age ($\pm$ 2 years) with the whiplash injured subjects.

Subjects were required to attend a single testing session that involved: collection of demographic and motor vehicle accident information; assessment of pain using the MPQ; measurement of paravertebral muscle tenderness using a pain threshold meter; measurement of ROM using OB goniometers; and assessment of PIVM using Maitland's (1986) manual assessment techniques.

The data generated by the PDIS, and the temporal properties and PPI index of the MPQ were analyzed using descriptive statistics. The pain drawing of the MPQ was qualitatively described. Independent t-tests were used to assess comparability of age and BMI between the whiplash and comparison groups, and to analyze the MPQ and PIVM data. Pain threshold and ROM data were analyzed using 2-way ANOVAs.

Additional analyses of gender and point of impact differences, and relationships between the dependent variables were also conducted. Gender differences were assessed using an independint t-test for the MPQ, a 2-way

ANOVA for the manual data, and 3-way ANOVAs for pain threshold and ROM data. Point of impact was analyzed using t-tests (MPQ, PIVM) and 2-way ANOVAs (PTM, ROM). Pearson product moment correlations were conducted to assess the association between variables.

Post-hoc analyses were conducted using Tukey's HSD multiple comparison test when indicated. The adjusted Bonferroni procedure (Ottenbacher 1991) was utilized to minimize potential Type I error associated with the multiple statistical comparisons of the main analyses. The probability level for all the additional tests was established at $p \leq .05$.

Conclusions

The following conclusions can be drawn based on the results of this study:

1. Test-retest reliability of the tester for the assessment of pain threshold, ROM, and PIVM was very high.
2. Whiplash injured subjects had significantly greater thoracic pain than non-injured subjects.
3. Pain threshold of cervical and thoracic paravertebral muscles, and tibialis anterior muscles was significantly lower in whiplash subjects relative to comparison subjects.
4. Pain threshold of the tibialis anterior muscle was significantly greater than the thoracic muscles, which in turn was significantly greater than the cervical muscles.
5. ROM of the upper and middle thoracic spine into flexion/extension, side flexion, and rotation, was not significantly different between the whiplash injured and non-injured groups.
6. Rotation ROM was significantly greater than flexion/extension and side flexion ROM.

7. Whiplash injured subjects had a significantly greater number of upper and middle thoracic motion segments exhibiting abnormal joint mobility compared to non-injured subjects.
8. There were no gender differences in response to the MPQ and the assessment of PIVM.
9. Female whiplash subjects demonstrated significantly lower thoracic PTMs than male and female comparison subjects, and significantly lower tibialis anterior PTMs than male whiplash, and female and male comparison subjects.
10. Female whiplash subjects had significantly less ROM than male whiplash subjects.
11. Point of impact (front vs rear-end collision) did not significantly affect any of the dependent variables assessed.
12. Minimal to poor correlations were found between pain, pain threshold, ROM, and PIVM.

<u>Recommendations for Further Study</u>

On the basis of the above study, the following recommendations for further study are presented:

1. Variables most affecting normal thoracic spine function should be identified. For example, active and passive ROM, strength of the functional muscle groups of the thorax, joint mobility of the intervertebral and costal joints, pain, and muscle tenderness could be assessed with respect to specific functional tasks involving the thoracic region. Regression analysis of the data could be used to identify those factors most important to the specified tasks.
2. Further to the above suggestion, normative data should be collected on the variables identified.
3. The effect of whiplash injury on the thoracic spine with regard to the variables identified should be

assessed. The suggested study design would be a prospective controlled study, that followed subjects for a minimum of six months from the onset of the whiplash injury.

4. The influence of gender and point of impact on whiplash signs and symptoms should be assessed.
5. The association of variables believed to affect thoracic spinal function should be evaluated.

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APPENDIX A

INTERNATIONAL ASSOCIATION FOR THE STUDY OF PAIN
PAIN DEFINITION - APPENDED NOTE
(Merskey et al. 1979)

Note: Pain is always subjective. Each individual learns the application of the word through experiences related to injury in early life. Biologists recognize that those stimuli which cause pain are liable to damage tissue. Accordingly, pain is that experience which we associate with actual or potential tissue damage. It is unquestionably a sensation in a part or parts of the body but is also always unpleasant and therefore also an emotional experience. Experiences which resemble pain., e.g., pricking, but are not unpleasant, should not be called pain. Unpleasant abnormal experiences (dysaesthesiae) may also be pain but are not necessarily so because, subjectively, they may not have the usual sensory qualities of pain.

Many people report pain in the absence of tissue damage or any likely pathophysiological cause; usually this happens for psychological reasons. There is no way to distinguish their experience from that due to tissue damage if we take the subjective report. If they regard their experience as pain and if they report it in the same ways as pain caused by tissue damage, it should be accepted as pain. This definition avoids tying pain to the stimulus. Activity induced in the nociceptor and nociceptive pathways by a noxious stimulus is not pain, which is always a psychological state, even though we may well appreciate that pain most often has a proximate physical cause.

APPENDIX B

MCGILL PAIN QUESTIONNAIRE
(Melzack 1975)

Part 2. Where is your pain?

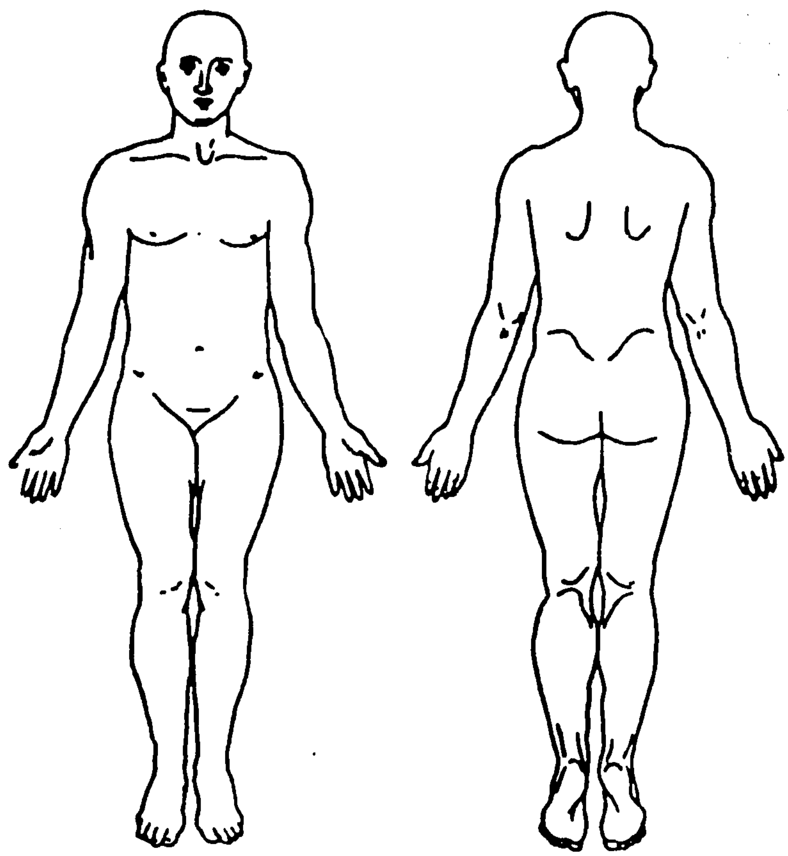

Figure B.1. Body drawing of the McGill Pain Questionnaire.

Part 3. What does your pain feel like?

1	2	3	4
Flickering	Jumping	Pricking	Sharp
Quivering	Flashing	Boring	Cutting
Pulsing	Shooting	Drilling	Lacerating
Throbbing		Stabbing	
Beating		Lancinating	
Pounding			

5	6	7	8
Pinching	Tugging	Hot	Tingling
Pressing	Pulling	Burning	Itchy
Gnawing	Wrenching	Scalding	Smarting
Cramping		Searing	Stinging
Crushing			

9	10	11	12
Dull	Tender	Tiring	Sickening
Sore	Taut	Exhausting	Suffocating
Hurting	Rasping		
Aching	Splitting		
Heavy			

13	14	15	14
Fearful	Punishing	Wretched	Annoying
Frightful	Gruelling	Blinding	Troublesome
Terrifying	Cruel		Miserable
	Vicious		Intense
	Killing		Unbearable

17	18	19	20
Spreading	Tight	Cool	Nagging
Radiating	Numb	Cold	Nauseating
Penetrating	Drawing	Freezing	Agonizing
Piercing	Squeezing		Dreadful
	Tearing		Torturing

Part 4. How does your pain change with time?

Constant Periodic Brief

Part 5. How strong is your pain?

1	2	3	4	5
Mild	Discomforting	Distressing	Horrible	Excruciating

Protocol. The instructions for completion of each of parts 2-5 of the MPQ were read out loud to the subjects by the principal investigator to ensure that they were fully understood. (Part 1 of the MPQ was not used in the study). The verbal instructions for each successive part were read when the preceding part had been completed. The instructions were as follows:

Part 2: The first part of the questionnaire is a body drawing. Please mark, on the front and back views of the bodies, any areas where you feel pain.

Part 3: The second part of the questionnaire is a list of words that are often used to describe pain. The words are divided into 20 groups. Please check only those words that best describe the pain you feel in your upper and middle back, and/or your chest wall. Check only one word in each group; leave out any group that does not describe your pain.

Part 4: The third part of the questionnaire lists three words that describe the pattern of pain over time. Please check the one word that best describes the pattern of pain in your upper and middle back, and/or chest wall.

Part 5: The fourth part of the questionnaire lists 5 words that are often used to describe the intensity or strength of pain. Please check the one word that describes your upper and middle back, and/or chest wall pain right now.

McGill

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May 19, 1992

Ms. Candis Carrothers
Department of Physical Therapy
Faculty of Rehab. Medicine
Room 2-50 Corbett Hall
University of Alberta
Edmonton, Alberta
T6G 264

Dear Ms. Carrothers:

It is a pleasure to give you permission to use The McGill Pain Questionnaire. I am also enclosing a copy of the Major Properties and Scoring Methods. Make as many copies of the Questionnaire as you need.

You will also find enclosed a notice that is now going out to users of the MPQ. As you will see, it involves an "honour system" of payment to the International Association for the Study of Pain.

Sincerely,

Ron Melzack/bl

Ronald Melzack
Professor

APPENDIX C

PAIN THRESHOLD MEASUREMENT

Plate C.1. Pain threshold measurement using a pressure threshold meter.

The pressure threshold meter (Pain Diagnostics and Thermography, 17 Wooley Lane East, Great Neck, New York) (Plate C.1) is a force gauge consisting of a body, a metal rod protruding from the body, and a rubber disc with a surface area of 1 cm^2 which screws onto the rod. Pressure on the rubber disc is transmitted through the rod, and moves the indicator in the body in a clockwise direction. A maximum hold feature maintains the measure of the achieved force value until the zeroing knob is pushed to return the indicator to zero. The range of pressure that can be measured by the gauge is 0-11 kg/cm^2. This range is divided into .1 kg/cm^2 divisions.

Protocol. Subjects were told that muscle tenderness was going to be assessed by measuring pain threshold. They were informed that they would feel a gradual increase in pressure, and when the pressure began to become uncomfortable they were to say 'NOW', and the pressure would be released. It was emphasized that the purpose of the test was not to elicit pain, and therefore it was important that they indicate as soon as the pressure started to become uncomfortable. The instructions were followed by a demonstration of the test procedure on the subject's hand to familiarize them with the instrument and the procedure, and to ensure that they understood the instructions.

Subjects were then positioned in forward lean sitting on a stool, with the upper body supported on a mobilization bed. Assessment of the paravertebral muscles of the cervical and upper and middle thoracic spine was completed in this position. Subjects were then positioned in supine lying to assess muscle tenderness of the tibialis anterior muscles.

The points to be tested were marked with a felt pen. The rubber tip of the pressure threshold meter was positioned over the pen mark of the point being tested, so that the long axis of the shaft was perpendicular to the surface being assessed. One of the tester's hands was used to stabilize the pressure threshold meter to prevent it from slipping off the point being measured. The other hand held the instrument, and applied pressure at a constant rate of 1 kg/cm^2 per second until the subject indicated that the threshold had been reached. Two measures were taken at each point. Approximately 3 seconds were given between measures at different points, and 4-5 minutes were given between the two trials at a single point.

APPENDIX D

OB (MYRIN) GONIOMETER

The OB (Myrin) goniometer (Olle Blomqvist Rehab-Produkter AB, Olaus Petrigatan 10-Fack, 10051 Stockholm) is presented in Plate D.1. This goniometer was designed to enable measurement of ROM of most of the joints of the body. It consists of a round, fluid-filled case which sits upon a rotatable compass housing, a compass needle, and a gravity-dependent inclination needle. A scale of 2 x 180 degrees is marked on the rotatable plate; the scale is divided into 2 degree divisions. A small piece of velcro on the back surface of the goniometer allows attachment of the goniometer.

Adhesive TNS electrodes measuring 53 mm x 34 mm (Tenzcare #6860, 3M Medical-Surgical Division, St. Paul, MN 55144-1000) with velcro glued on the non-adhesive side were used for attachment of the goniometers to the subject. Indirect attachment of the goniometers via a right angled plexiglass plate allowed the orientation of the goniometers to be altered depending on the movement being measured. (The face of the goniometer must lie parallel to the plane of movement being measured so that an accurate measurement of angular motion can be obtained.)

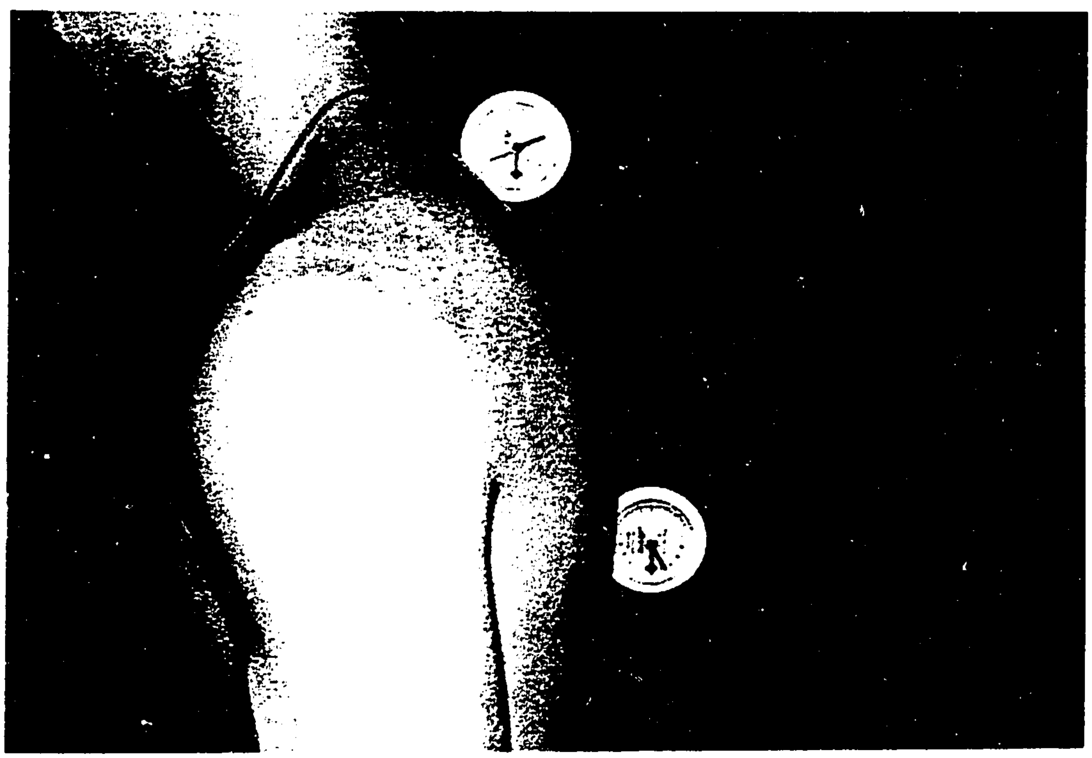

Plate D.1. OB (Myrin) Goniometer. Placement for measuring sagittal ROM.

APPENDIX E

PILOT STUDY

The pilot study was conducted to determine intra-rater reliability of the principal investigator for measuring muscle tenderness, ROM, and PIVM, using a pressure threshold meter, OB (Myrin) goniometers, and Maitland's (1986) manual assessment techniques respectively. The testing procedures followed in the pilot study were the same as those described for the study proper. All testing took place at Corbett Hall, University of Alberta, and each session lasted 20-45 minutes.

Subjects. Twelve subjects, 6 female and 6 male, participated in the testing of each of the 3 measurement protocols. Some subjects volunteered to participate in all 3 assessments which involved 2-3 separate testing sessions, while others participated in only 2 measures involving 1-2 sessions. The age ranges and mean ages of the subjects for each of the testing procedures are presented in Table E.1. All subjects were volunteers, and all except 4 were recruited from the University of Alberta student population.

Table E.1. Age ranges and means of pilot study subjects.

VARIABLE	RANGE (years)	MEAN (years)
PAIN THRESHOLD MEASUREMENT	19-34	25.3
RANGE OF MOTION WITHOUT OVERPRESSURE	19-46	30.6
RANGE OF MOTION WITH OVERPRESSURE	19-34	25.6
PASSIVE INTERVERTEBRAL JOINT MOBILITY	19-46	26.1

Methodology. The purpose of the pilot study was explained verbally to all subjects prior to their agreement to participate. In addition, an informed consent form was signed by all participants prior to the onset of data collection.

Pain threshold measurement (Appendix C). Subjects were instructed that the test was a measurement of pain threshold, not pain tolerance, and that they were to indicate as soon as the pressure became uncomfortable. The procedure was demonstrated on the subject's hand to familiarize them with the instrument and to ensure they understood the instructions. Subjects were then positioned on a stool in forward lean sitting onto a mobilization bed with their forehead resting on their hands. The points to be assessed were marked with a felt marker; bilaterally, 2 cm. from the midline of levels T1-T4. The sequence of assessment was as follows: right side of T1, left side of T1, right side of T2, left side of T2, and so on. Three trials were conducted and the mean score of T1-T4 inclusive for each trial was calculated.

Range of motion. ROM measurements were initially tested without the application of passive overpressure at the end range of the active movements. The results of the analysis of this data were very poor (see Results and Discussion), therefore ROM measurements were re-tested with passive overpressure being applied at the end range of all the active movements. Other than the inclusion of passive overpressure in the re-testing of ROM, the protocol for ROM measurement was as follows.

Subjects were positioned in sitting on a stool with their feet flat on the floor. Adhesive pads with velcro on the other side were positioned over the T1 and T8 spinous processes, and the OB goniometers (Appendix D) were attached to the pads directly (to measure coronal plane movement), or indirectly via a right-angled plate (to measure movement in the sagittal and horizontal planes).

A single practice session of each of the movements was conducted to ensure subjects understood the way in which the movement was to be performed. Flexion was conducted by having the subject relax their arms by their sides, tuck their chin to their chest and then slump forward; extension involved tipping the head back and arching the upper and middle back; rotation was completed by having the individual place their hands on their contralateral shoulders, and then turning to the right, and then the left as far as possible; side flexion involved the subject relaxing their arms by their side and then bending sideways to the right, and then the left as far as possible. After the practice session each of the above movements was measured in the order listed above, and then repeated another 2 times for a total of 3 measured trials.

For each individual trial, the score for flexion and extension was combined to obtain a score for sagittal plane mobility, the score for right and left rotation was combined to obtain a score for horizontal plane mobility, and the score for right and left side flexion was summed to obtain a score for coronal plane mobility.

Passive intervertebral joint mobility. Three subjects, all male or all female, participated in each of 4 sessions of the PIVM testing; order of testing of the 3 subjects for each of the 3 trials conducted per session was determined by random assignment. The principal investigator was blindfolded throughout the testing session, and a second person was responsible for organizing subjects during the testing procedure and recording the results. Subjects were instructed to remain quiet throughout the testing procedure to facilitate the attempt to blind the principal investigator as to the identity of the test subject.

Passive physiological and accessory joint mobility was assessed for each of the motion segments T1/2 - T8/9 according to Maitland's (1986) manual assessment techniques. A description of these techniques is outlined in Appendix H.

Joint mobility for each motion segment was graded according to a 5-point rating scale (Appendix I), and subsequently categorized as having either normal or abnormal mobility. The number of abnormally moving joints were summed to obtain a single score for PIVM for each of the 3 trials.

Analyses. The data from each of the 3 tests were analyzed using a 1-way ANOVA with repeated measures (time) to determine F-ratios, probability of F values, standard error of the measurement (SEM) values, and intra-class correlation coefficients (ICC). The use of ICC to determine intra-rater reliability was in accordance with the guidelines suggested by Shrout and Fleiss (1979) Type (1,1).

Results. The raw data generated by the pilot study is presented in Table E.2. The results of the data analyses are presented in Table E.3. The results indicate that the ICCs for PTM, ROM with overpressure, and PIVM are very good, while the ICCs for ROM without overpressure are poor. The SEM values calculated for all measures except ROM without overpressure are within acceptable limits. The F-ratios and the probability of F for the main effect, time, indicate that there were no significant differences between the measures of Time 1, Time 2, and Time 3 for any of the tests except rotation ROM without overpressure.

Discussion. Good reliability of measures is dependent on their being no significant difference demonstrated by the analysis of variance, high ICC values, and low SEM values. Intra-rater reliability as determined by this pilot study was very good for the measures of pain threshold, ROM with overpressure, and PIVM. Intra-rater reliability for the measurement of ROM without overpressure was very poor, as indicated by the generally low ICC values, and relatively high SEM values. All of the analyses (except the rotation ROM without overpressure) indicated no significant difference between repeated measures. However, it should be noted that the sample size (N = 12) was so small that there

Table E.2. Means (SD) of the raw data for each of the three trials of assessing pain threshold, range of motion with and without passive overpressure, and passive intervertebral joint mobility.

VARIABLE		TRIAL 1	TRIAL 2	TRIAL 3
PAIN THRESHOLD MEASUREMENT (kg/cm^2)		3.47 (1.43)	3.52 (1.58)	3.54 (1.50)
RANGE OF MOTION WITHOUT OVERPRESSURE	F/E	42.25 (10.89)	36.33 (16.36)	45.75 (19.77)
	SF	49.67 (14.96)	51.58 (21.26)	49.75 (14.91)
	ROT	62.17 (19.72)	50.83 (14.54)	61.58 (18.70)
RANGE OF MOTION WITH OVERPRESSURE	F/E	38.50 (12.03)	40.17 (13.82)	40.83 (11.65)
	SF	26.83 (12.01)	24.67 (12.10)	24.83 (8.63)
	ROT	79.00 (28.81)	75.67 (30.02)	73.17 (32.49)
PASSIVE INTERVERTEBRAL JOINT MOBILITY		2.67 (1.30)	2.67 (1.30)	2.83 (1.03)

Abbreviation Key:
F/E = flexion/extension SF = side flexion ROT = rotation

would have to be a very large difference between the means of the measurements to demonstrate a significant difference.

Conclusion. Based on the very good intra-rater reliability indicated by this pilot study for the measures of pain threshold, ROM with overpressure, and PIVM, it was determined that the same measurement instruments and protocol used in the pilot study could be reliably used by the principal investigator in the study entitled "The Effect of Whiplash Injury on the Thoracic Spine".

Table E.3. Results of the 1-way ANOVAs for the measurements of pain threshold, range of motion, and passive intervertebral joint mobility.

VARIABLE		ICC	SEM	F-RATIO	PROB OF F
PAIN THRESHOLD MEASUREMENT		.988	.16	0.43	0.656
ROM WITHOUT OVERPRESSURE	F/E	.583	10.58	2.79	0.083
	ROT	.540	12.34	4.02	0.033*
	SF	.590	10.95	0.11	0.898
ROM WITH OVERPRESSURE	F/E	.879	4.36	0.90	0.420
	ROT	.955	6.51	2.79	0.083
	SF	.879	3.84	1.20	0.320
PASSIVE INTERVERTEBRAL JOINT MOBILITY		.831	.5	0.42	0.660

*significant at $p \leq .05$

Abbreviation key:
ICC = intra-class correlation coefficient
SEM = standard error of measurement
Prob of F = probability of F-ratio
ROM = range of motion
F/E = flexion/extension
ROT = rotation
SF = side flexion

APPENDIX F

CONSENT FORM

Title: The Effect of Motor Vehicle Accidents On the Thoracic Spine

Principal Investigator: Candis Carrothers
Department of Physical Therapy
Faculty of Rehabilitation Medicine
250 Corbett Hall, University of Alberta
(403) 492-5983; 433-0209

Purpose: The purpose of this project is to determine if there are differences in muscle tenderness and movement in the upper and middle region of the back between persons who were involved in a motor vehicle accident, and persons who were not. You will be placed in one of two groups depending on whether or not you were involved in a motor vehicle accident. You will attend a single session, and on this occasion you will be asked to fill out one questionnaire, after which a physical therapist will assess joint movement of your upper and middle back, and muscle tenderness of your neck, upper and middle back, and a muscle in your lower leg. The appointment will take approximately one and one half hours.

Consent: I, ______________________________, agree to take part in the above named project. I understand that my participation in this study is voluntary. Individual subject assessment findings will not be released for personal use, as all results will be considered in the form of grouped data only, rather than as individual cases. I may not personally benefit from participation in the project, but the overall study findings may be useful in improving medical care of persons who are involved in a motor vehicle accident. I may withdraw from this study at any time without prejudice or consequence to myself.
If I experience any pain during the testing session I may ask that the assessment be stopped immediately. I understand that I may experience some mild discomfort and irritation of my present signs and symptoms following the examination, but that any irritation will subside within a short period of time. If an increase in signs and symptoms persists longer than 24 hours, I have been advised to call the principal investigator.

I also understand that all the information that will be obtained in this study will be treated confidentially. My name will not appear on any of the data sheets, and any information that is published or presented at conferences will not refer to me by name. All data sheets will be kept in a locked drawer and will be destroyed once the final report has been completed.

Any concerns I had have been addressed to my satisfaction, and any further questions that I have with regard to the research project will be answered by a member of the research team at any time. I acknowledge that I have received a copy of this consent form.

Participant's Signature

Signature of Investigator

Date

Signature of Witness

APPENDIX G

PERSONAL DATA INFORMATION SHEET

Assessment Date:______________________________

Subject's Code #:__________ Ph:(H)__________ (W)__________

Address:____

Age:_______________ Gender:__________________

BMI [Wt (kg)/Ht^2 (m)] (Health & Welfare Canada, 1988):______

Occupation:____

Medications:____

Date of Accident:_________________ Point of Impact:________

Position in Car: driver______ passenger: front____________

back_____________

Seat Belt: shoulder/lap belt______ lap belt______ none______

Head Restraint Used: Yes_________ No__________

Physician's Name:____

Medical Treatment to Date:___________________________________

____

____

____

Other Health Care Professionals:_____________________________

____

Treatment to Date:____

____

____

Litigation Pending: Yes________ No_________ Maybe________

APPENDIX H

MAITLAND'S MANUAL ASSESSMENT TECHNIQUES OF PIVM
(Maitland 1986)

Passive Physiological Movements of the Thoracic Spine

1. T1-T4 Flexion/Extension

Starting position (Plate H.1): Subject in side lying. Therapist stands in front of the subject and cradles his head in her arm, stabilizing it between her forearm and the front of her shoulder. Her other forearm is positioned along the subject's back to stabilize the thorax. The interspinous space at the level being assessed is palpated using the pads of the fingers.

Method: The therapist used her arm that is cradling the subject's head to flex and extend the subject's lower neck and upper thoracic spine. The amount of movement is limited to that required to move through the full available range of the joint being assessed.

Plate H.1. Positioning for the assessment of upper thoracic flexion, extension, lateral flexion, and rotation.

2. T1-T4 Lateral Flexion

Starting position: as in (1)

Method: The therapist produces lateral flexion of the joint being assessed by lifting the patient's head and lower neck with the ulnar border of her hand which is supporting the head at the cervico-thoracic junction.

3. T1-T4 Rotation

Starting position: as in (1).

Method: The therapist produces rotation of the joint being assessed by rotating the lower neck and upper thoracic spine with the ulnar border of her hand.

4. T4-T8 Flexion/Extension

Starting position (Plate H.2): Subject is sitting with his hands clasped behind neck or arms crossed over his chest. The therapist stands by the subject's side and interlocks one arm with the subject's arms. Her other arm is placed across the subject's spine just below the level being assessed. The interspinous space of the segment being assessed is palpated with the pads of the fingers to feel the movement.

Method: The therapist supports the subject's upper trunk with her anterior arm. The therapist flexes or extends the subject's thorax by side bending her own trunk until movement occurs at the level being assessed. With the extension movement the therapist assists the extension by applying pressure with the heel and ulnar border of her posterior hand to the inferior vertebrae of the segment being assessed.

5. T4-T8 Lateral Flexion

Starting position: Subject as in (4). The therapist stands just behind the subject with her anterior arm reaching high around the front of the subject to grasp behind the opposite shoulder. The subject's trunk is held closely between the therapist's arm and axilla. The heel of the therapist's posterior hand is positioned at the level being examined and the finger pads palpate the interspinous space of the area being tested.

Method: The therapist supports the subject's trunk, and side bends the subject toward her to produce a lateral flexion movement at the level being assessed.

Plate H.2. Positioning for the assessment of middle thoracic flexion, extension, and lateral flexion.

6. T4-T8 Rotation

Starting position (Plate H.3): Subject is side lying with his hips and knees comfortably flexed. The therapist stands in front of the subject and leans over his trunk to cradle the pelvis between her side and her caudal arm. Her forearm is aligned along the subject's spine and her hand reaches to the level being examined, so that her fingers can palpate the interspinous space of this level. The therapist's other forearm is positioned along the subject's anterior chest and her hand reaches over the scapular area.

Method: The therapist rotates the subject's trunk back and forth to produce rotary movement at the level being examined. Force is applied through the arm on the anterior aspect of the patient's trunk.

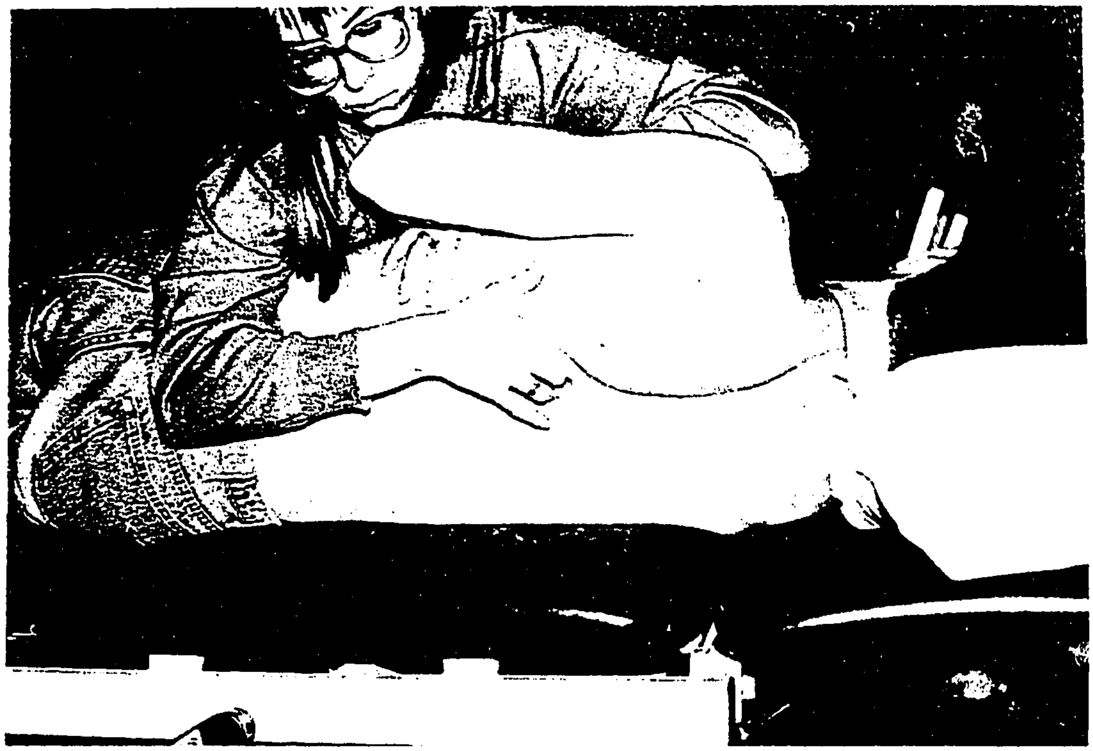

Plate H.3. Positioning for the assessment of middle thoracic rotation.

Passive Accessory Movements of the Thoracic Spine

Movement is assessed by applying pressure through the tips of the thumbs against the spinous processes or the articular pillar of the vertebrae. Two or three oscillatory movements are performed at each level. There are three primary directions in which pressures are applied: a) posterior-anterior on the spinous process, (b) posterior-anterior on the articular pillar, and (c) transversely on the lateral surface of the spinous process. The direction of the force can be varied by inclining the force in a cephalad or caudal direction, in a medial or lateral direction, or a combination of these movements, to produce flexion, extension, side flexion, or rotation movements.

1. Posterior-anterior central vertebral pressure

Starting position (Plate H.4): Subject is lying prone. The therapist stands at the subject's head when assessing T1-T5 levels, and at the subject's side facing the head when assessing T5-T8 levels. The therapist places the pads of her thumbs on the spinous process of the vertebrae to be examined. The fingers of each hand are spread out on the posterior aspect of the chest wall.

Method: The therapist applies an oscillatory pressure produced by the body that is transmitted through the arms to the thumbs.

Plate H.4. Positioning for the assessment of posterior-anterior central vertebral passive accessory movement of the upper thoracic spine.

2. Transverse vertebral pressure
Starting position (Plate H.5): Subject in prone. Therapist stands at the subject's side at the level of the vertebrae being tested. The pads of her thumbs are adjacent to the side of the spinous process, one reinforcing the other, and her fingers spread over the patient's ribs on the opposite side.
Method: Pressure is applied to the spinous process through the thumbs, producing an oscillatory movement.

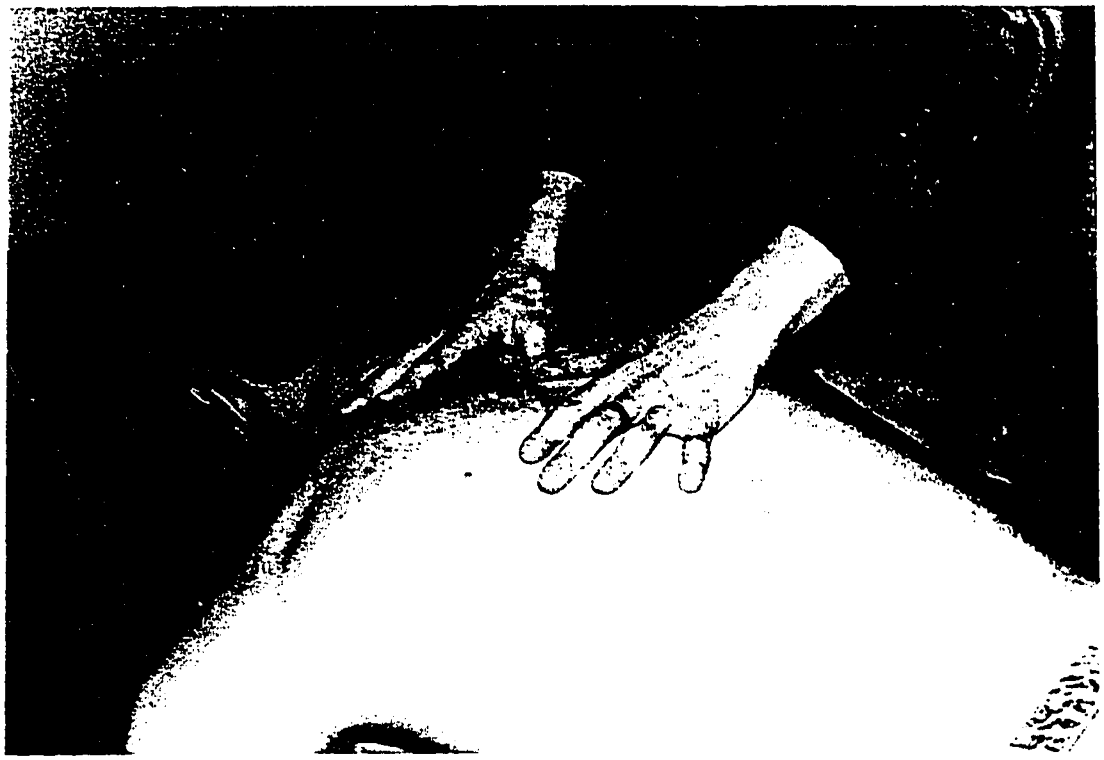

Plate H.5. Positioning for the assessment of transverse vertebral passive accessory movement of the upper and middle thoracic spine.

3. Posterior-anterior unilateral vertebral pressure

Starting position: Subject is prone. The therapist stands at the subject's head when assessing the upper thoracic spine, and at the subject's side when examining the middle thoracic region. The pads of the thumbs lie over the transverse processes and the fingers are spread over the chest wall.

Method: A steady pressure is applied until the resistance of the muscle tissue had been taken up, and a firm contact has been established. An oscillatory movement is then produced.

APPENDIX I

PASSIVE JOINT MOBILITY RATING SCALE

Table I.1. Rating system for evaluating passive intervertebral joint mobility of the spine. (Adapted from Gonnella et al. 1982; Jull & Bullock 1987a).

Grade	Description	Criteria
0	Locked	No detectable movement. Hard abrupt endfeel.
1	Capsular Hypomobility	Decrease in expected range. Significant resistance to movement. Firm, hard stretch endfeel.
2	Myofascial Hypomobility	Decrease in expected range. Resistance begins early in range, and continues throughout range. Elastic resistance, or spasm early in range.
3	Normal	Expected range. Uniform movement throughout range. Normal elastic resistance limits motion.
4	Hypermobility	Excessive range. Eventually restricted by capsular and ligamentous structure, or may be spasm late in range.

Grade 3 = Normal Grades 0,1,2,4 = Abnormal

APPENDIX J

RAW DATA

Table J.1. Raw data of the comparison group for the variables age, gender, body mass index, McGill Pain Questionnaire, pain threshold, range of motion, and passive intervertebral joint mobility.

SUBJECT	AGE	GENDER	BMI	MPQ	PTMC	PTMT	PTML	F/E	SF	ROT	PIVM
5	43	F	19.14	0	1.58	2.73	4.90	18	64	58	1
6	39	F	22.47	0	2.73	3.17	7.73	40	28	46	2
7	21	M	20.39	0	2.43	4.99	5.95	46	24	54	2
8	47	M	22.41	0	1.97	3.29	5.48	24	40	36	4
16	25	M	25.53	0	1.78	3.30	5.50	32	26	42	0
17	20	F	22.85	8	1.39	2.31	5.10	92	50	68	0
19	25	M	19.75	0	1.85	3.76	5.68	32	26	70	0
24	24	F	23.52	0	1.52	2.71	4.79	46	34	50	0
28	24	M	25.97	0	1.73	2.82	6.95	30	50	76	2
29	36	F	23.07	0	1.90	2.70	4.90	62	40	18	1
30	23	M	22.53	0	2.25	4.02	7.79	52	28	44	0
31	23	F	18.85	0	1.24	1.85	2.04	42	34	52	1
35	21	F	21.45	0	2.04	3.69	4.00	26	34	60	1
38	21	F	22.23	0	1.94	3.54	4.50	52	36	68	0
39	21	F	25.08	0	2.66	5.47	6.21	36	36	56	2
41	31	F	28.72	0	3.80	4.75	5.31	38	16	52	1
42	19	M	21.79	0	1.62	2.63	4.34	38	26	66	0
44	36	F	23.62	0	3.00	5.15	5.18	32	20	54	0
53	18	F	22.46	0	2.65	4.91	7.73	28	18	52	3
54	18	F	26.23	0	1.53	2.77	5.66	20	34	44	0
55	21	M	23.66	0	2.71	4.67	6.20	46	34	58	0
57	25	F	23.97	0	2.17	3.46	4.73	34	20	40	2
58	23	F	21.99	0	2.69	4.08	8.83	40	20	68	2
59	42	M	25.64	0	2.47	5.29	6.25	42	26	52	0
61	36	F	28.27	0	2.11	3.17	6.31	32	32	40	1
60	38	M	24.54	0	2.41	4.55	4.98	42	26	58	2
62	45	M	25.86	0	2.48	4.27	5.41	26	28	36	0
63	24	M	23.78	0	2.66	5.18	6.48	32	30	86	0
64	38	F	21.87	0	2.13	3.54	6.34	26	38	48	1
65	38	F	22.73	0	2.23	3.92	7.63	32	30	50	0

Abbreviation Key:
F = female M = male
BMI = body mass index MPQ = McGill Pain Questionnaire
PTM = pain threshold measurement
C = cervical spine T = thoracic spine
L = leg F/E = flexion/extension
SF = side flexion ROT = rotation
PIVM = passive intervertebral joint mobility

Table J.2. Raw data of the whiplash group for the variables age, gender, body mass index, McGill Pain Questionnaire, pain threshold, range of motion, and passive intervertebral joint mobility.

SUBJECT	AGE	GENDER	BMI	MPQ	PTMC	PTMT	PTML	F/E	SF	ROT	PIVM
1	37	F	38.60	12	.93	1.40	2.60	23	34	20	3
2	24	M	25.76	21	.88	1.68	3.08	18	42	62	1
3	44	F	24.14	11	.83	1.56	1.69	24	40	56	4
4	46	M	24.89	9	3.18	5.57	8.98	28	36	52	2
9	39	M	24.87	22	1.83	1.96	3.54	48	40	78	1
12	42	M	26.99	28	1.03	2.35	4.14	6	28	28	4
13	26	M	29.95	15	2.27	4.53	6.81	36	50	46	3
14	36	F	19.65	0	1.40	2.74	4.14	31	34	18	3
15	22	M	31.29	27	1.24	1.83	5.69	28	22	40	4
18	22	F	18.51	0	1.46	2.53	3.94	12	30	46	4
21	22	F	19.30	40	.74	1.46	1.93	24	28	32	2
22	24	M	27.58	0	1.90	3.13	4.31	34	62	54	2
23	32	F	25.28	16	1.53	2.70	3.31	40	38	64	2
25	24	F	23.94	12	.74	1.12	1.94	10	10	60	5
26	21	M	22.32	0	3.06	4.99	11.00	48	36	78	1
32	20	F	20.66	0	1.13	1.70	2.83	18	28	32	2
33	20	M	27.02	0	3.39	6.18	8.38	54	54	56	2
34	43	M	26.84	6	2.20	3.69	4.33	36	38	48	3
36	19	F	21.69	0	1.45	2.31	4.50	36	16	48	3
37	20	F	26.42	0	2.05	3.89	5.38	64	36	48	0
40	38	F	22.52	39	1.83	2.77	2.60	24	30	48	3
43	37	F	21.68	18	1.00	1.79	2.94	30	28	50	2
45	39	F	20.23	18	1.26	2.25	3.69	14	14	34	3
46	38	F	21.22	32	1.15	1.97	3.48	34	30	66	2
48	21	M	20.31	0	1.90	2.96	6.38	40	34	48	2
49	17	F	22.21	17	1.02	1.78	2.63	30	24	46	2
50	18	F	21.23	24	1.16	2.08	3.34	40	34	52	0
51	27	F	23.23	0	1.99	3.08	5.56	62	26	38	0
52	22	M	22.75	0	1.98	3.93	6.74	56	56	46	3
56	24	F	18.42	0	1.20	1.73	5.53	16	18	20	2

Abbreviation Key:
F = female — M = male
BMI = body mass index — MPQ = McGill Pain Questionnaire
PTM = pain threshold measurement
C = cervical spine — T = thoracic spine
L = leg — F/E = flexion/extension
SF = side flexion — ROT = rotation
PIVM = passive intervertebral joint mobility

Table J.3. Raw data of the whiplash group for factors related to the motor vehicle accident.

SUBJECT	DAYS	IMPACT	POSITION	SEATBELT	HEADREST	DOCTOR	PHYSIO	CHIRO	LITIG
1	13	R	D	Y	N	Y	2	0	M
2	12	R	D	Y	N	Y	5	0	Y
3	21	R	P	Y	N	Y	3	0	N
4	21	R	D	Y	N	Y	3	0	N
9	31	R	D	Y	N	Y	3	0	M
12	7	R	D	Y	N	Y	1	0	M
13	22	F	P	Y	N	Y	1	0	Y
14	46	F	D	Y	N	N	0	0	N
15	23	F	D	Y	Y	Y	6	0	Y
18	31	F	D	Y	N	N	0	0	N
21	8	F	D	Y	Y	Y	0	0	N
22	36	F	D	Y	N	N	0	0	N
23	50	R	P	Y	N	N	0	0	Y
25	32	F	P	N	N	Y	4	0	Y
26	21	R	P	Y	N	Y	0	0	N
32	22	F	D	Y	N	N	0	0	N
33	19	R	D	Y	N	Y	0	0	N
34	38	R	D	Y	Y	Y	0	6	Y
36	19	F	P	Y	N	N	0	0	N
37	29	F	D	Y	N	N	0	0	N
40	61	R	P	Y	N	N	0	2	Y
43	71	F	D	Y	N	Y	0	0	Y
45	75	R	D	Y	N	Y	6	0	Y
46	44	R	D	Y	N	Y	6	0	Y
48	21	R	D	Y	N	Y	0	0	N
49	90	R	P	N	N	Y	0	2	Y
50	90	R	P	Y	N	Y	0	0	Y
51	5	F	D	Y	N	N	0	0	N
52	17	R	D	N	N	N	0	0	N
56	70	F	D	1	N	Y	5	0	N

Abbreviation Key:
DAYS = number of days post-accident
IMPACT = point of impact
POSITION = position in vehicle
PHYSIO = number of physiotherapy treatments
CHIRO = number of chiropractic treatments
LITIG = litigation pending
F = front R = rear D = driver
P = passenger Y = yes N = no M = maybe

APPENDIX K

RESULTS OF THE ADDITIONAL ANALYSES

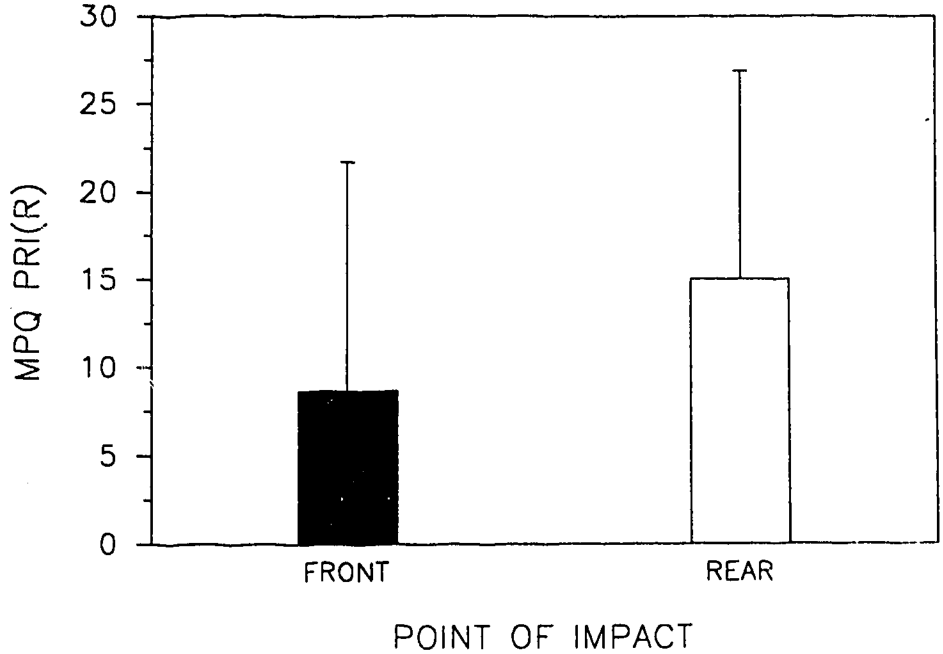

Figure K.1. Comparison of females (N=18) and males (N=12) of the whiplash group on the MPQ PRI(R).

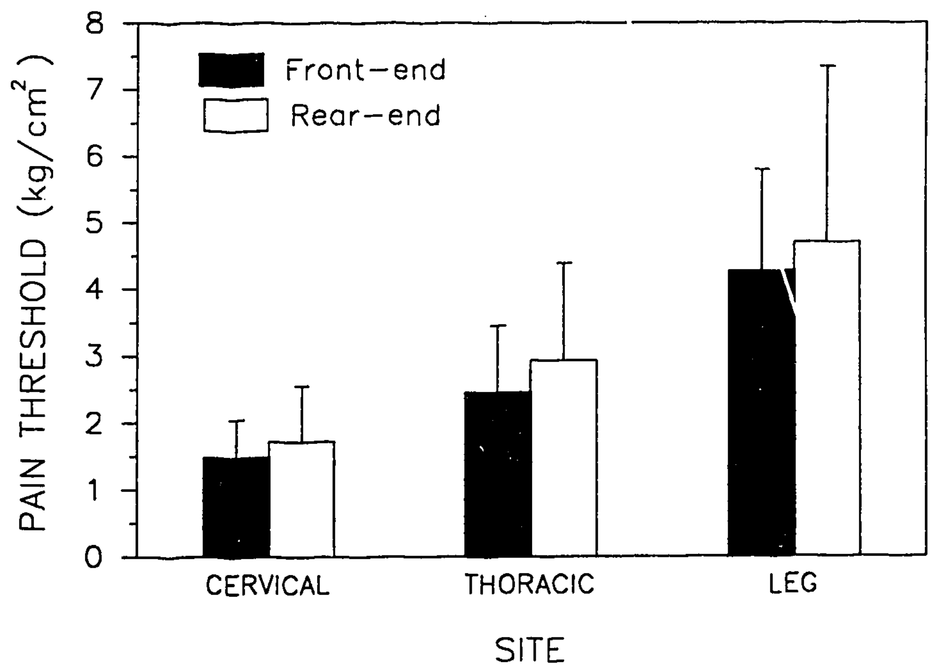

Figure K.2. Comparison of females (N=18) and males (N=12) of the whiplash and comparison groups for PIVM.
*Significant ($p \leq .05$) difference between groups.

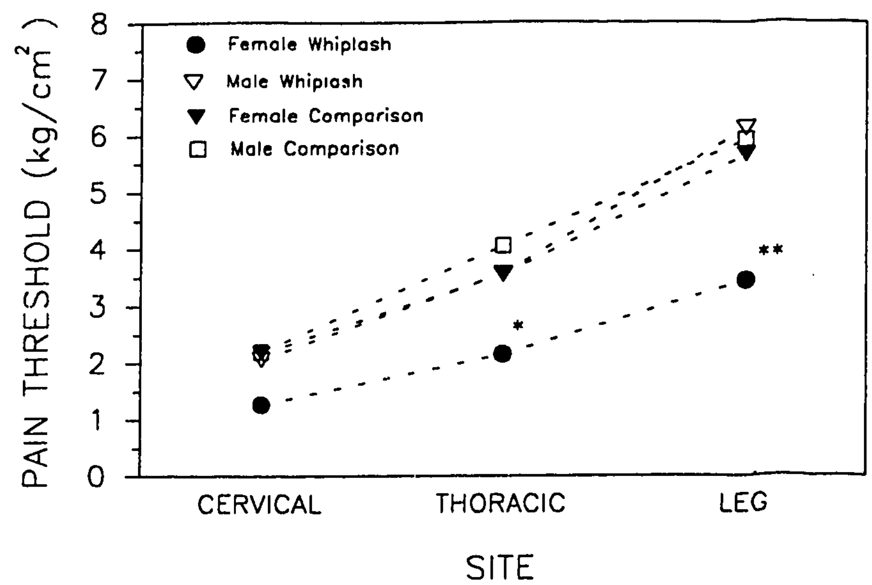

Figure K.3. Means of PTM by gender and group. *Significantly ($p \leq .05$) different from comparison subjects. **Significantly ($p \leq .05$) different from male whiplash, and female and male comparison subjects. Leg PTM significantly > thoracic PTM > cervical PTM ($p \leq .05$).

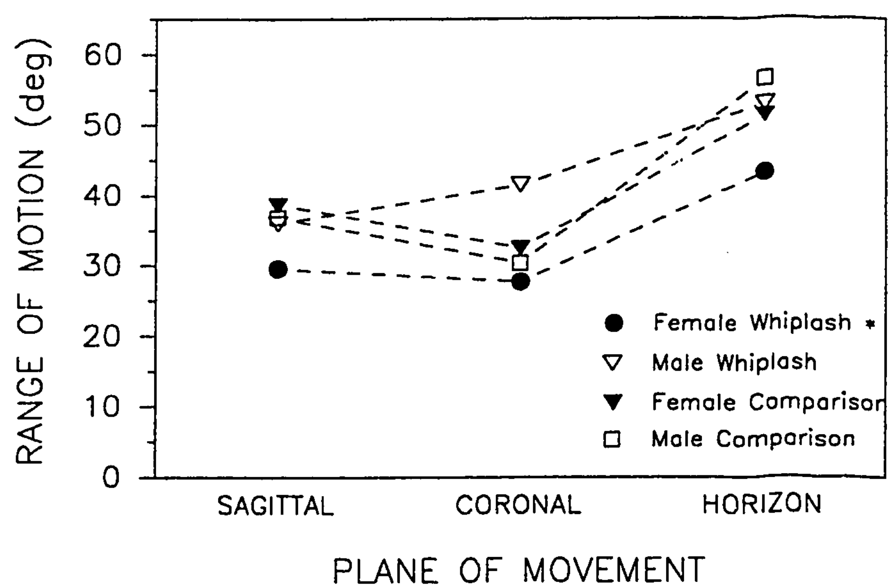

Figure K.4. Means of ROM by gender and group. *Significantly ($p \leq .05$) different from male whiplash group. Horizontal ROM significantly > sagittal and coronal ROM ($p \leq .05$).

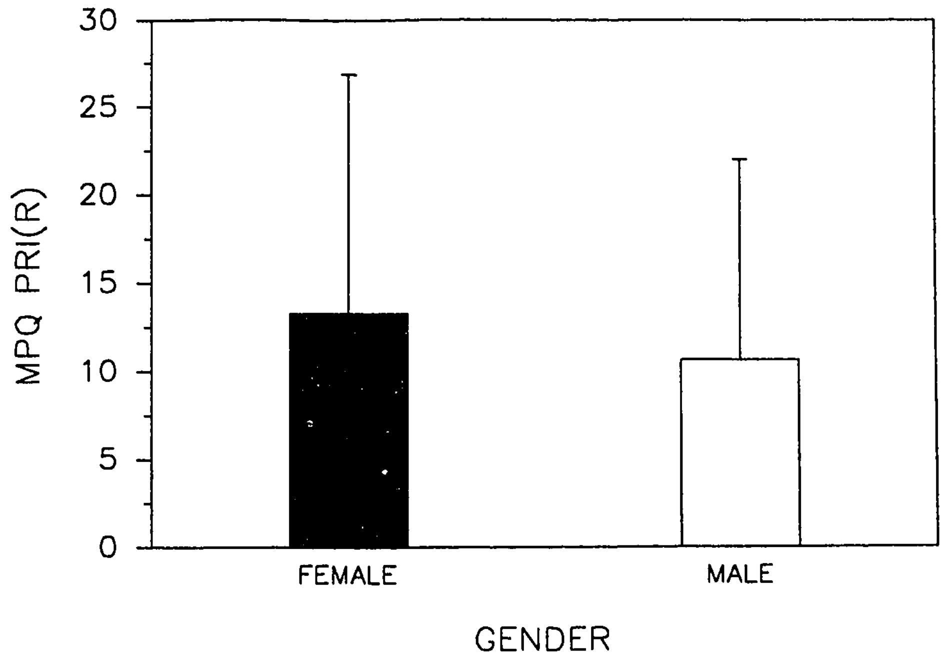

Figure K.5. Comparison of front-end (N=13) and rear-end (N=17) impacts on the MPQ.

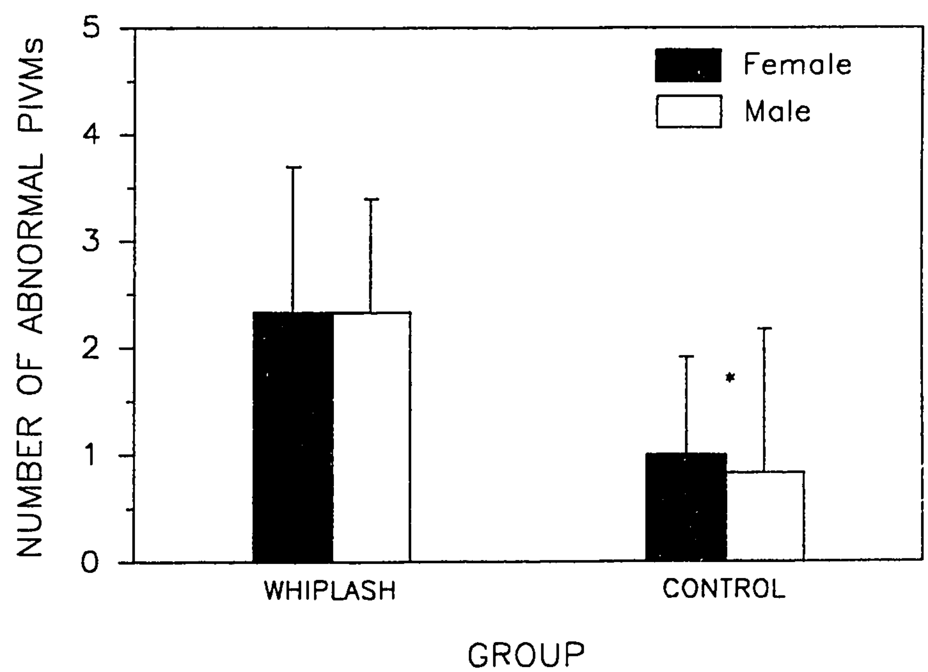

Figure K.6. Comparison of front-end (N=13) and rear-end (N=17) impacts on PTM. Leg PTM significantly > thoracic PTM > cervical PTM ($p \leq .05$).

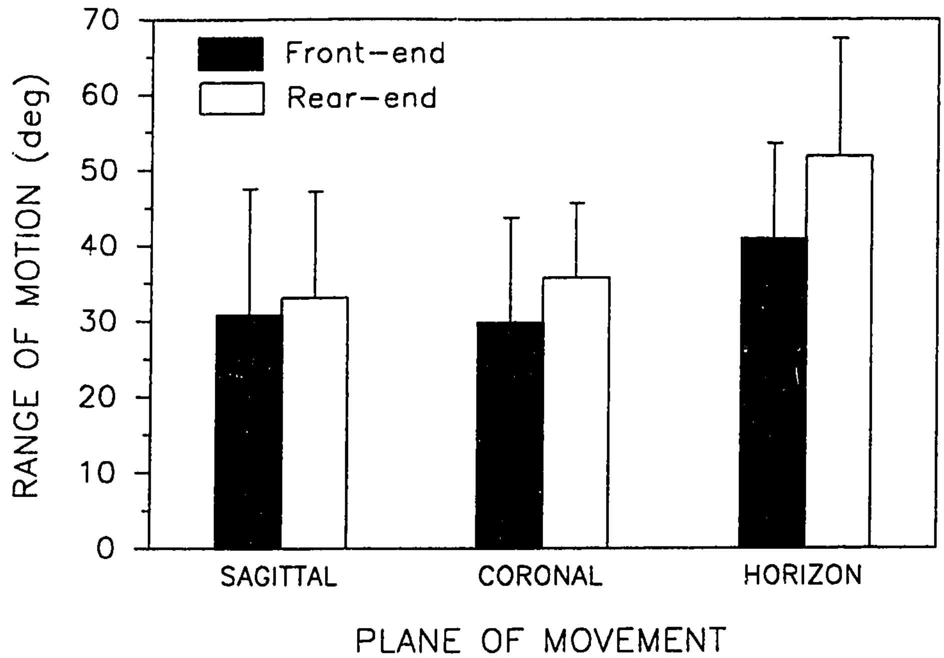

Figure K.7. Comparison of front-end (N=13) and rear-end (N=17) impacts on ROM. Horizontal ROM significantly > sagittal and coronal ROM ($p \leq .05$).

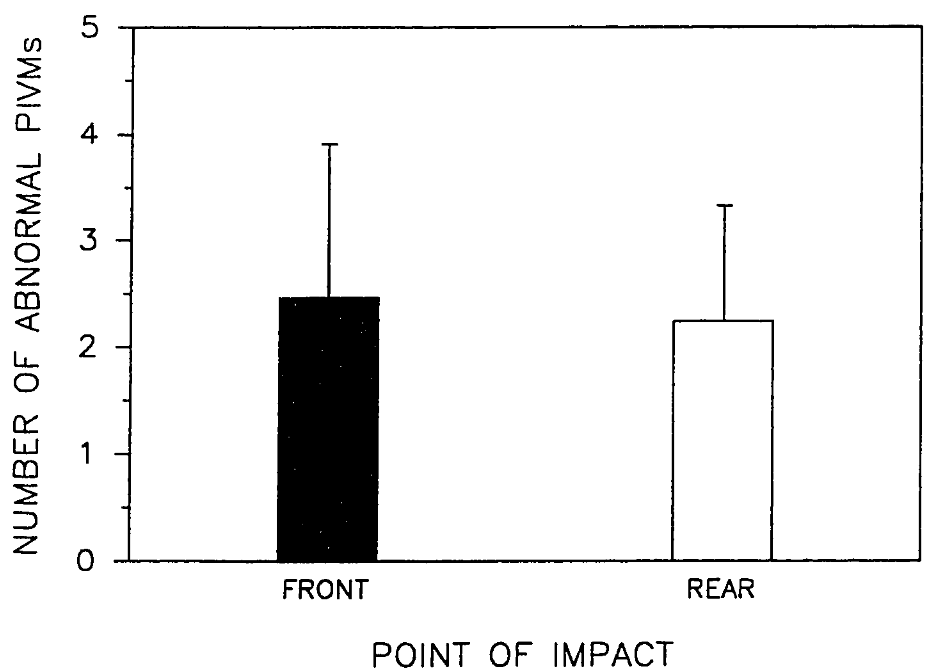

Figure K.8. Comparison of front-end (N=13) and rear-end (N=17) impacts on number of abnormal PIVMs.

Table K.1. Pearson product moment correlation matrix for the measures of thoracic function.

	MPQ	PIVM	FE	SF	ROT	PTMC	PTMT	PTMTA
MPQ	1.00							
PIVM	.34*	1.00						
FE	-.26	-.48**	1.00					
SF	-.07	-.08	.28	1.00				
ROT	-.06	-.29	.25	.19	1.00			
PTMC	-.50**	-.31*	.34*	.02	.27	1.00		
PTMT	-.49**	-.30*	.30*	.08	.28	.92**	1.00	
PTMTA	-.50**	-.24	.31*	.11	.21	.76**	.74**	1.00

1-tailed significance: * - .01 ** - .001

Abbreviation key:
MPQ = McGill Pain Questionnaire
PIVM = passive intervertebral joint mobility
FE = flexion/extension range of motion
SF = side flexion range of motion
ROT = rotation range of motion
PTMC = pain threshold measurement of the cervical spine
PTMT = pain threshold measurement of the thoracic spine
PTMTA = pain threshold measurement of the tibialis anterior muscle