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# **THE EFFECT OF MICROADJUSTMENT ON LOW BACK COMFORT IN THE CONTEXT OF AUTOMOBILE SEATING**

by

**Mike Kolich**

A Thesis

Submitted to the Faculty of Graduate Studies and Research  
through the Department of Industrial & Manufacturing Systems Engineering  
in Partial Fulfilment of the Requirements for  
the Degree of Master of Applied Science at the  
University of Windsor

Windsor, Ontario, Canada

1996

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## ABSTRACT

In the context of automobile seating, microadjustment attempts to deal with the problem of postural fixity by forcing the occupant to undertake subtle shifts in body position. These subtle shifts are thought to promote blood flow and, thereby, delay the onset of fatigue. As a result, occupant comfort should be enhanced. This concept has never before been evaluated.

The micro-adjuster control system, which was built directly into the lumbar support part of an automobile seat, was provided by *Schukra of North America*. For this thesis, three factors at two levels were studied. They were: cycle (2 min and 5 min), wait (15 sec and 30 sec), and pulse (0.8 sec and 1.1 sec). Based on this arrangement, a  $2^3$  full factorial, repeated measures design was employed. In each condition, subjects were required to sit on the experimental automobile seat for two hours.

Ten relatively healthy subjects (five males and five females), ranging in age from 19 to 27 years, agreed to participate in this study. Data were obtained using electromyography (EMG). The response variable was the change in root mean squared ( $\Delta$ RMS) values. As a supplement, two questionnaires were developed specifically for



this study.

The purpose of this thesis was to determine the most optimal combination of cycle, wait, and pulse. The results indicated that cycle had a statistically significant effect on  $\Delta$ RMS values ( $p < .05$ ). More specifically, 5 min cycles were superior to 2 min cycles. Similarly, the cycle by wait interaction was statistically significant ( $p < .05$ ). The best results were obtained when a 5 min cycle was combined with a 15 sec wait. Statistically, no optimal level of pulse could be identified. However, 1.1 sec pulses seemed to produce better results than 0.8 sec pulses. Therefore, in terms of delaying the onset of back muscle fatigue due to postural fixity, the most advantageous combination of variables includes a 5 min cycle, a 15 sec wait, and a 1.1 sec pulse. The results of the questionnaires verify this conclusion. In general, based on over 160 hours of investigation, the benefits of microadjustment are best realized with long cycles, short waits, and high pulses.

## **DEDICATION**

To my parents, Mike and Metka Kolich.

## **ACKNOWLEDGEMENT**

I would like to thank my supervisor, Dr. S.M. Taboun, and my committee members, Dr. M. Wang and Dr. G.W. Marino, for their insight and support throughout the course of this thesis. I would also like to thank our departmental secretary, Ms. Jacquie Mummery, for her help. Last, but certainly not least, I would like to express my sincere gratitude to Miss Heidi Palajsa (she knows why).

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# CHAPTER 1

## INTRODUCTION

Comfort is a subjective concept which is difficult to define and measure. It has been suggested by a plethora of researchers that, like health, the only appropriate definition of comfort is in terms of its absence, thus arguing that it is only possible to measure varying degrees of discomfort. Nevertheless, some investigators have tried to measure degrees of positive comfort (Osborne, 1978). Whether the designer's philosophy is to attempt to reduce discomfort to minimum levels or to induce a positive feeling of comfort, the outcome of the attempt should be the same -namely the production of some sort of optimal state for the human being.

The design of automotive seating for improved occupant comfort is one of the primary goals for seat system engineering teams. Comfort measurement is difficult because of such factors as user subjectivity, occupant anthropometry, seat geometry, and amount of time spent sitting (Thakurta et al., 1995). In the past, the evaluation of seat design utilized subjective methods such as questionnaires filled out by the seated



occupants. Recently, the automotive seating industry has begun to examine and use seating evaluation methodologies which provide objective quantitative data. The predominating philosophy is to combine objective and subjective measurement systems for the seat evaluation process. With this, it is anticipated that the task of designing comfortable automobile seats will become easier and more efficient.

Unfortunately, in spite of the increased emphasis on human comfort brought on by the emergence of ergonomics as a legitimate science, modern automobile designers, in their quest for functionality and fuel economy, may be contributing to occupant discomfort. To elaborate, newer automobiles are being engineered with lower roof-lines. This fact has reduced the general upright sitting space in automobiles to between 110 and 120 cm (Mohamed, 1996). To accommodate the average driver, who requires approximately 132 cm of upright sitting space, the seat is tipped back and lowered. As a result, overall comfort may be compromised.

Beyond the concept of comfort and perhaps more importantly, driving has been implicated in the onset of low back pain. In fact, Coventry (1968) called low back pain a disease of the automotive age. Dainoff and Dainoff (1986) even suggest that attached to every seat should be a tag that says, "Caution: Prolonged sitting may be hazardous to your health." This contention is supported by more recent investigations which have

demonstrated a causal relationship between driving motor vehicles and back pain. Considering these studies, what is immediately evident is that, with regards to the relationship between sitting postures and back pain, far more data are available on upper back and upper extremity disorders than on those of the lumbo-sacral region.

Sitting is hypothesized to be a risk factor for low back pain because of what Grieco (1986) calls postural fixity. This phenomenon occurs when an individual sits in one position, without significant postural movement, for an extended period of time. It almost goes without saying that this is extremely common in the driving environment where postures are determined and therefore fixed by the pedals, the steering wheel, the seat belt, the visual demands of the task, and the seat itself. Static loading of the body's musculature in this fashion has a detrimental effect on many physiological events, including the flow of blood (which transports metabolic products) to and from localized areas. To prevent postural fixity, a properly designed seat should support the body with anatomical integrity and, in addition, promote normal body functions.

Fixed postures, particularly sitting postures, which are the most common, appear to be relatively neglected even though they are progressively and constantly increasing in frequency. Fortunately, they are now being studied as a new problem, not only for the workplace, but for lifestyle in general. This thesis is a testament to this fact.

## **1.1 Objectives**

This thesis is designed to evaluate the feasibility of a micro-adjuster control system implemented into the lumbar portion of an automobile seat back rest. Basically, the micro-adjuster control system is designed to improve occupant comfort by dealing with the problem of postural fixity. The mechanical design aspects of this micro-adjuster control system are not the focus of this study. Instead, the investigation is rooted in the science of ergonomics, which can be defined as the study of human comfort. Therefore, the objectives can be summarized as follows:

1. To determine if microadjustment reduces postural fixity and therefore improves driver comfort.
2. To determine the optimum overall cycle time.
3. To determine the optimum delay between successive microadjustments.
4. To determine the optimum amount of adjustment.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Functional Anatomy of the Lower Back**

A thorough understanding of the functional anatomy of the lower back was deemed essential in order to satisfactorily evaluate the purported benefits and potential shortcomings of the micro-adjuster control system. BODYWORKS (Information Graphics Corp., 1991), which is a type of computer software, was used to obtain much of the information outlined in this section.

##### **2.1.1 Bones**

The back is made up of vertebrae. A typical vertebra has a drum-shaped body (centrum) that forms the thick, anterior portion of the bone. Projecting from the back of each body are two short stalks called pedicles. They form the sides of the vertebral foramen. Two plates (laminae) arise from the pedicles and fuse in the back to become

spinous processes. The pedicles, laminae, and spinous process together complete a bony vertebral arch around the vertebral opening, through which the spinal cord passes. Between the pedicles and laminae of a typical vertebra is a transverse process that projects laterally and toward the back. Various ligaments and muscles are attached to the spinous process and transverse process. On the surfaces of the vertebral pedicles are notches that align to create openings, called intervertebral foramina. These openings provide passageways for spinal nerves that proceed between joining vertebrae and connect to the spinal cord.

The *lumbar vertebrae* are designed for the attachment of the powerful lumbar muscles and for the support of the body's weight. They are, therefore, much stronger and larger than the other vertebrae and have short thick processes. There are five of these vertebrae. In the research literature, they are identified according to the level of their corresponding spinous process. In this fashion, the lumbar vertebrae are abbreviated L1, L2, L3, L4, and L5.

Inferior to the lumbar vertebrae is the *sacrum*. It articulates with the fifth lumbar vertebra above, the coccyx below, and the two iliac bones on either side. The *coccyx*, known as the tail bone, is occasionally contused, leading to annoying discomfort when sitting.

The *pelvis* consists of a ring of bone which articulates with the sacrum posteriorly and with itself at the pubic symphysis anteriorly. The bones of the pelvis consist of the ilium superiorly, the ischium inferiorly, and the pubic bone anteriorly. Landmarks which can be easily identified are the anterior superior iliac spines, the iliac crests, and the posterior superior iliac spines. All three portions of the pelvic bone meet laterally at the *acetabulum*, a deep socket which, together with the *femur*, forms the hip joint.

### **2.1.2 Intervertebral Discs**

The intervertebral discs, which separate adjacent vertebrae, cushion and soften the forces encountered by the back and thereby prevent fractures of the vertebrae which might otherwise occur. Therefore, the intervertebral discs are among the most important structures of the back. Unfortunately, they are frequently subjected to injury, particularly in the lower lumbar and lumbo-sacral areas. The intervertebral disc between the fifth lumbar vertebra and the sacrum is subjected to severe shear and torsional forces, so that this articulation has the highest incidence of disc protrusion and degeneration. This articulation is frequently referred to as the L5-S1 joint. The disc consists of the *annulus fibrosus*, which is composed mainly of dense fibrous rings surrounding the soft gel-like interior known as the *nucleus pulposus*.

### 2.1.3 Ligaments

Only a few of the major ligaments will be discussed in this section. The *anterior longitudinal ligament* is very powerful and helps to limit hyperextension of the spine as well as forward motion of one vertebra upon another, especially of the fifth lumbar onto the sacrum. It is attached to the annulus and the intervertebral discs and prevents forward bulging of the annulus.

The *posterior longitudinal ligament* lies anterior to the spinal cord and has strong attachments to the rim of the vertebral body and to the central portion of the annulus. The posterolateral corner of the annulus is poorly covered and this produces a weak area where disc protrusion frequently occurs.

The *posterior ligamentous system* is well developed in the lumbo-sacral area. It consists of the lumbodorsal fascia and the interspinous and supraspinous ligaments. It helps resist shear stress as well as forward bending. However, the interspinous and supraspinous ligaments are frequently found to be weak or ruptured at L4-L5, L5-S1, or both in those over thirty years of age.

#### **2.1.4 Muscles**

The muscles of the lower back are the primary focus of this thesis. Therefore, these muscles will be concentrated on in the remainder of this section. The information found here was obtained from Clemente (1985).

The *erector spinae* (sacrospinalis) is a great mass of muscle that stretches from the sacrum to the skull. It is the most superficial muscle group of the back. This mass splits in the upper lumbar region into lateral, intermediate, and medial columns of muscles that lie parallel. These columns are further subdivided into three muscles according to the vertebral region to which each attaches superiorly. Muscles comprising the erector spinae primarily extend and laterally bend the vertebral column. They are the:

Iliocostalis muscle (lateral column)

Iliocostalis lumborum

Iliocostalis thoracis

Iliocostalis cervicis

Longissimus muscle (intermediate column)

Longissimus thoracis

Longissimus cervicis

Longissimus capitis

Spinalis muscle (medial column)

Spinalis thoracis

Spinalis cervicis

Spinalis capitis



For the purposes of this thesis, the iliocostalis lumborum is the most important.

The erector spinae muscle and its prolongations are covered in the lumbar and thoracic regions by the lumbodorsal fascia. This large muscular and tendinous mass varies in size and structure at different parts of the vertebral column. For instance, in the sacral region it is chiefly tendinous; while in the lumbar region it is larger, and forms a thick fleshy mass which, in its ascending course, is subdivided into three vertical columns. These gradually diminish in mass as parts of the muscle insert successively into the vertebrae and ribs.

The erector spinae arises from the anterior surface of a broad and thick tendon, which is attached to the median sacral crest, to the spinous processes of the lumbar and lower two thoracic vertebrae and their supraspinous ligaments, to the inner aspect of the dorsal part of the iliac crests, and to the lateral crests of the sacrum, where it blends with the posterior sacroiliac ligament. The muscle fibres form a large fleshy mass which splits, in the upper lumbar region, into three columns (as previously described).

The iliocostalis lumborum splits from the erector spinae mass at the upper lumbar level and ascends to be inserted by six or seven flattened tendons into the inferior borders of the angles of the last six or seven ribs. This muscle acts as an

extensor of the vertebral column and is also able to bend the column to one side (lateral flexion) and assist in its rotation. Additionally, the iliocostalis lumborum can depress the ribs.

Throughout the course of this thesis, reference will be made to a group of muscles collectively known as the gluteus muscles. This group consists of three separate muscles. They are the gluteus maximus (which extends the thigh), the gluteus medius and the gluteus minimus (which work together to abduct and medially rotate the thigh). This muscle group is commonly referred to as the buttocks.

### 2.1.5 Nerves

The spinal nerves arise from the spinal cord within the spinal canal and pass out through the intervertebral foramina. The 31 pairs are grouped as follows: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal.

The *sciatic nerve* is the longest nerve in the body. It is formed by the sacral plexus of nerves and consists of rami L4 and L5 and S1, S2, and S3. It runs deep to the gluteus maximus. Thereafter, it travels down the posterior aspect of the thigh to supply the lower leg and foot via its main branches, the tibial nerve and the common peroneal

nerve. Nerves forming the sciatic nerve can be compressed by a protruding or herniated lumbar disc, particularly at the L4-L5 and L5-S1 interspaces.

## **2.2 Driving and Lower Back Pain**

Lumbar backache is one of the most common afflictions of the human race. Very few people are exempt from experiencing this most annoying and at times incapacitating malady, at some point in their lives. There are many hypotheses as to the causes of back pain, and, while no unanimous opinion can be reached, many researchers have noted that one of the predominant factors associated with back pain is the time spent driving motor vehicles.

For example, Kelsey and Hardy (1975), in a case-control study of the epidemiology of acute lumbar intervertebral disc herniation, estimated that men who spend half or more of their time on their job driving a motor vehicle are about three times as likely to develop an acute lumbar disc herniation as those who do not hold such jobs. These researchers also found that persons of either sex who said that they drove a car (either away from work or at work) were more likely to develop an acute lumbar disc herniation than those who did not drive at all. According to Kelsey and Hardy

(1975) these associations could not be attributed to any confounding variables considered in the study. Frymoyer et al., (1983) and Porter (1994), based on their studies, arrived at similar conclusions.

Prior to these investigations, Andersson et al., (1974d) described the situation of the driver as one of physical rest in a permanent state of alert. As such, the driver must maintain a constant position for an extended period of time in a vibrational environment; thus, loading the spine. Both posture and vibration have been theoretically implicated in the development of disc degeneration (Andersson, 1981; Keegan, 1953; Sandover, 1983; Wilder et al., 1982).

In another attempt to identify the causal relationships between motor vehicle driving and back pain, Troup (1978) identified postural stress, vibration, muscular effort, and impact and shock as the main contributors to lower back pain in drivers. Postural stress occurs when an individual is exposed to long-term sitting in the same position. Later in this chapter, this concept (referred to as postural fixity) will be discussed in more detail. Vibrations are transmitted from the car through the seat. Muscular effort contributes to occupant fatigue and discomfort through poor seat design and occupant packaging. Impact and shock are road hazards. In these factors, exposure is the critical parameter.

### **2.2.1 Back Pain and Muscular Fatigue**

Bridger (1995) shows that the lumbar muscles of chronic low back pain sufferers fatigue more rapidly than those of non-sufferers. Presumably, pain occurs both directly, as a result of stimulation of pain receptors in the muscles due to the biochemical changes which accompany fatigue, and indirectly as a result of the increased load on soft tissues in the lumbar spine itself. It seems that a lack of back muscle endurance, rather than a lack of strength, is the defining characteristic of chronic low back pain sufferers who exhibit no other obvious physical abnormalities or pathological conditions (Bridger, 1995). This finding helps to explain why chronic low back pain sufferers are at risk in activities that require sustained activity of the back extensors, like sitting.

### **2.2.2 The Physiology of Muscle Fatigue**

A minor digression is necessary, at this point, in order to discuss the physiology of muscle fatigue. Muscular fatigue is the inability to maintain or repeat the production of a given force by muscular contraction. Everyone has experienced fatigue. Its rate of onset affects comfort. Accordingly, an examination of a few of the possible mechanisms of fatigue is warranted in this type of thesis.

There are many experimental studies that demonstrate a rather straightforward relationship between the depletion of energy sources such as creatine phosphate and glycogen and the progression of fatigue (Bergstrom et al., 1971; Karlsson, 1972; Karlsson et al., 1972; Saltin and Karlsson, 1971). The depletion of energy stores is one of the most accepted explanations for fatigue.

Another commonly accepted explanation for fatigue is the accumulation of lactic acid in the muscle. Again, there is a large body of evidence to support this notion (Lamb, 1984). The theory that lactic acid accumulation in the muscles limits muscular performance has been widely held since at least 1935 (Simonsen, 1971). More recently, the concentration of lactic acid in muscle has been shown to be strongly related to the progression of fatigue, as well as the time course of recovery from fatigue (Fitts and Holloszy, 1976; Fitts and Holloszy, 1978; Karlsson, 1971).

The effect of lactic acid on promoting early fatigue is probably the result of the accumulation of hydrogen ions ( $H^+$ ), which lowers the pH of the muscle (Fitts and Holloszy, 1976). One of the effects of such a reduction in pH is a decrease in the binding of calcium to troponin, thereby reducing the activation of actin-myosin cross bridges in muscle contraction (Bianchi and Narayan, 1982; Fitts and Holloszy, 1976; Gollnick and Hermansen, 1973). Also, several key enzymes of glycolysis, including

glycogen phosphorylase and phosphofructokinase, are inhibited by excess acidity (Bergstrom et al., 1971; Gollnick and Hermansen, 1973). This means that less energy (in the form of ATP) can be replenished by glycogen breakdown when lactic acid levels are high.

Regardless of which explanation is accepted, it should be evident that blood flow has a large role to play in the rate of onset of fatigue. Blood flows to all muscles via an intricate system of veins and arteries. Blood is an extremely important medium because it brings essential nutrients (eg. oxygen, glycogen, and creatine phosphate) to the muscles and exports waste products like carbon dioxide and lactic acid. Most activities are dynamic in nature and therefore involve alternating bouts of contraction and relaxation. Under these conditions blood flows freely through the muscles. When muscles are contracted statically, some arteries and veins may be closed by the mechanical pressure of the contracting muscles, and blood flow may be reduced. In these circumstances, lactic acid accumulates more rapidly and the inevitable result is muscular fatigue.

## 2.3 Electromyography

The electromyogram (EMG) is a record of the electrical activity (action potentials) in contracting muscle. The recorded EMG voltage, called myoelectric activity, is usually the sum of several motor unit action potentials. Totally inactive muscles are electrically silent. The EMG activity is monitored by electrodes placed on the skin above a muscle (surface EMG) or by electrodes inserted directly into muscle fibres. Because of the differences in the two types of electrodes, the signals picked up vary considerably in their characteristics. Surface electrodes record the algebraic sum of all motor unit potentials reaching the electrode site. They are useful particularly for recording the activity of superficial muscles and in situations where a more general recording is sufficient. For detailed analysis of individual muscle activities, indwelling electrodes must be used. They require a hypodermic needle for insertion, but are comfortable following needle withdrawal.

According to Giroux and Lamontagne (1990), surface electrodes are more reliable on day-to-day investigation, quick and easy to attach, do not cause discomfort or pain, and have good reproducibility. Many other investigators, including Mohamed (1996), have shown the test-retest reliability of surface electrodes to be very high.



The primary reason for the recording and processing of myoelectrical signals is to predict muscle tension. The relationship of EMG activity to muscle force is dependent on several factors. For the purposes of this thesis, the most important physiological factor is fatigue. According to Chaffin and Andersson (1991), as a particular muscle fatigues, EMG activity increases. In ergonomics literature, this relationship has usually been studied using low pass filtering techniques or so-called full-wave rectification.

Lee et al., (1995), upon review of the test data obtained from their protocol, concluded that a specific subject's muscle geometry will influence signal values, as will the events that preceded the acquisition of the signal. In other words, an EMG signal can be affected by glucose levels, diet, variation in sleep patterns, and levels of activity prior to the test. These parameters make EMG signals very difficult to control in a test environment.

Given that so many factors affect the relationship between the electrical activity of a muscle and the force produced by that muscle, care is necessary when predicting muscle contraction levels from EMG data. To minimize errors in these estimates, the electrodes should first be attached to the individual in a way that achieves a low electrical impedance between the electrodes. Often this may require shaving of hair and

abrading of the epidermal layer to remove dry, high-resistance skin cells. In addition, the use of a bio-compatible electrode paste, between the skin and electrode, is frequently advocated.

Once a reasonably low impedance is achieved (which may require a few minutes of 'settling' time) the myoelectric activity, usually the root mean squared (RMS) values, can be recorded. The use of RMS values is recommended by Basmajian and DeLuca (1985). Holewijn and Hues (1992) reported that RMS values increase with increasing levels of muscular fatigue.

There are disadvantages associated with the use EMG. Not the least of which is the cumbersome test equipment (ie. electrodes, amplifier, personal computer). In addition, the electrodes may be perceived as annoying and may, therefore, negatively affect the comfort of the subject. Nevertheless, EMG is still widely used as an objective indicator of fatigue. This is especially the case when assessing automobile seat comfort (Bush et al., 1995; Greiff and Guth, 1994; Lee and Ferraiuolo, 1993; Sheridan et al., 1991).

## **2.4 Postural Fixity**

Grieco (1986) coined the term 'postural fixity' to describe static postures of the head, neck, and trunk which occur in VDT work. This notion can also be applied to the driving environment. Postural fixity occurs when an individual sits in one position for long periods without significant postural movement. Static loading of the back and shoulder muscles in this fashion can result in aches and cramping as well as a restriction of blood flow, which can cause fatigue and discomfort. Simply put, the human body is not made to sit in one position for long periods of time.

Based on both epidemiological data on the frequency of disorders of the back in groups of subjects occupationally exposed to prolonged sitting postures and studies on the mechanism of nutrition of the intervertebral disc it is possible to conclude that, in addition to causing discomfort, postural fixity is a risk factor for the various spinal segments.

A far reaching epidemiological investigation on the frequency of low back pain in eight occupational groups was conducted by Magora (1972). In this study, he also examined the frequency of this syndrome in groups of persons who, for occupational reasons, worked in a seated position very often (more than 4 hours per shift), sometimes

(for 2 to 4 hours per shift), and rarely or never (less than 2 hours per shift). The findings, independent of the methodological problems and details concerning the different occupations, enabled Magora (1972) to establish that both excess and rare occurrences of seated postures, over time, are two factors associated with a high frequency of low back pain, while subjects who vary their working positions, alternating sitting positions with mobile positions, have, on the whole, a negligible frequency of low back pain. Other studies and authors have tended in some way to confirm the assumption that fixed and prolonged sitting postures increase the risk of alterations and disorders of the lumbar spine (Kelsey, 1975; Andersson, 1981; Damkot et al., 1984).

In addition, Grieco (1986) notes that since the intervertebral discs have no direct blood supply, the variations in the loading to which they are subjected as a result of activities of daily living provide a useful function in 'pumping' intercellular fluid into and out of the disc. This provides nutrients and removes waste products. Fixed postures are thought to be hazardous because they interfere with this nutrient exchange mechanism. Therefore, sitting in one posture, no matter how good it is, will result in reduced nutritional exchanges and in the long term may promote degenerative processes in the discs.

## **2.5 Automotive Seat Design for Sitting Comfort**

The automobile's evolution as a universal means of personal transportation has focused seat design attention upon the occupant's comfort and health. However, the growth of an international automotive market has increased diversity in seat design. As a result, unique but functionally equivalent seats are built to satisfy similar design goals. Ideally, good seat design should apply knowledge of human sitting posture to accommodate occupant preference in vehicle seating.

According to Reynolds (1993) there are four design criteria for a driver's seat.

1. The seat should position the driver with unobstructed vision and within reach of all vehicle controls.
2. The seat must accommodate the driver's size and shape.
3. The seat should be comfortable for extended periods.
4. The seat should provide a safe zone for the driver in a crash.

The primary focus of this thesis is design criteria number three (above), although some time will be spent addressing the size and shape of the driver (design criteria number two).

Seats are, theoretically, designed to fit at least 90 per cent of the population ranging from small to large body sizes. A small female has some dimensions less than or equal to the fifth percentile. A large male has some dimensions larger than or equal to the 95th percentile. The range between the small female and large male approximates the adjustments needed in seating to accommodate anthropometric differences in body size.

Body composition may also be an important consideration. It is defined as the proportion of fat, muscle, and bone making up the body (Nieman, 1990). *Obesity* is a closely related term which is generally defined as an excess of body fat. In large population studies of obesity, a commonly used measure of obesity is the *body mass index* (Revicki and Israel, 1986). A number of body mass indices (BMIs) have been developed, all derived from body weight and height measurements. These BMIs are popular in large population studies because of their simplicity of measurement and calculation, and low cost. One of the most widely accepted BMIs is the *Quetelet Index*. To calculate the Quetelet Index body weight in kilograms is divided by height in meters squared. Based on this calculation, Table 2.1 can be used for obesity classification.

20-25 kg/m <sup>2</sup>	Desirable range for adult men and women
25-29.9 kg/m <sup>2</sup>	Grade 1 obesity
30-40 kg/m <sup>2</sup>	Grade 2 obesity
> 40 kg/m <sup>2</sup>	Grade 3 obesity (morbid obesity)

Table 2.1: Quetelet Index for Obesity Classification

Based on this classification, invaluable insight into somatotype (ie. body type) can be obtained. For example, if an individual falls in the ‘desirable range’, he/she will most probably be a *mesomorph*. Mesomorphs possess athletic, muscular body types. If an individual falls in any other category listed in Table 2.1, he/she can be considered an *endomorph*. People with excessive levels of body fat are said to be endomorphic. Finally, people who are *ectomorphic* (lean, thin, and linear) usually have low amounts of body fat.

The geometric features of seat design include: cushion size, seat back size, and back angle. Cushion size accommodates the seated occupant’s buttock and thigh dimensions. The distance from the buttock to popliteal region (ie. the popliteal length) delimits the loaded cushion’s length from seat back to the waterfall line. Therefore, the fifth percentile female popliteal length is used. Grandjean (1980) recommends that cushions be 440 to 550 mm long. Lateral space is also important for physical and

psychological comfort. Given the fact that female hip breadth is generally greater than male hip breadth, the 95th percentile female hip breadth determines cushion width. Thus, Grandjean (1980) recommends a cushion width of 480 mm (adjusted for clothing and leg splay).

The seat back supports the trunk while sitting, but it also must be considered a barrier to arm reach and vision. Seat back height is, therefore, determined by the fifth percentile female sitting shoulder height. In terms of seat back height, Grandjean (1980) recommends 500 mm. Seat back width may be divided into lower and upper regions. Large torso breadths at the hip, waist, and chest determine the lower space requirements. The upper region of the seat back should accommodate the static and dynamic breadth of the shoulder. Grandjean (1980) recommends 480 mm for seat back width. It should be stated that it is not uncommon to find tapered automobile seats (wider at the bottom than at the top). In this way movement of the arm is not constrained at the shoulder joint.

Back angle adjustments accommodate differences in arm length and occupant preferred hip angle. Typically, the seat back is reclined 15° to 25° from vertical. Increasing the seat angle decreases pressure on the disc (Andersson et al., 1975). However, the seat back angle has only a slight effect on lumbar lordosis (Andersson et



al., 1979). Recommendations for optimal seat back orientation range from 105° (Keegan and Radke, 1964) to 120° (Hosea et al., 1986; Andersson et al., 1974d) with a lumbar support. Other investigations indicate that the orientation of the cushion and seat back should be adjustable (Reynolds, 1993).

Hubberd et al., (1994) concluded that if there is conflict between the human anthropometry and seat geometry, then the seat will intrude on the body, pressure will be concentrated, and comfort will suffer. The geometric contours between the human body and the seat determine the pressure distributions on these contours; these pressures relate to blood flow and nerve compression. Body position is posture, and posture is a primary determinant of muscle tension. Thus, the geometric characteristics of people and their geometric interactions with seats are directly related to the physiological factors of seating comfort.

## **2.6 The Concept of Microadjustment**

When a person stands erect, the vertebral column is normally straight in the anteroposterior aspect and curved in the lateral aspect, producing a compound curvature referred to as cervical lordosis, thoracic kyphosis, and lumbar lordosis. The

lumbar curve is lordotic because the vertebrae and discs are thicker anteriorly than posteriorly. This is necessary because the upper surface of the sacrum is normally at a forward sloping angle to the horizontal plane. The lumbar spine is fixed to the sacrum and as the sacrum is fixed to the pelvis, it follows that a rotational movement of the pelvis influences the shape of the lumbar spine. Sitting can be considered a rotational movement. When an individual sits with the thighs at 90° and no back support, the lumbar region of the back flattens out and may even assume an outward bend (convex), that is, it becomes kyphotic. This occurs because the hip joint rotates only about 60°, forcing the pelvis to rotate backward about 30° to achieve a 90° thigh angle (Sanders and McCormick, 1993). Lumbar kyphosis results in increased pressure on the discs located between the vertebrae of the spine (Chaffin and Andersson, 1991).

An important preliminary issue surrounds that of 'lumbar support' for the promotion of lumbar lordosis. Keegan (1953) and Keegan and Radke (1964) were among the first to recommend that a firm pad be located in the lower part of the seat back to restrain the lumbar spine from flexing extensively. These studies suggested that seats be designed to produce a lumbar lordosis about midway between the typical standing lordosis and a flat contour. This recommendation was made because it was observed that people under treatment for low back disorders were often more comfortable sitting in a reclined posture with lumbar lordosis than in an upright posture

with a flat spine curvature.

By the mid 1970s, most lumbar support recommendations were strongly influenced by physiological studies of the load on the lumbar spine. Andersson et al., (1974a, 1974b, 1974c, 1974d) used quantitative measurements of back extensor muscle activity and internal lumbar disc pressure to assess spine loads for a range of postures. Andersson et al. found that disc pressure was lower in standing than in a wide range of seated postures, both unsupported and supported. Back extensor muscle activity was also low both in standing and supported sitting with reclined back angles.

In general, Andersson and his coworkers found that, for reclined postures, increasing the lumbar lordosis toward the standing posture decreases lumbar intradiscal pressure. In subsequent experiments with a car seat, Andersson et al. (1974d) found the lowest levels of back extensor muscle activity and intradiscal pressure with a seat back angle of 120° and a lumbar support prominence of 50 mm. Based on the assumption that low myoelectric activity and disc pressure are favourable, he and his coauthors recommended these as target values for seat design.

The substantial work of Andersson's research team led to recommendations that lumbar supports be constructed to preserve, to the extent possible, the standing lumbar

lordosis in sitting, with the objective of reducing lumbar spine loads as measured by intradiscal pressure and myoelectric activity. These recommendations have been echoed by many others since (Chaffin and Andersson, 1991; Reynolds, 1993, Reed et al., 1995). A lumbar support intended to preserve the standing lordosis will be located at approximately the apex of the standing curvature, around L3, and will be longitudinally convex to mate with the desired spine curvature.

In this context, microadjustment extends the idea of lumbar support by attempting to deal with the previously described concept of postural fixity. The micro-adjuster control system, which is the focus of this study, is built directly into the lumbar support mechanism. It is designed to combat the musculoskeletal problems associated with fixed sitting postures by forcing the user to assume a variety of postures at predetermined time intervals. This is accomplished through a series of timed 'in' and 'out' movements which alter the degree of the lumbar support prominence. At its maximum point, the micro-adjuster control system protrudes 5 cm into the seated occupants lower back. In general, microadjustment is thought to be beneficial because it stimulates blood flow to the musculature of the lower back. This musculature would, under normal sitting conditions, be statically contracted. Therefore, the onset of fatigue is delayed and occupant comfort is enhanced.

## CHAPTER 3

### EXPERIMENTAL METHODOLOGY

#### 3.1 Apparatus

A Cadillac automobile seat provided by *Schukra of North America* was used for the purpose of this study. The seat was mounted on a wooden base and equipped with a micro-adjuster control system built directly into the lumbar support part of the back rest. The micro-adjuster moved horizontally in two directions; in (moving away from the seated occupant) and out (moving towards the lower back of the seated occupant). The movement was controlled by a motor. The corresponding circuit required a 12 V power supply. A digital counter was placed in the circuit in order to provide a means of counting the total number of pulses to the motor. It should also be stated that, for this study, the seat back was fixed at an angle of 120° (Hosea et al., 1986; Andersson et al., 1974d).

In order to measure low back muscle activity and therefore obtain an indication of fatigue, six pairs of 10 mm diameter bipolar surface electrodes were attached to both sides of the vertebral column. These electrodes were manufactured by the Grass Instrument Company. The 'Gold Disk Electrodes' (type ESGH), as they are called, were made from heavy gold plate and pure solid silver.

An amplifier was used to amplify the EMG signals obtained. This amplifier was a high performance AC preamplifier (model P511) made by the Grass Instrument Company. The amplifier settings are included in Appendix A.

Data collection was aided by a 486 personal computer equipped with software called VIEWDAC (Keithley ASYST, 1992). A VIEWDAC sequence was used to capture the data collected using an analog-to-digital conversion program. The sequence was set to capture 45 readings per second from six channels. In addition, VIEWDAC allowed macros to be written which took the RMS values from all six channels and computed an average. The average RMS value at each time period was used in the subsequent analysis. These macros simplified the data collection process.

A photograph of the entire experimental set-up is included in Appendix B.

### 3.2 Experimental Design

In this study, there were three main factors under investigation. They were: the cycle, the wait, and the pulse. To begin, these terms should be operationally defined. *Cycle* was the time duration for controlling the direction (in and out) of the microadjustments. It could range from zero to 12 minutes. *Wait* was the time delay between microadjustments. It could range from zero to three minutes. *Pulse* was the time duration of the microadjustment. It could be considered an index of intensity. That is, the greater the pulse, the more pronounced the microadjustment. It could range from zero to 1.2seconds. These definitions are best understood through an examination of Figure 3.1 (provided by *Schukra of North America*).

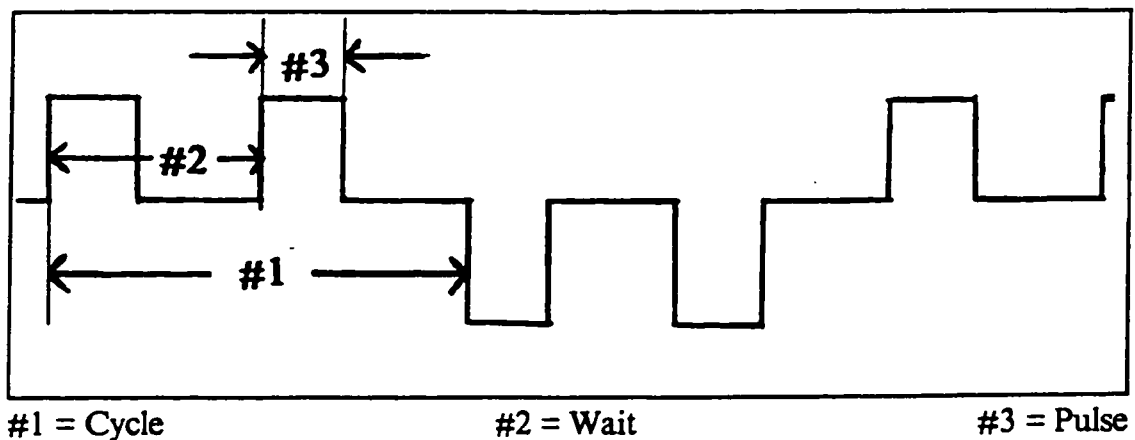


Figure 3.1: Operational Definitions of Independent Variables

For this thesis, cycle was set to two levels; 2 min and 5 min. The wait was also set to two levels; 15 sec and 30 sec. Similarly, pulse was set to two levels; 0.8 sec and 1.1 sec. Therefore, this results in a design with  $2^3$  possible combinations. In each condition, subjects sat on the automobile seat for at least two hours. Table 3.1 summarizes the details of the above design.

Condition	Cycle (min)	Wait (sec)	Pulse (sec)
1	2	15	0.8
2	2	15	1.1
3	2	30	0.8
4	2	30	1.1
5	5	15	0.8
6	5	15	1.1
7	5	30	0.8
8	5	30	1.1

Table 3.1: Experimental Design

It should also be stated that each subject participated in each condition, making this a full factorial repeated measures design.



### **3.3 Procedure**

The experimental sessions were scheduled for a time convenient to both the volunteer subject and the investigator. Subjects were asked to refrain from any strenuous physical activity for the time frame leading up to a particular test session. Before the beginning of the first experimental session, the procedure was thoroughly explained and each subject was asked to sign a consent form. A copy of this form is included in Appendix C.

Before each session, the subject was asked to pick a number from 1 to 8. Each number corresponded to one of the possible conditions outlined in Table 3.1. Once a condition was selected, all reference to it was removed from the table so that, during the next experimental session, the subject would not select the same condition. This was done to avoid any unnecessary replication of conditions. In this way the conditions were randomized.

During the first session with each subject, a few demographic (age and sex) and anthropometric (height and weight) characteristics were obtained and recorded. Standing height and body weight were actually measured at this time. This anthropometric data was used to classify each subject according to somatotype. To this

end, the Quetelet Index, as previously described, was used.

At this point in the procedure, part A of a pre-prepared questionnaire was administered. There are two versions of this questionnaire. Version #1 was used during the first session while version #2 was used in all subsequent sessions. The versions are identical except that version #1 contains a few more questions. In fact, the questions in version #2 are numbered exactly as they were in version #1. This was done to simplify the data analysis process. Two versions were deemed necessary in order to eliminate as much redundancy as possible. The questions in part A were designed to assess the subjects' musculoskeletal condition in terms of the neck and shoulders, the back, and the lower extremities (ie. buttocks and legs). In version #1 the subject's past and present musculoskeletal condition was evaluated, while in version #2 only the subject's current musculoskeletal condition was evaluated.

After completing part A of the appropriate questionnaire, electrodes were attached to the lumbar area of the subject. Extreme care was exercised when positioning these electrodes. Muscle geometry and bone location, which can both affect the myoelectrical signal, were important parameters to consider. Following the lead of Andersson et al. (1974d), the six pairs of electrodes were placed 3 cm lateral to the vertebral column (three pairs on each side) at the L1, L3, and L5 levels. The vertebral

level is determined by the level of the tips of the spinous processes, which can be palpated. This arrangement, shown in Figure 3.2, targets the erector spinae muscle group.

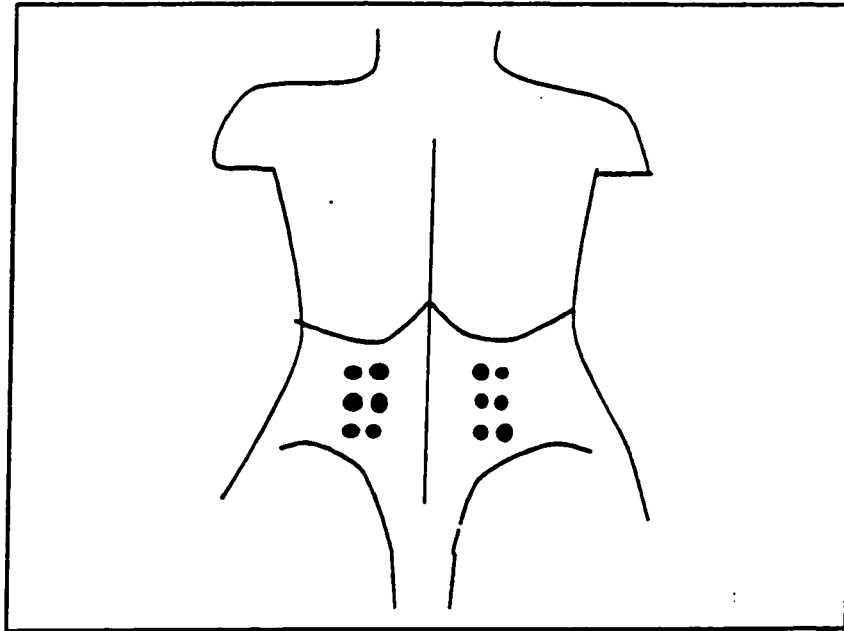


Figure 3.2: Electrode Arrangement

The electrodes were filled with an electrolyte paste and attached using medical tape. This methodology has only one known side effect. It is possible that some subjects could have experienced temporary skin irritation as a result of the use of the electrolyte. In addition, three separate electrodes acted as neutral leads. Neutral leads are a requirement of all EMG studies. These electrodes were attached to the elbow (a bony area).

Prior to actually attaching the electrodes, the aforementioned area was carefully cleaned using a piece of cotton moistened with rubbing alcohol. If there was hair covering the attachment sites it was first shaved. These precautions were taken to ensure that a pure myoelectric signal was obtained (ie. one with little noise).

During the course of the test session, data was collected using part B of the pre-prepared questionnaires, along with EMG. In this section, subjects were asked to rate their perceived level of comfort using a specially developed scale. This was done every 30 minutes for the entire duration of the experiment.

EMG data was collected every 10 minutes for the full two hour test session. To aid in this process, time triggers were built into the software. It should also be stated that EMG data was collected only when the microadjustment was moving away from the subject's back (ie. the 'in' direction). When the microadjustment is moving 'out' it presses against the electrodes attached to the lower back. It was feared that if this precaution was not taken, the EMG signal would have been unnecessarily noisy. To accomplish this, the entire experimental session needed to be planned around the cycle time of the particular condition under investigation. Recall that one cycle includes all the microadjustments occurring in one direction. When the cycle was set to 5 min (for example), the software was not activated until the subject reported feeling the first

microadjustment in the 'in' direction. This ensured that, at every 10 minute mark, the microadjustment was moving in the 'in' direction.

At the conclusion of the experimental session, part C of the questionnaires was administered. Both version #1 and version #2 began with an evaluation of the subjects' current musculoskeletal condition. Once again, this was done in terms of the neck and shoulders, the back, and the lower extremities. Both versions continued by assessing various seat design attributes, including those specific to each subject's experimental condition. The final few questions in version #1 were geared towards obtaining a general indication of the subject's thoughts concerning the micro-adjuster control system. Copies of the questionnaires employed can be found in Appendix D.

Finally, the electrodes were removed and the subject's lower back was cleaned with a wet towel (to remove any excess electrolyte paste) and dried. In preparation for the next experimental session, the electrodes were rinsed and dried.

## CHAPTER 4

### RESULTS AND DISCUSSION

The effect of microadjustment on automobile seat comfort was studied using both objective (EMG) and subjective (questionnaires) methods. Therefore, the results are divided into objective and subjective sections.

#### 4.1 Objective Results

##### 4.1.1 Subjects

A total of ten subjects volunteered for this study. The subjects' demographic and anthropometric characteristics are listed in Appendix E. The number of males and females were equally distributed. The mean age of the sample was 21.9 years (SD = 2.3). The mean body weight was 74.3 kg (SD = 11.44) and the mean standing height was 1.72 m (SD = 0.06). Together, these two anthropometric characteristics were used

to classify individuals according to somatotype. The simple technique employed is known as the Quetelet Index (discussed in Chapter 2). The average index was 24.9 kg/m<sup>2</sup>. Therefore, in terms of body composition, the sample falls within the desirable range for adult men and women.

However, when the male subjects were considered separately the average Quetelet Index was 26.0 kg/m<sup>2</sup>. This result suggests that the males in this sample were slightly endomorphic. The implication is that these subjects contain excess subcutaneous fat. Subcutaneous fat is found between the skin and the superficial musculature. Inevitably, some of this subcutaneous fat is found in the mid section of the body, including the lower back region. For this reason, the microadjustment may not be serving its intended purpose of eliminating erector spinae muscle fatigue due to postural fixity. That is, the male subjects may not be experiencing the full benefit of the microadjustment.

An additional concern involved the relatively diminutive stature of three of the female subjects (subject #3, #7, and #9). Because of their stature, the microadjustment was not directly concentrated on the lumbar portion of their backs. In fact, subject #3 (the tallest of the three) reported feeling the microadjustment in the vicinity of T10-T12 (ie. the lower thoracic region). Under normal circumstances, this area of the back is

kyphotic (Chapter 2). This may be confounding the results of this experiment. Therefore, the micro-adjuster control system should be adjustable.

#### **4.1.2 General Effect of Microadjustment**

The designers of the micro-adjuster control system hypothesized that microadjustment would prevent the negative effects of postural fixity, as compared to no microadjustment. To test this hypothesis, subject #1 (a male) participated in a condition involving microadjustment and a condition involving no microadjustment. Figure 4.1 represents the results of this comparison in terms of erector spinae muscle activity (ie. RMS values). These conditions were tested on two separate days therefore the data was normalized. In the microadjustment condition, the subject displayed a drastic decrease in RMS values after the 50 minute mark. This decreasing trend continued until the end of the experimental session. In the no microadjustment condition, RMS values were maintained at approximately the same level throughout the course of the experiment. This is an expected result given that Hosea et al. (1986) found absolutely no EMG evidence of fatigue even after 3.5 hours of automobile driving. Based on this simple comparison, it was concluded that microadjustment appeared to have a beneficial effect on erector spinae muscle activity. This preliminary result served to fuel the remainder of this thesis.



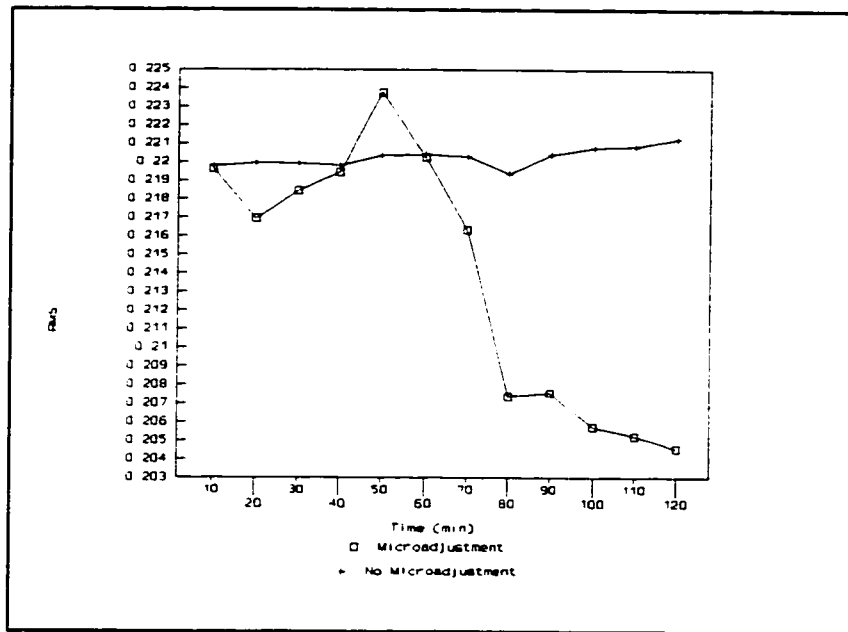
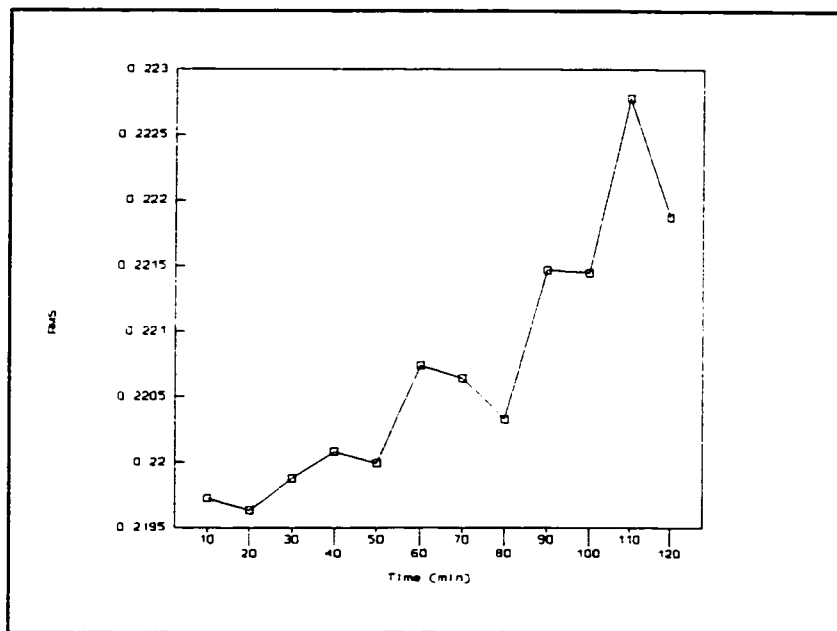


Figure 4.1: Microadjustment vs No Microadjustment (Normalized RMS Data)

#### 4.1.3 Effect of Main Factors

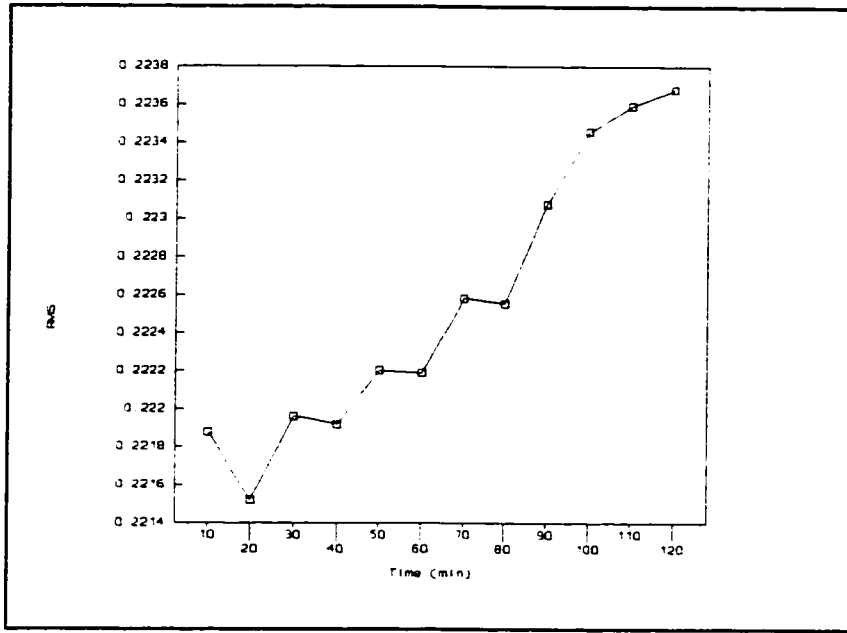
To objectively evaluate the effect of the variables manipulated in this investigation,  $\Delta$ RMS was used. For this thesis,  $\Delta$ RMS was defined as the change in RMS values over the two hour experimental session. To simplify,  $\Delta$ RMS is the difference between the highest and lowest RMS value. A positive  $\Delta$ RMS value was found when the highest RMS value occurred toward the beginning of the experimental session and the lowest RMS value occurred toward the end of the experimental session. This implies that the experimental treatment had a beneficial effect on EMG activity. Similarly, a negative  $\Delta$ RMS value was found when the highest RMS value occurred

toward the end and the lowest RMS value occurred toward the beginning of the experimental session (the opposite scenario). A negative  $\Delta$ RMS value implies that the treatment had a detrimental effect on EMG activity (ie. the erector spinae muscle group began to fatigue). The following eight figures reveal the results for each of the eight experimental conditions. In these figures the average RMS values, for all the subjects, were compiled and plotted against time. Then, from these figures,  $\Delta$ RMS values were obtained. This information is presented in raw form in Appendix F. The raw data from this thesis are similar to Mohamed's (1996) raw data. This data can, therefore, be considered valid.



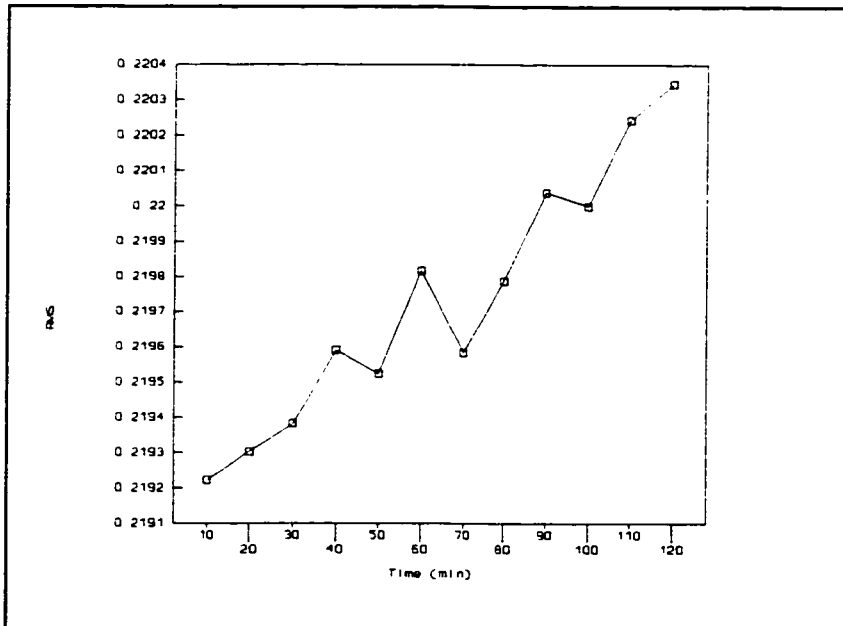
$$\Delta\text{RMS} = -0.0042306$$

Figure 4.2: Average RMS Values for Condition #1



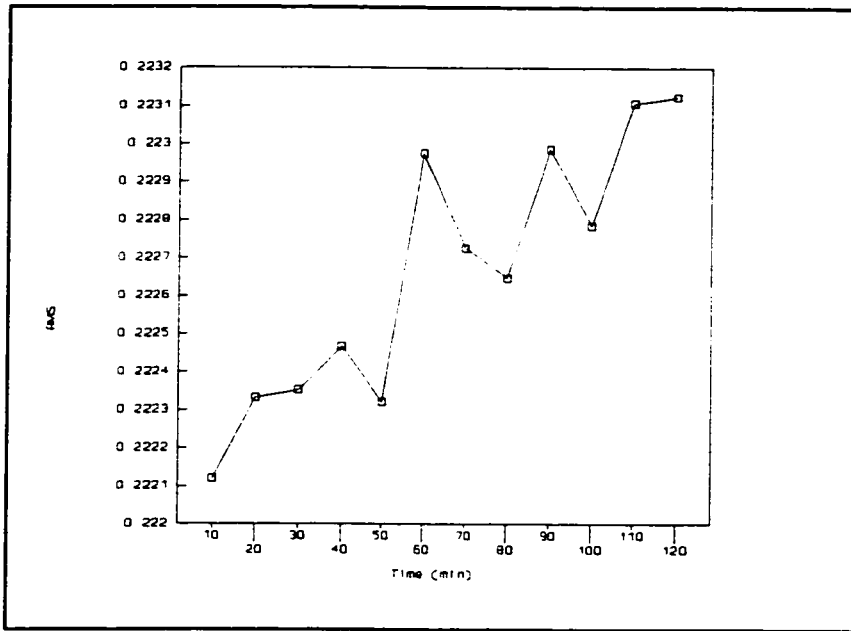
$\Delta RMS = -0.0029725$

Figure 4.3: Average RMS Values for Condition #2



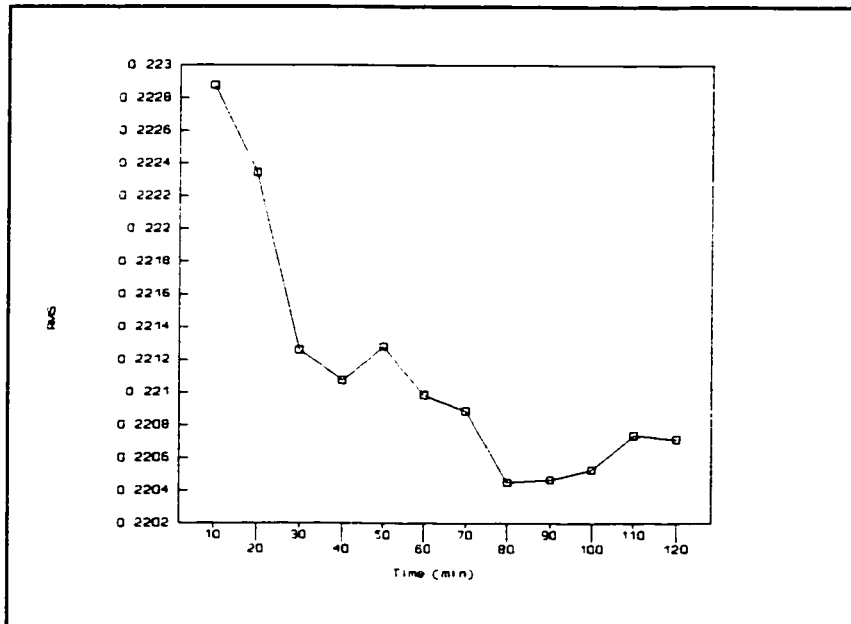
$\Delta RMS = -0.0011418$

Figure 4.4: Average RMS Values for Condition #3



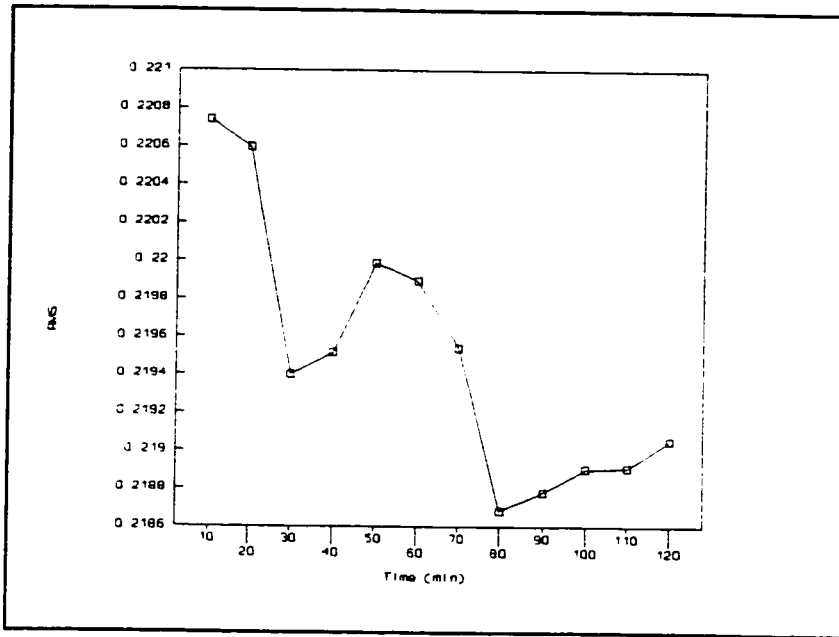
$\Delta$ RMS = -0.0007423

Figure 4.5: Average RMS Values for Condition #4



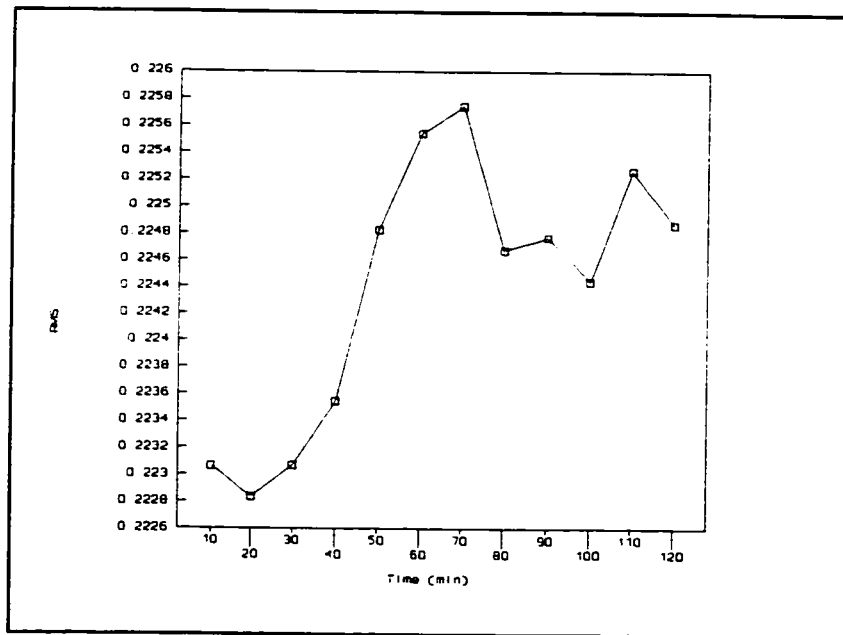
$\Delta$ RMS = 0.003325

Figure 4.6: Average RMS Values for Condition #5



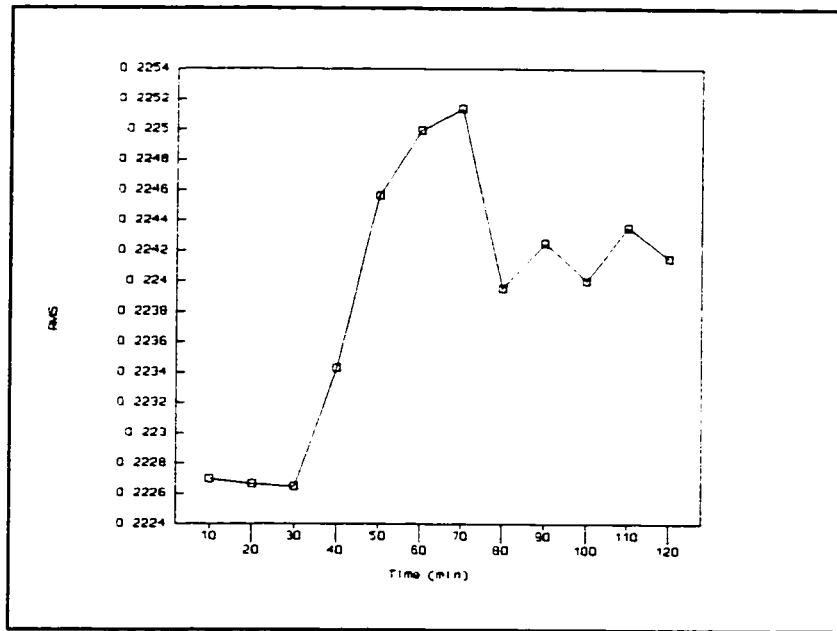
$\Delta RMS = 0.0029468$

Figure 4.7: Average RMS Values for Condition #6



$\Delta RMS = -0.0023284$

Figure 4.8: Average RMS Values for Condition #7



$\Delta RMS = -0.0014885$

Figure 4.9: Average RMS Values for Condition #8

In terms of the two levels of cycle under investigation, Figure 4.10 illustrates that the group found 5 min cycles superior to 2 min cycles (as indicated by the mean  $\Delta RMS$  values). The male subjects, considered separately, exhibited a similar but more pronounced trend. The females, on the other hand, seemed to slightly prefer 2 min cycles to 5 min cycles. This ambiguity can best be explained by the small sample size.

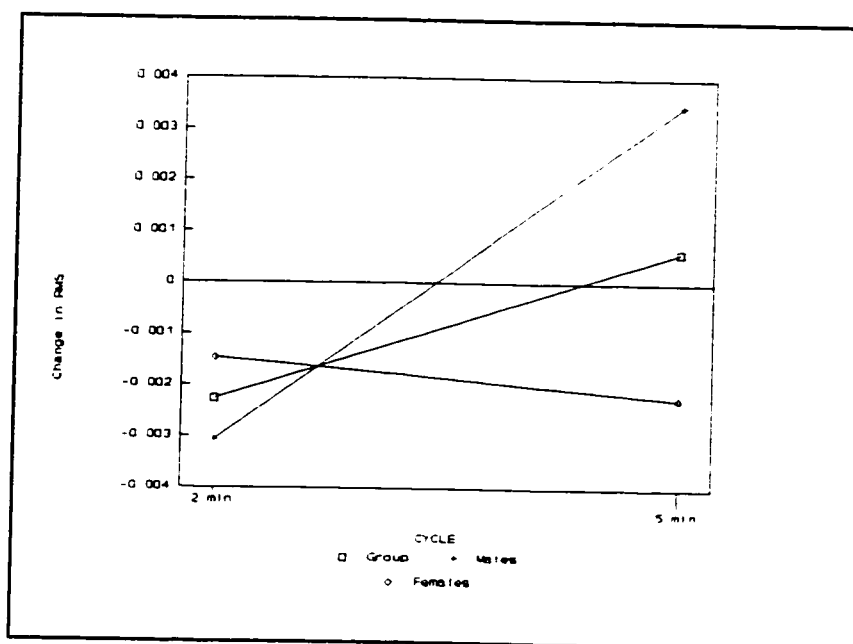


Figure 4.10: Comparison Between Two Levels of Cycle

Identical trends were found when the two levels of wait were considered (Figure 4.11). The group, as well as the males (considered separately), seemed to prefer 15 sec over 30 sec, while the females slightly favoured 30 sec to 15 sec. It is speculated that a larger sample size would have resulted in a more uniform finding.

The results of the comparison between the two levels of pulse are much more definite. Figure 4.12 reveals that the group, the males, and the females all preferred 1.1 sec over 0.8 sec.

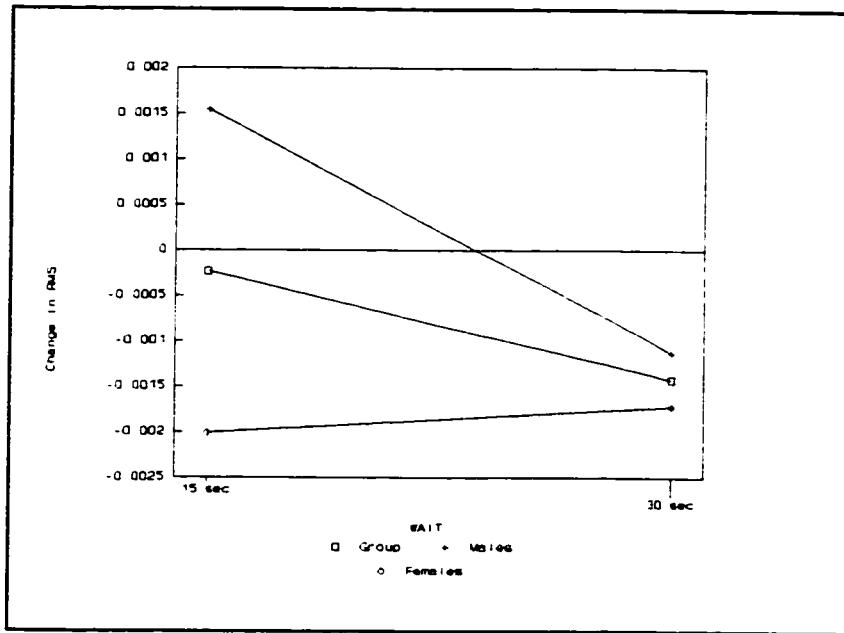


Figure 4.11: Comparison Between Two Levels of Wait

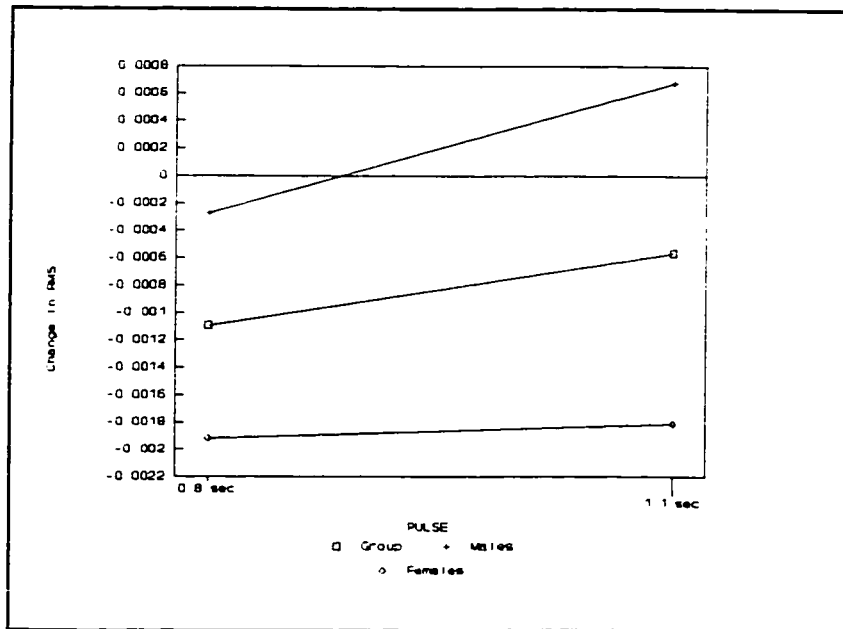


Figure 4.12: Comparison Between Two Levels of Pulse



To better evaluate the effect of each variable manipulated in this experiment, a statistical analysis of variance (ANOVA) was conducted on the  $\Delta$ RMS values. The results are summarized in Table 4.1.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value
Model	16	0.00146160	0.00009135	3.13*
Error	63	0.00183701	0.00002916	
Total	79	0.00329861		
Subjects	9	0.00095694	0.00010633	3.65*
Cycle (A)	1	0.00016653	0.00016653	5.71*
Wait (B)	1	0.00002844	0.00002844	0.98
AxB	1	0.00029675	0.00029675	10.18*
Pulse (C)	1	0.00000561	0.00000561	0.19
AxC	1	0.00000179	0.00000179	0.06
BxC	1	0.00000016	0.00000016	0.01
AxBxC	1	0.00000539	0.00000539	0.18

\* = significant at 0.05 level

Table 4.1: ANOVA Summary Table

The difference between subjects is statistically significant [(E (9, 63) = 3.65,  $p < .05$ )]. From Figure 4.10, 4.11, and 4.12, it is rather obvious that the male subjects exhibited greater  $\Delta$ RMS values than their female counterparts. To elaborate, the mean

$\Delta$ RMS value for the males, irrespective of the experimental condition, was 0.000205 (SD = 0.004013), while the mean  $\Delta$ RMS value for the females was -0.001863 (SD = 0.002195). Based on this result, it is evident that the males in this sample found microadjustment more beneficial than the females.

Considering the main effects, the ANOVA reveals that the difference between 2 min cycles and 5 min cycles is statistically significant [(E (1, 63) = 5.71,  $p < .05$ )]. A comparison of the mean  $\Delta$ RMS values (as in Figure 4.10), indicates that 5 min cycles are superior to 2 min cycles.

The other two variables manipulated (ie. wait and pulse) did not produce statistically significant main effects. This may be due to the similarity of the levels selected for this thesis.

#### **4.1.4 Interaction Effects**

Table 4.1 indicates that the interaction between cycle and wait was statistically significant [(E (1, 63) = 10.18,  $p < .05$ )]. Although the levels of wait selected for this study were statistically identical, their interaction with the levels of cycle was extremely significant. In fact, considering only the three variables under investigation, the cycle-

wait interaction made the greatest contribution to the total sum of squares. This result suggests that 5 min cycles and 15 sec waits are most beneficial in terms of  $\Delta$ RMS values. This is obvious when considering Figure 4.2 to 4.9. Condition #5 (Figure 4.6) and condition #6 (Figure 4.7) were the only experimental treatments which resulted in positive  $\Delta$ RMS values. Both of these conditions had a cycle of 5 min and a wait of 15 sec.

## 4.2 Subjective Results

Any investigation designed to improve automobile seat comfort must consider the human occupant's perceptions. In the past, this was the sole method of evaluation. Today, sophisticated equipment provides researchers with the ability to obtain objective data. Nevertheless, the importance of subjective information cannot be understated. In chapter 1 it was stated that the predominating philosophy is to combine objective and subjective measurement systems for the seat evaluation process. Based on this reality, two questionnaires were developed (specifically for this thesis) to help in the systematic collection of subjective data. The results are summarized in Appendix G.

Question #1, #3, and #5 of version #1 of the questionnaire (found in Appendix D) provide a history of the type and frequency of musculoskeletal problems encountered by subjects in this sample. These questions are focused on the neck and shoulders, the back, and the lower extremities, respectively. The results of these questions are illustrated in Figure 4.13. As is evident, considering only the past 12 months, the subjects in this sample are fairly fit from a musculoskeletal standpoint. That is, an overwhelming majority of subjects reported 'seldom' or 'never' experiencing any aches, pains, and/or discomforts in the specified parts of their bodies.

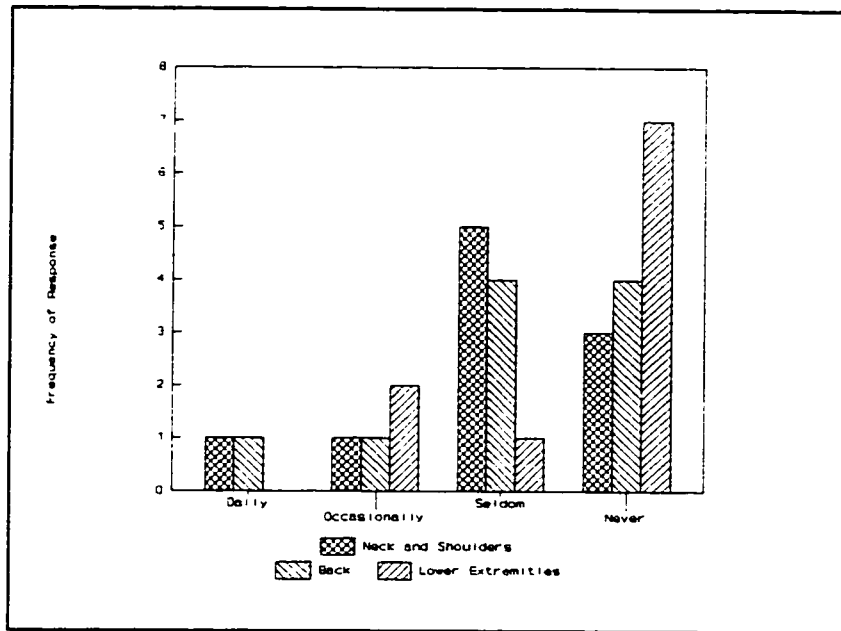


Figure 4.13: Musculoskeletal History

At this point it is appropriate to compare the number of reported musculoskeletal complaints before and after the experimental sessions. Once again, this is done in terms of the neck and shoulders, the back, and the lower extremities. Table 4.2 summarizes these results as a percentage of all 80 experimental sessions.

Pre-Experiment vs Post Experiment	Neck and Shoulders	Back	Lower Extremities
No Complaints Before - No Complaints After	73.75%	73.75%	88.75%
No Complaints Before - Complaints After	17.5%	17.5%	2.5%
Complaints Before - Complaints After	0%	6.25%	8.75%
Complaints Before - No Complaints After	8.75%	2.5%	0%

Table 4.2: Pre-Experiment vs Post Experiment Musculoskeletal Condition

Most subjects reported absolutely no musculoskeletal problems before or after the experimental session. This was the case for the neck and shoulders (59/80), the back (59/80), and the lower extremities (71/80). This was an expected result given that all the subjects were relatively young and healthy.

Following the experimental session, a few subjects complained of various musculoskeletal problems that were not initially evident [neck and shoulders (14/80), back (14/80), and lower extremities (2/80)]. In more general terms, subjects were asked about their current musculoskeletal condition prior to the experimental sessions (question #2, #4, and #6 of the questionnaires) and immediately following the experimental sessions (question #1, #2, and #3 of the questionnaires). In fact, the three questions were worded identically in both sections of the questionnaires. Figure 4.14

illustrates the results.

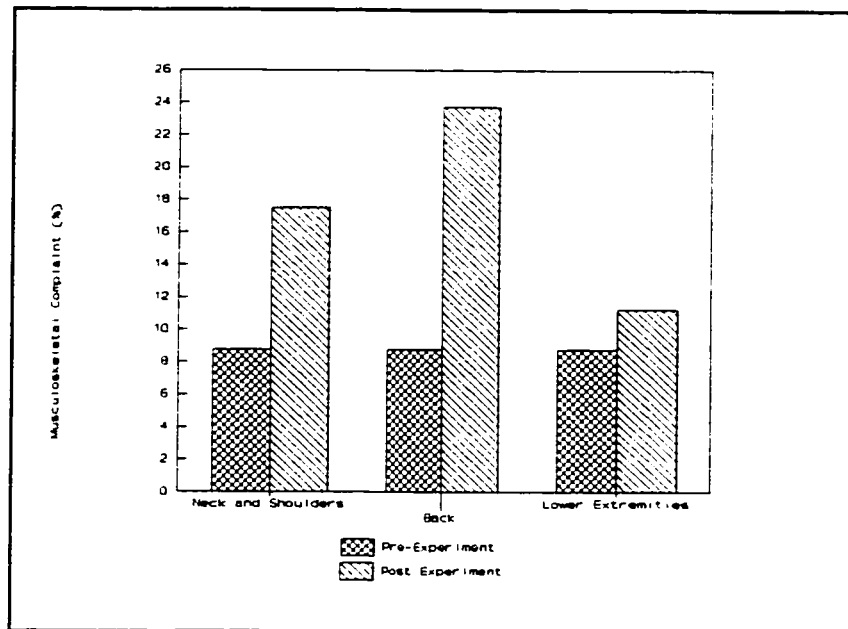


Figure 4.14: Pre-Experiment vs Post Experiment Musculoskeletal Condition

From this figure, it is clear that subjects reported a greater incidence of aches, pains, and discomforts following the experimental sessions, irrespective of the part of the body considered. Based on this result, one may be tempted to conclude that microadjustment had a detrimental effect on the musculoskeletal comfort of some of the subjects. However, it is definitely more realistic to attribute the increased incidence of aches, pains, and discomforts to the act of prolonged sitting (which was shown to be detrimental in Chapter 2).

Some subjects reported experiencing various musculoskeletal problems before the beginning of the experimental sessions. In these cases it was interesting to note how the experimental session affected the subject's post experiment musculoskeletal condition. The results (found in Table 4.2) indicate that some subjects exhibited no beneficial change in musculoskeletal condition due to the experimental session [neck and shoulders (0/80), back (5/80), and lower extremities (7/80)], while other subjects were relieved of their original problems [neck and shoulders (7/80), back (2/80), and lower extremities (0/80)]. For the purposes of this thesis, the most important of these results is that back aches, pains, and discomforts may be relieved through microadjustment. This result demonstrates the potential therapeutic effect of microadjustment.

In chapter 3, it was stated that subjects were asked to indicate their perceived level of comfort for several different sections of the body using a five point scale. This was done at 30 minute intervals during the course of the experimental session (part B of the questionnaires). Figure 4.15, 4.16, 4.17, and 4.18 present the average results for the neck and shoulders, the upper back, the lower back, and the lower extremities, respectively. In each figure the average comfort rating, irrespective of the experimental condition, is plotted against time. In this way, a general understanding of subjects' perceptions regarding the effect of microadjustment was obtained.



Figure 4.15 reveals that, on average, the group reported feeling slightly less comfortable in the neck and shoulder region at the 120 minute mark (ie. the end of the experimental session) than at the 30 minute mark.

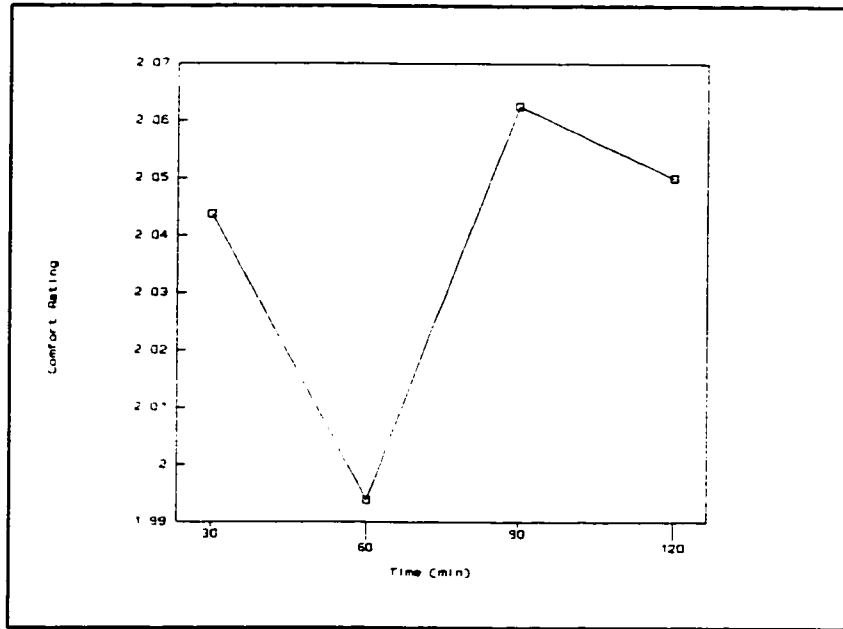


Figure 4.15: Perceived Level of Neck and Shoulder Comfort

Regarding subjects' perceptions of upper back comfort, Figure 4.16 indicates that the group was slightly more comfortable at the end of the experimental session than they were at the beginning. This is a pleasantly surprising result given that the micro-adjuster control system was designed to target the lumbar area of the back. Taken at face value, this result seems to suggest that the benefits of microadjustment are carrying over to the upper back.

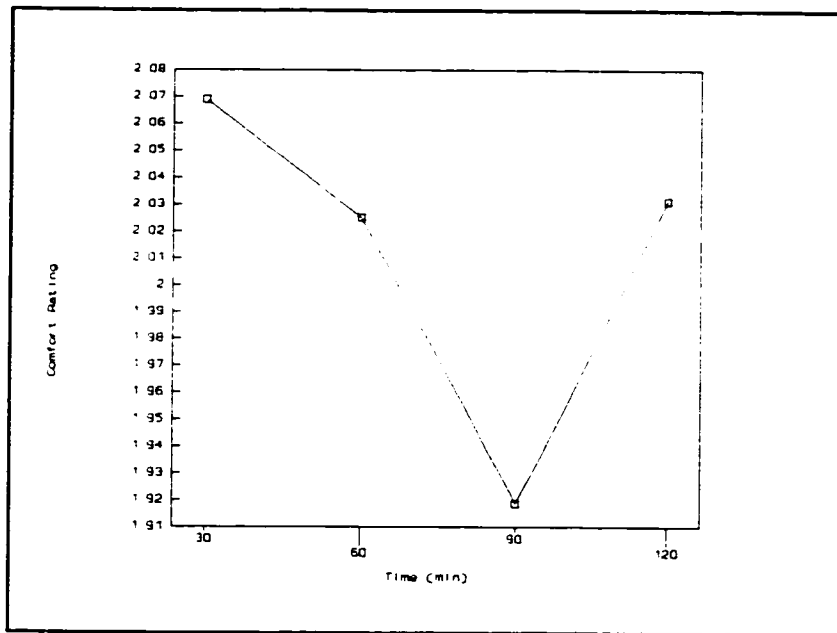


Figure 4.16: Perceived Level of Upper Back Comfort

Figure 4.17 indicates that the group was more comfortable in the lower back region at the end of the experiment than they were at the beginning. This is an extremely important result given that the micro-adjuster control system was developed to directly affect this part of the body. Although not represented in Figure 4.17, the aforementioned result is even more pronounced when the female subjects are considered separately. They reported becoming progressively more comfortable as the experimental session continued.

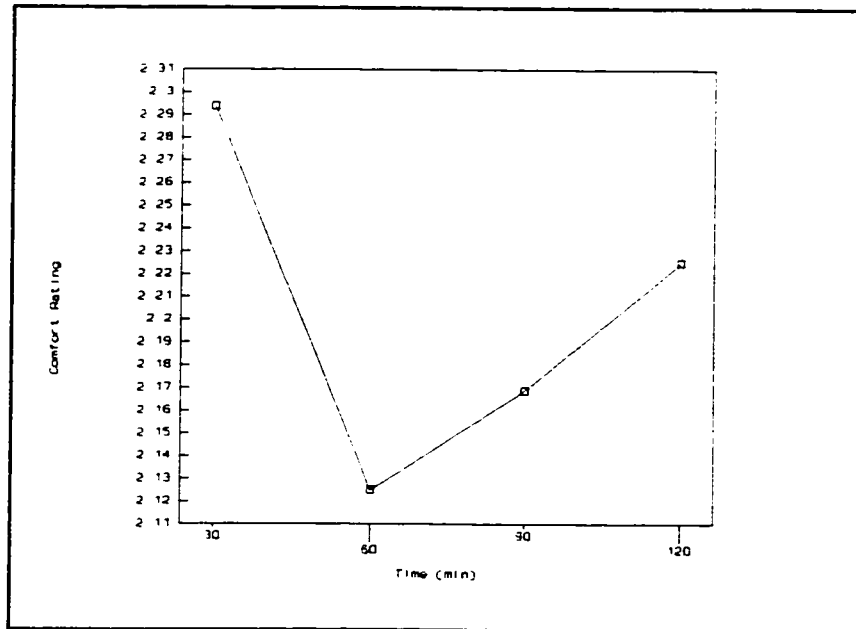


Figure 4.17: Perceived Level of Lower Back Comfort

The results presented in Figure 4.15, 4.16, and 4.17 are not as definitive as one would hope. That is, comfort ratings were not found to increase or decrease uniformly with time, thus making the results difficult to interpret. Figure 4.18, on the other hand, makes it evident that subjects were less comfortable, in terms of their lower extremities, at the end of the experimental session than they were at the beginning. Once again, although not illustrated, this effect is especially obvious when considering the female subjects separately.

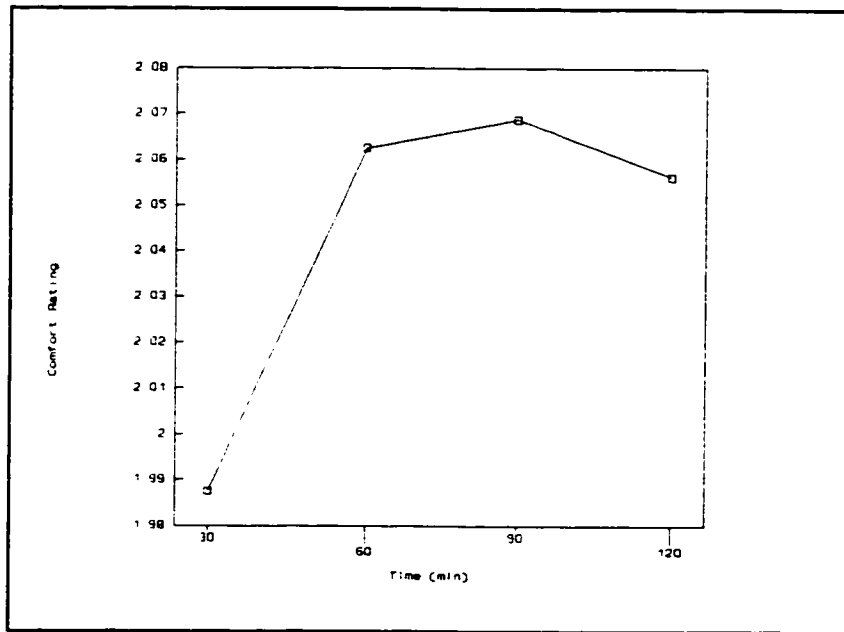
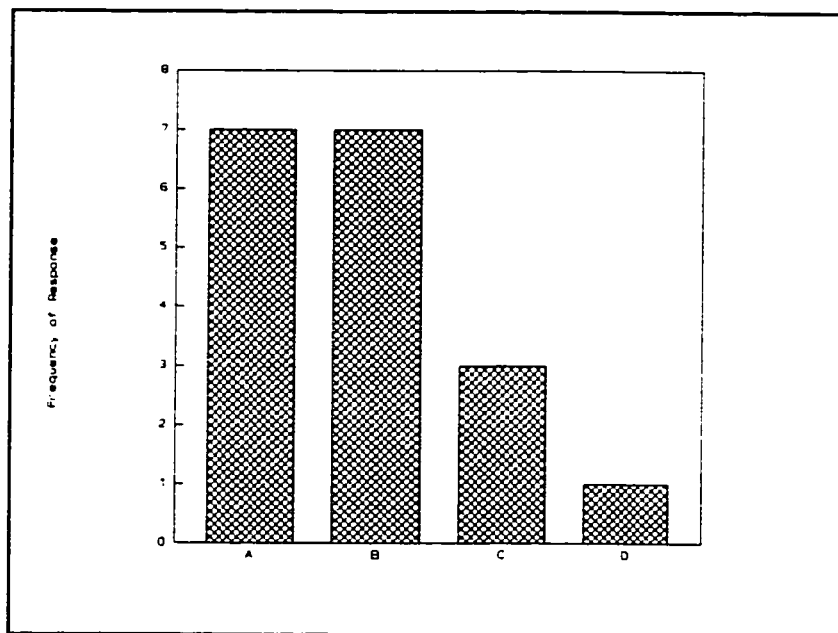


Figure 4.18: Perceived Level of Lower Extremity Comfort

It is not unrealistic to assume that comfort in one part of the body can affect comfort in another part, particularly since comfort is such a subjective construct. From Figure 4.15 and 4.18 it is evident that, at the conclusion of the experimental sessions, the subjects were less comfortable in the neck and shoulder and lower extremity regions than they were at the beginning of the experimental sessions. For this reason, it can be argued that, in this sample, negative perceptions of neck and shoulder and lower extremity comfort may be adversely affecting lower back comfort.

This notion is extended in Figure 4.19. When asked, "What would you recommend be changed?" (question 13 of version #1 of the questionnaire), seven of the

ten subjects said that microadjustment for other parts of the body, including the lower extremities and upper back, should be considered. This finding illustrates that subjects consider overall body comfort more important than comfort confined to a particular part of the body. This result supports the previously made contention that a lack of comfort in certain parts of the body may be negatively affecting perceptions of comfort in the lower back region.



- A. Microadjustment for Lower Extremities / Upper Back
- B. Anthropometry / Seat Design
- C. Cycle, Wait, and Pulse
- D. Decrease Noise

Figure 4.19: Recommendations for Change

Seven recommendations were also made concerning anthropometric and seat design issues (Figure 4.19). More specifically, one female subject, who's diminutive stature has already been discussed, insisted that the seat back was too wide to comfortably support her lower back. In addition, a few of the subjects expressed concern over the lack of arm rests and/or inadequate head rest. Finally, one subject felt that the angle of the seat back (ie. 120°) was too great.

As outlined in Figure 4.19, three of the recommendations were specifically related to the variables under investigation (ie. cycle, wait, and pulse). Two of these recommendations dealt with the direction of the microadjustment. One subject preferred the 'in' direction, while another subject preferred the 'out' direction. In both circumstances, the least preferred direction was considered a nuisance. Grouped into this category of recommendations was a concern expressed by a very perceptive female subject. She indicated that she was not feeling every single microadjustment. This is a possible occurrence. A clicking noise can be heard each time a microadjustment takes place; therefore, subjects can determine whether a microadjustment did occur as intended. With some combinations of cycle, wait, and pulse there may not be enough time for each microadjustment to take place (the micro-adjuster lumbar support system can only protrude to a maximum of a 5 cm). This was the case when the experimental condition involved a cycle of 5 min, a wait of 15 sec, and a pulse of 0.8 sec. In this

combination four microadjustments should take place every minute. Since the cycle is 5 min long, a total of 20 microadjustments should be encountered per cycle. That is, the lumbar support mechanism should travel in one direction ('in' or 'out') 20 times before changing directions. This female subject only felt six or seven of the microadjustments per cycle. In other words, the maximum point of protrusion was reached after only six or seven microadjustments.

Finally, one subject was annoyed by the sound associated with each microadjustment. This subject felt that the system's motor was too loud.

Specifically related to the two levels of pulse under investigation (0.8 sec and 1.1 sec), subjects were asked if the microadjustments should have been more pronounced, less pronounced, or if they were fine as they were (question #8 of the questionnaires). Each level of pulse was tested a total of 40 times. The results are shown in Figure 4.20. In both circumstances, just over 50% of the subjects felt that the pulse was 'fine as is'. When the pulse was set to 0.8 sec, 35% of the subjects stated that the microadjustment should have been more pronounced. Similarly, 30% of the subjects stated that a pulse of 1.1 sec should have been more pronounced. This was not possible because the current control system only allows pulse to be set to a maximum of 1.2 sec. At a pulse of 0.8 sec, 12.5% of the subjects said that the microadjustment should have been less

pronounced, while at a pulse of 1.1 sec, 15% of the subjects said that it should have been less pronounced. It must be concluded that the two levels of pulse are too similar to allow for this type of comparison. This finding is in accord with the objective results (ie. statistically there was no difference between the two levels of pulse).

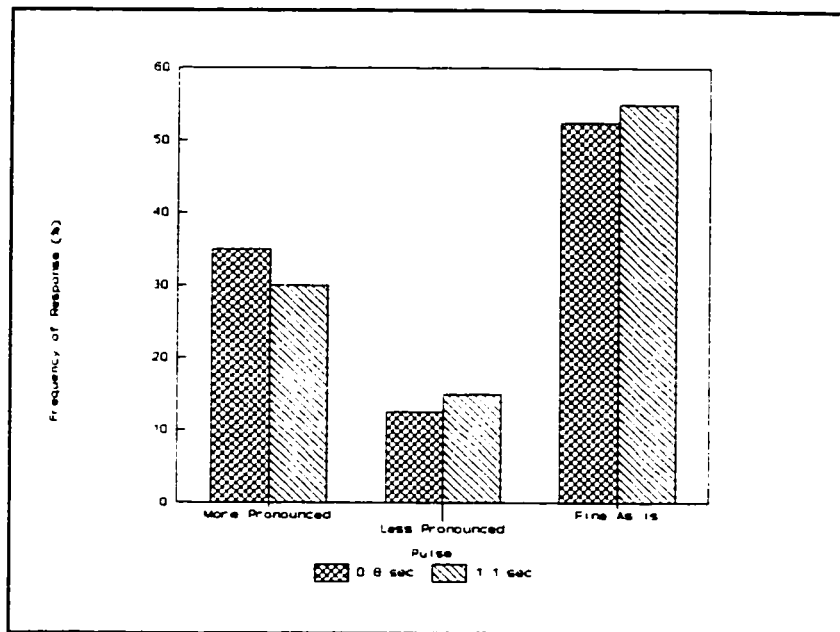


Figure 4.20: Opinion Regarding Levels of Pulse

To evaluate the two levels of wait (15 sec and 30 sec), two questions were asked. Firstly, subjects were asked if the time period between successive microadjustments was acceptable (question #9 of the questionnaires). At a wait of 15 sec, 60% of the subjects responded 'yes' while at a wait of 30 sec, only 50% of the subjects responded 'yes'. To get a better indication of the frequency of microadjustments considered superior by the



subjects in this sample, those that felt that the period of time between successive microadjustments was unacceptable were asked if more frequent or less frequent microadjustments would have been preferred (question #10 of the questionnaires). A wait of 15 sec was deemed unacceptable a total of 16 times. More frequent microadjustments would have been preferred on 11 of these occasions (68.75%). A wait of 30 seconds was considered unacceptable 20 times. Fifteen of these times a more frequent microadjustment was recommended (75%). This information is displayed in Figure 4.21. This result seems to suggest that subjects prefer more frequent microadjustments. Once again, this is in accord with the objective results described in section 4.1.

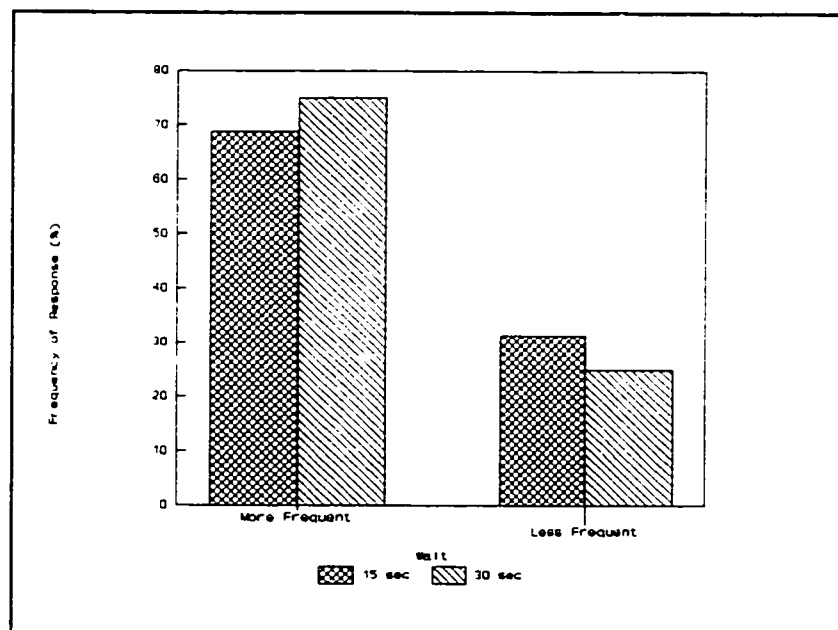


Figure 4.21: Opinion Regarding Levels of Wait

Figure 4.22 reveals the results of the following question: "What do you think of the car seat (ie. micro-adjuster lumbar support system)? Is it: excellent, good, fair, or poor?" (question 11 of version #1 of the questionnaire). Eight of the ten subjects rated the micro-adjuster control system favourably (ie. 'excellent' or 'good'). Only two subjects (both females) rated the micro-adjuster lumbar support system negatively (ie. 'fair' or 'poor').

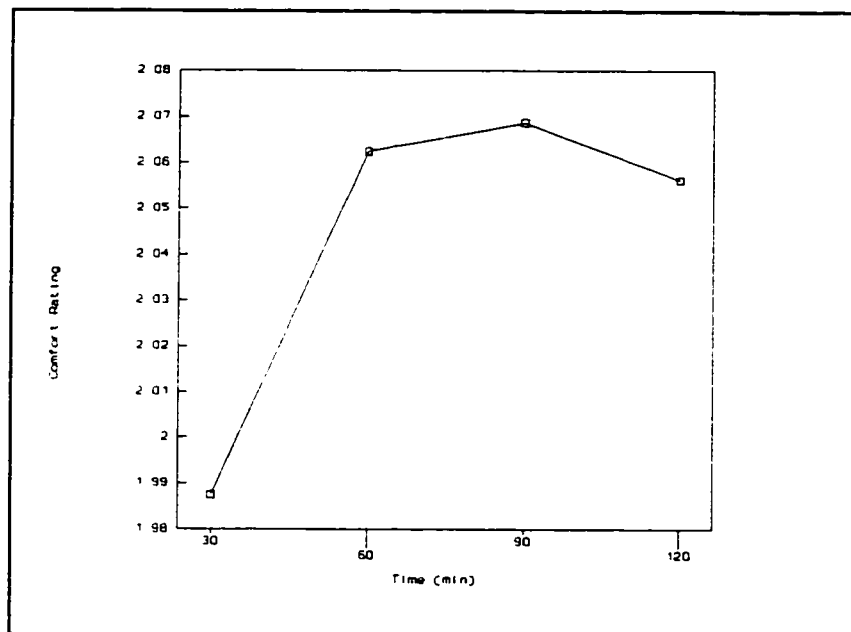


Figure 4.22: Opinion of Micro-Adjuster Lumbar Support System

The two subjects that rated the micro-adjuster lumbar support system negatively were the same subjects who indicated, in response to question #4 and question #5 of

version #1 of the questionnaire, that the seat back and seat pan were uncomfortable. They were the only two subjects to respond in this manner. Simply put, these subjects did not like the automobile seat. This fact may have had an effect on their rating of the micro-adjuster lumbar support system.

In addition, it should be stated that most people do not drive with a seat back angle of  $120^\circ$ . Nine of the ten subjects stated that their preferred setting was less than  $120^\circ$  but greater than  $90^\circ$ . In this sample, only one subject felt that the seat back angle was appropriately set. Figure 4.23 makes this point abundantly clear.

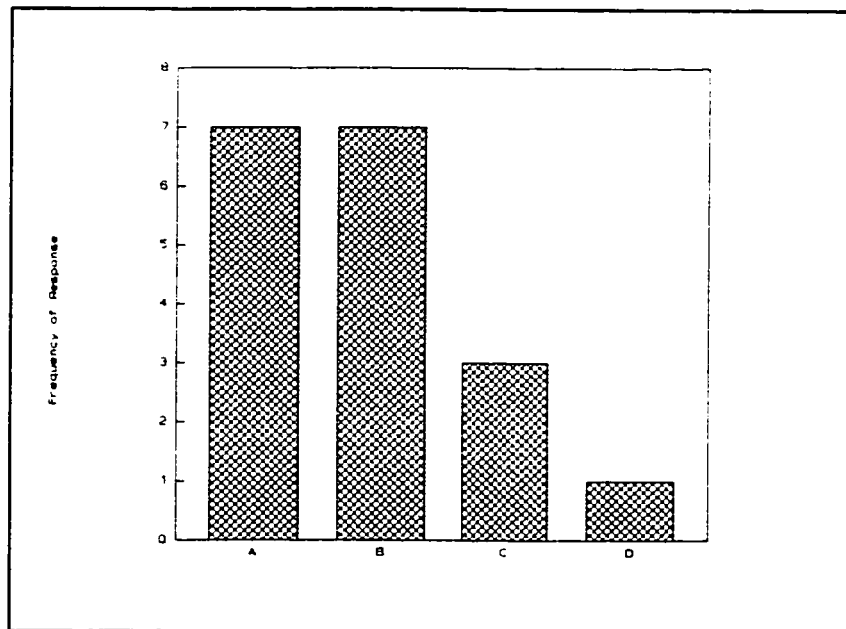


Figure 4.23: Preferred Angle of Seat Back

From Figure 4.22, it is difficult to ascertain whether the subjects were merely impressed with the gadgetry of the novel device or whether microadjustment is truly comfortable and therefore worthwhile. For this reason, subjects were asked, "Based on your participation in this study, would you purchase an automobile with a micro-adjuster lumbar support system built into the seat?" (question 14 of version #1 of the questionnaire). The underlying assumption is that subjects would not consider purchasing this option if it was not comfortable. Interestingly enough, all five male subjects and only two of the five female subjects said they would purchase this option (Figure 4.24).

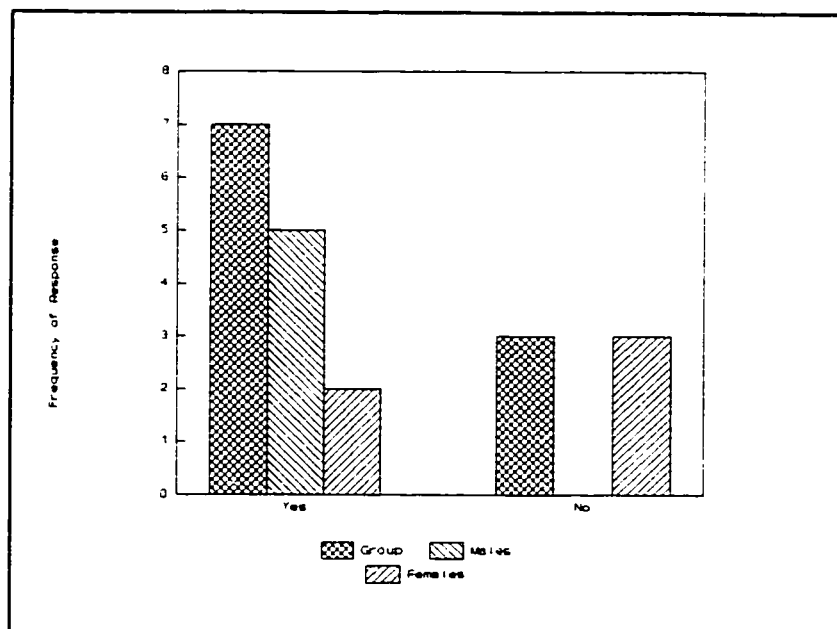


Figure 4.24: Would You Purchase This Option?

## CHAPTER 6

### CONCLUSIONS

#### 6.1 Summary

In general, the results of this investigation suggest that microadjustment, when compared to no microadjustment, has a beneficial effect on muscle activity over a two hour time period. In other words, microadjustment delays the onset of erector spinae muscle fatigue due to postural fixity. This fact, coupled with positive subjective responses on indices of comfort and user satisfaction, warrants the endorsement of the micro-adjuster control system in the context of automobile seating.

Considering the group as a whole, condition #5 and condition #6 were the only experimental settings that resulted in a decrease in RMS values with time (ie. positive  $\Delta$ RMS values). This result implies that, in these conditions, the erector spinae muscle group did not fatigue. In both conditions, cycle was set to 5 min and wait was set to 15 sec. In fact, the ANOVA showed that the cycle by wait interaction was statistically

significant. This is the most important result of this thesis.

The same statistical analysis showed that 5 min cycles were superior to 2 min cycles. Currently, the micro-adjuster control system allows cycles to be set up to 12 min. Therefore, it would be logical and worthwhile to evaluate the range of cycles between 5 and 12 minutes.

Unfortunately, an optimum level of pulse could not be determined. Statistically, there was no significant difference found between the two levels of pulse. Similarly, the interaction between pulse and the other two variables was not statistically significant. It is obvious, based on this conclusion, that other levels of pulse need to be evaluated. Considering the mean  $\Delta$ RMS values, as in Figure 4.12, subjects seemed to slightly prefer 1.1 sec pulses to 0.8 sec pulses. Furthermore, subjects expressed a desire for more pronounced microadjustments in 30% of the treatments where pulse was set to 1.1 sec. Therefore, pulses greater than 1.1 sec should be studied. However, given the current state of the micro-adjuster control system, pulse can only be set to a maximum of 1.2 sec. This maximum level needs to be reconsidered.

Based on this thesis, it can be concluded that long cycles, short waits, and high pulses provide the best results in terms of delaying the onset of erector spinae muscle

fatigue due to postural fixity. More specifically, within the limits of this investigation, the most advantageous setting included a 5 min cycle, a 15 sec wait, and a 1.1 sec pulse.

In chapter 2, consistent static loading of the musculature due to prolonged sitting was shown to be detrimental. In the same chapter, it was stated that alternating bouts of contraction and relaxation, which are common in most activities, may delay the onset of fatigue by allowing the blood to flow freely. Based on this line of reasoning, *Schukra of North America* incorporated a massage system into the lumbar support part of an automobile seat back rest. The massage system was designed to force the muscles of the back to continuously contract and relax (ie. assume dynamic postures). Mohamed (1996) evaluated this product. In terms of delaying the onset of back muscle fatigue, he demonstrated that massage was beneficial. In the most beneficial setting, the massage system stimulated the back muscles for one minute after each five minute interval throughout the course of a two hour experimental session. In other words, the back musculature was stimulated (which allows the blood to flow freely) for one minute followed by five minutes of static loading.

The underlying theory behind microadjustment is different. It involves intermittent bouts of static and dynamic loading. More specifically, when compared to massage, microadjustment stimulates the musculature of the lower back for extremely

short periods of time (i.e. the maximum is 1.2 sec) followed by much briefer periods of static loading. However, in the most beneficial setting found in this thesis, the musculature of the back is stimulated every 15 sec. The frequency of this stimulation approaches the dynamic posture brought on by Mohamed's (1996) massage system. In addition, it can be argued that microadjustment in the 'in' direction does not stimulate the back musculature to the same extent as microadjustment in the 'out' direction. Therefore, the 'in' direction can be considered a period of static loading. The most beneficial microadjustment setting included a 5 min cycle. A combination of these facts leads to the conclusion that dynamic loading of the back musculature followed by a 5 min period of static loading provides the best results in terms of delaying the onset of erector spinae muscle fatigue. In summary, the findings of this thesis parallel the findings of the massage study conducted by Mohamed (1996).

## **6.2 Potential Problem Areas**

A valid criticism of this thesis surrounds the question of realism. Currently, during the experimental session, subjects sit on the automobile seat just like they would sit on any other office or household chair. Obviously, automobile seats are different from office or household chairs in that they are usually confined and always under



dynamic conditions during their usage. Not only does an automobile seat need to provide comfortable support, but it has to allow for comfortable operation of the vehicle. Therefore, because of differences in comfort requirements, automobile seats deserve more than just static evaluations. This realization, coupled with the fact that even postural fixity depends on the degree of complexity of the information that is processed (Grieco, 1986), implies that this type of product testing should be conducted under real driving conditions (ie. a road test). The next best option is a full fledged driving simulator. More simply, some realism could be added to the experimental sessions by including standard automobile seat features which are not currently in place. For example, the experimental seat lacked arm rests and a seat belt. These features may affect both objective and subjective levels of comfort. Unfortunately, all three of these options were deemed impractical due to the available resources.

Realism was also compromised by fixing the seat back angle at 120°. Most people do not drive in such a reclined posture. In fact, nine of the ten subjects estimated the angle of the seat back in the automobile they drive to be less than 120°. In the real world, automobile drivers set the seat back angle according to their own preferences. Therefore, at the risk of introducing an extraneous variable, it may be more appropriate to allow the subjects to select their own seat back angles. It is assumed that most subjects would select an angle less than 120° but greater than 90°.

### **6.3 Recommendations for Future Work**

In chapter 5, the potential therapeutic effects of microadjustment were highlighted. More specifically, with regards to the lower back, aches, pains, and discomforts that were initially present appeared to have been relieved by the microadjustment. Given the prevalence of back pain in today's society, this is an extremely interesting result -one that deserves further investigation. If microadjustment is shown to be beneficial in this regard, low back pain sufferers would be afforded the luxury of driving and receiving therapy at the same time.

To further this discussion, the micro-adjuster control system could be evaluated using chronic low back pain sufferers as subjects. If this avenue is pursued it would be wise to incorporate an additional objective data collecting technique. More specifically, intra-disc pressure measurement could be employed. This technique would, undoubtedly, yield valuable information regarding low back pain. Unfortunately, this technique should only be used by individuals trained in needle insertion. Therefore, this type of study would probably need to be carried out in a clinical setting.

In this thesis, body composition was determined using a body mass index known as the Quetelet Index. At best, this technique provides a rough estimate of somatotype.

Even based on this crude estimate, it was hypothesized that somatotype may be affecting the results of this experiment. More specifically, excess subcutaneous fat in the lower back region may be interfering with the microadjustments which are intended for the superficial musculature (ie. the erector spinae). To determine if excess body fat does indeed interfere with the beneficial effects of microadjustment, the necessary first step involves the measurement of lower back subcutaneous fat levels. This can be done rather reliably using skin fold callipers (Nieman, 1990). These measurements are considered much more accurate than body mass indices. Then, based on this method, samples can be drawn from each somatotype. Only then can future investigators learn how microadjustment affects individuals of different somatotype.

As it currently operates, the micro-adjuster control system is designed to positively affect the comfort of the lower back. In other words, attempts at improving comfort are confined to the lower back, while other parts of the body are neglected. It has been speculated that negative perceptions of comfort in one part of the body may be adversely affecting lower back comfort, thus making the subjective results difficult to interpret. In the future, the concept of microadjustment could, quite easily, be applied to other parts of the automobile seat. This is not a novel idea. Katsuraki et al., (1995) stated that continuous support, taking into account the movements of each part of the skeleton, is more effective than localized support (ie. only the lumbar area).

Seven of the ten subjects in this sample seemed to agree with this assessment. They recommended microadjustment for other parts of the body, including the lower extremities and upper back.

Chapter 2 revealed that lumbar supports should preserve the standing lumbar lordosis in sitting. To ensure that the microadjustments are concentrated at the L3 level for all users, the height of the micro-adjuster control system should be adjustable. This recommendation stems from the fact that one of the female subjects, due to her diminutive stature, reported feeling the microadjustment in the lower thoracic region. Microadjustment, therefore, forced this part of her back to assume a lordotic posture. Under normal circumstances, the thoracic region is kyphotic. *Schukra of North America* could include the proposed adjustability feature in one of two ways. Firstly, the micro-adjuster control system could be designed to allow for the maximum point of protrusion to occur at different levels. Currently, the maximum point of protrusion occurs at the midpoint of the micro-adjuster control system. To accommodate individuals of all sizes, it should be possible to skew the maximum point of protrusion towards the high side or low side of the midpoint. Secondly, an option could be built into the automobile seat that allows the entire micro-adjuster control system to be moved up or down depending on the user's anthropometry and/or preference.

## **6.4 Concluding Remarks**

Automobile seat designers are continuously attempting to improve occupant comfort. In doing so the onus of movement or postural adjustment has been removed from the individual. Therefore, in a sense, automobile seats may be becoming too comfortable. A similar conclusion was reached by Grieco (1986). He found that newer, more comfortable VDT workstations increased postural fixity (as compared to older workstations). Fortunately, the developers of the micro-adjustment lumbar support system realized the potential pitfalls inherent in designing increasingly comfortable seats. Their product, while still comfortable, attempts to deal directly with the problem of postural fixity by forcing occupants to undertake subtle shifts in body position.

A study geared toward the evaluation of this type of product can have a tremendous impact on occupant comfort and health, given the prevalence of the automobile in today's society. In addition, since the results of this experiment prove that microadjustment is beneficial, it is logical to believe that this product could, in the very near future, be applied to a variety of different types of chairs and seats. Considering the amount of time the average human being spends sitting, the importance of this investigation cannot be overstated. The results of this thesis may affect the human race for years to come.

## **APPENDICES**

**APPENDIX A: Amplifier Settings**

**APPENDIX B: Experimental Set-up**

**APPENDIX C: Consent Form**

**APPENDIX D: Questionnaires**

**APPENDIX E: Subjects' Characteristics**

**APPENDIX F: Average RMS Data**

**APPENDIX G: Results of Questionnaires**

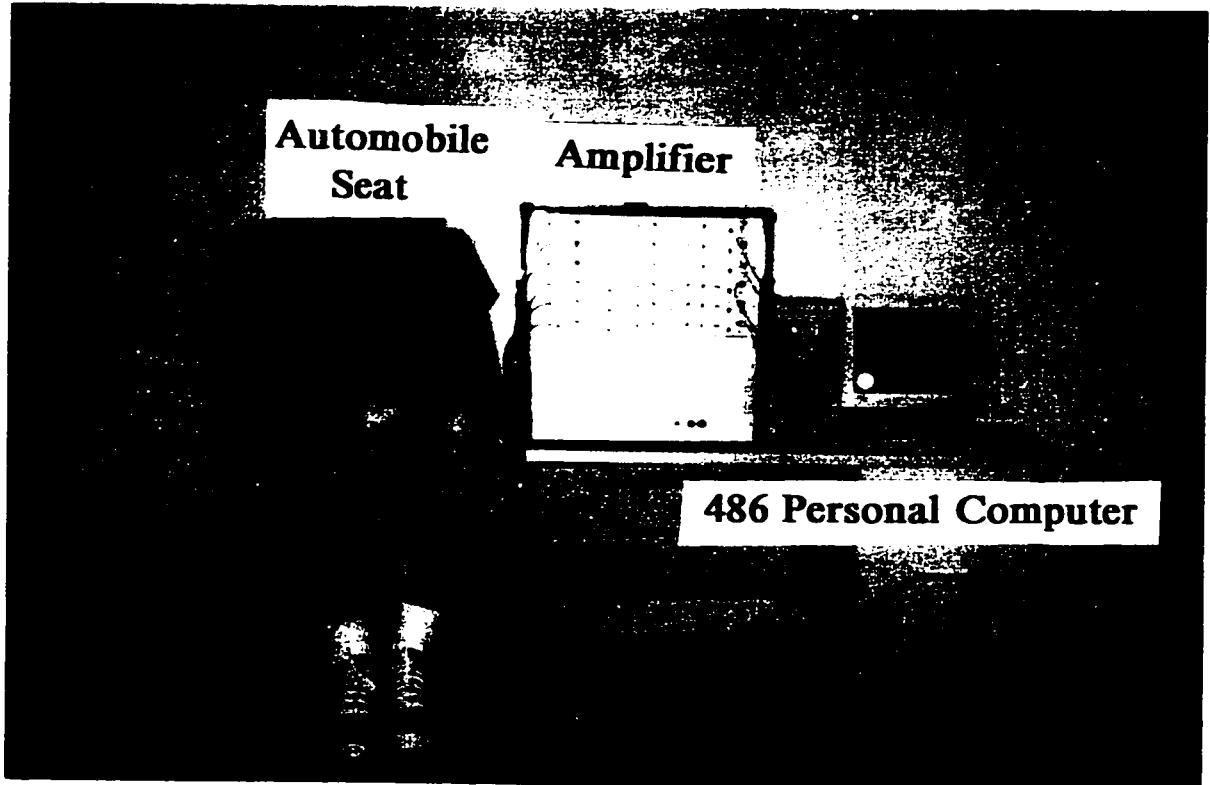
**APPENDIX A**  
**Amplifier Settings**

Calibration	1 mV
Input - Use - Cal - A/C - D/C	Use D/C
1/2 Amp. Lo Freq.	3 Hz
Amplification	2000 (10 x 200)
Amplification Calibration	Manual Adjustment
1/2 Amp. Hi Freq.	0.3 kHz
60 Hz Filter	In



## **APPENDIX B**

### **Experimental Set-up**



## **APPENDIX C**

### **Consent Form**

## CONSENT FORM

I, \_\_\_\_\_, am participating in this study on my own free will. The decision to participate is completely voluntary on my part. No one has coerced or intimidated me to participate.

The investigator has answered any and all questions I have asked about this study, my participation, and the procedures involved, which are described in the attachment to this consent form, which I have initialled.

I understand that the investigator or his supervisor will be available to answer any questions concerning procedures throughout this study. I understand that if significant new findings develop during my participation, I will be informed. I further understand that I may withdraw consent at any time and discontinue further participation at my discretion. I understand that the investigator or the supervisor or any medical consultant may terminate my participation in this study if it is felt to be in my best interest.

I do not have any disorders of my cardiovascular system, my spinal column, within my wrists, arms, shoulders or neck or any other disorders or deficiencies that make it inadvisable for me to participate as a subject in this experiment.

I understand that the results of my efforts will be recorded and in case of any photographic record made of the experiment, face appearance that may cause subject recognition will not be allowed. I consent to the use of the recorded information for scientific or training purposes and understand that any records of my participation in this study may be disclosed only according to federal and provincial law and that no one will be able to identify myself as a participant in this study from the reporting of any results or conclusions reached by the investigator. I also understand that personal information will not be released to an unauthorized third party without my permission.

I understand that I will be compensated at the minimum wage rate as set out by law. This money will be paid to me at the conclusion of my participation in this study. I understand that I will not be paid if I do not complete the study, unless I have a medical or other valid reason for not completing the study and documentation to support this fact.

I fully understand that I am making a decision whether or not to participate in the study. My signature indicates that I have decided to participate in the study. My signature indicates that I have decided to participate under the conditions described above.

Volunteer's Signature: \_\_\_\_\_ Date: \_\_\_\_\_

Signature of Witness: \_\_\_\_\_ Date: \_\_\_\_\_

## ATTACHMENT TO CONSENT FORM

You are invited to participate as a subject in an experiment to measure stress and fatigue in the back area in the situation of car driving. The data gathered in this study will be used to study the relative merits of the design of a car seat.

The experiment encompasses between three to twelve different designs with two hours of work required to complete testing on each design. The times required to conduct the experiment will be scheduled at mutually convenient times. If more than one design is to be tested a day, a rest of at least ten hours will be permitted between testing of designs in order to prevent fatigue acceleration.

In measuring your performance, six surface electrodes will be attached to your skin in the lower back area to monitor muscle activity. In agreeing to participate in this study you acknowledge that you have no objection, medical or otherwise, to being monitored in this manner. It is possible that you may experience temporary skin irritation as a result of the use of the electrolyte.

The results of your participation will be recorded and analyzed. Only overall results of all subjects who participate in this study will be reported. There will be no reporting of results in a manner that would allow anyone to specifically identify your results.

Before your use as a test subject, you must inform the investigator or supervisor of any change to your physical status. This information will include any medication taken or medical care or conditions that will directly or indirectly affect the experiment.

If you have any questions you can reach the investigator (Mike Kolich) or the supervisor (Dr. S. Taboun) via the Department of Industrial and Manufacturing Systems Engineering at the University of Windsor at (519) 253-4232, ext. 2607, during normal business hours.

Volunteer's Initials: \_\_\_\_\_

**APPENDIX D**  
**Questionnaires**

## QUESTIONNAIRE

Name: \_\_\_\_\_

Date: \_\_\_\_\_

Condition: \_\_\_\_\_

### Subject Characteristics:

Age:

Sex:

Weight:

Height:

Somatotype:

## PART A: PRE-EXPERIMENT

### Neck and Shoulders:

- (1) Have you at any time during the past 12 months experienced pains, stiffness, cramps, and/or fatigue in your neck and/or shoulders?

Daily  
 Occasionally  
 Seldom  
 Never

If your response is **NEVER**, do not answer question (2).

- (2) Are you currently experiencing pains, stiffness, cramps, and/or fatigue in your neck and/or shoulders?

Yes  
 No

### Back:

- (3) Have you at any time during the past 12 months experienced aches, pains, and/or discomforts in your back?

Daily  
 Occasionally  
 Seldom  
 Never

If your response is **NEVER**, do not answer question (4).

- (4) Are you currently experiencing aches, pains, and/or discomforts in your back?

Yes  
 No



Lower Extremities:

- (5) Have you at any time during the past 12 months experienced tingling sensations, numbness, swelling, and/or pain in your lower extremities?

- [     ] Daily  
[     ] Occasionally  
[     ] Seldom  
[     ] Never

If your response is **NEVER**, do not answer question (6).

- (6) Are you currently experiencing tingling sensations, numbness, swelling, and/or pain in your lower extremities?

- [     ] Yes  
[     ] No

## PART B: DURING EXPERIMENT

- (1) For each body part indicate your perceived level of comfort using the following scale:

1 Very Comfortable

2 Comfortable

3 Fairly Comfortable

4 Uncomfortable

5 Very Uncomfortable

	1/2 hr	1 hr	1 1/2 hr	2 hr
Neck and Shoulders				
Upper Back				
Lower Back				
Lower Extremities				

### **PART C: POST-EXPERIMENT**

- (1) Are you currently experiencing pains, stiffness, cramps, and/or fatigue in your neck and/or shoulders?

[       ] Yes

[       ] No

- (2) Are you currently experiencing aches, pains, and/or discomforts in your back?

[       ] Yes

[       ] No

- (3) Are you currently experiencing tingling sensations, numbness, swelling, and/or pain in your lower extremities?

[       ] Yes

[       ] No

- (4) Does the seat back comfortably support the lumbar region of your spine?

[       ] Yes

[       ] No

- (5) Does the seat pan provide firm support and comfort?

[       ] Yes

[       ] No

- (6) In this experiment the seat back was fixed at 120°; estimate the angle of the seat back in the car you drive (ie. what is your preferred setting)?

[       ] Greater than 120°

[       ] Less than 120°, greater than 90°

[       ] 120°

[       ] 90°

(7) Did you feel the microadjustments?

- Yes
- No

If your response is **NO**, do not answer question (8), (9), and (10).

(8) Would you have preferred more pronounced or less pronounced microadjustments?

- More pronounced
- Less pronounced
- Fine as is

(9) In your estimation, was the period of time between successive microadjustments acceptable?

- Yes
- No

If your response is **YES**, do not answer question (10).

(10) Would you have preferred more frequent or less frequent microadjustments?

- More frequent
- Less frequent

(11) What do you think of the micro-adjuster lumbar support system? Is it:

- Excellent
- Good
- Fair
- Poor

(12) Are there things about the car seat (ie. lumbar support system) that you would change?

- Yes
- No

If your response is **NO**, do not answer question (13).

(13) What would you recommend be changed?

1.
2.
3.
4.
5.

(14) Based on your participation in this study, would you purchase an automobile with a micro-adjuster lumbar support system built into the seat?

Yes

No

## QUESTIONNAIRE

Name: \_\_\_\_\_

Date: \_\_\_\_\_

Condition: \_\_\_\_\_

### PART A: PRE-EXPERIMENT

#### Neck and Shoulders:

- (2) Are you currently experiencing pains, stiffness, cramps, and/or fatigue in your neck and/or shoulders?

[       ] Yes

[       ] No

#### Back:

- (4) Are you currently experiencing aches, pains, and/or discomforts in your back?

[       ] Yes

[       ] No

#### Lower Extremities:

- (6) Are you currently experiencing tingling sensations, numbness, swelling, and/or pain in your lower extremities?

[       ] Yes

[       ] No

## PART B: DURING EXPERIMENT

- (1) For each body part indicate your perceived level of comfort using the following scale:

1 Very Comfortable

2 Comfortable

3 Fairly Comfortable

4 Uncomfortable

5 Very Uncomfortable

	1/2 hr	1 hr	1 1/2 hr	2 hr
Neck and Shoulders				
Upper Back				
Lower Back				
Lower Extremities				

### **PART C: POST-EXPERIMENT**

- (1) Are you currently experiencing pains, stiffness, cramps, and/or fatigue in your neck and/or shoulders?

[        ] Yes

[        ] No

- (2) Are you currently experiencing aches, pains, and/or discomforts in your back?

[        ] Yes

[        ] No

- (3) Are you currently experiencing tingling sensations, numbness, swelling, and/or pain in your lower extremities?

[        ] Yes

[        ] No

- (7) Did you feel the microadjustments?

[        ] Yes

[        ] No

If your response is **NO**, do not answer question (8), (9), and (10).

- (8) Would you have preferred more pronounced or less pronounced microadjustments?

[        ] More pronounced

[        ] Less pronounced

[        ] Fine as is

- (9) In your estimation, was the period of time between successive microadjustments acceptable?

[        ] Yes

[        ] No

If your response is **YES**, do not answer question (7).

- (10) Would you have preferred more frequent or less frequent microadjustments?

[        ] More frequent

[        ] Less frequent



**APPENDIX E**  
**Subjects' Characteristics**

Ss #	Sex	Age (years)	Weight (kg)	Height (m)	Quetelet Index	
					kg/m <sup>2</sup>	Classification
1	male	22	91	1.79	28.4	Grade 1 Obesity
2	female	20	85	1.75	27.8	Grade 1 Obesity
3	female	20	58	1.66	21.0	Desirable Range
4	female	19	80	1.75	26.1	Grade 1 Obesity
5	male	27	83	1.80	25.6	Grade 1 Obesity
6	male	24	76	1.72	25.7	Grade 1 Obesity
7	female	21	63.5	1.65	23.3	Desirable Range
8	male	23	75	1.77	23.9	Desirable Range
9	female	20	54	1.63	20.3	Desirable Range
10	male	23	77.5	1.71	26.5	Grade 1 Obesity
Mean		21.9	74.3	1.72	24.9	Desirable Range
SD		2.3	11.44	0.06	2.55	

**APPENDIX F**  
**Average RMS Data**

## Subject #1 (male)

Time (min)	Cond. #1	Cond. #2	Cond. #3	Cond. #4	Cond. #5	Cond. #6	Cond. #7	Cond. #8	No Micro
10	0.262347	0.262226	0.255475	0.255860	0.248659	0.219033	0.219515	0.219631	0.209768
20	0.262231	0.262135	0.255375	0.255647	0.241393	0.216849	0.216906	0.216959	0.209953
30	0.262194	0.262111	0.255634	0.255868	0.241038	0.218396	0.218408	0.218452	0.209909
40	0.262382	0.262310	0.256132	0.256399	0.242727	0.218404	0.217885	0.219463	0.209797
50	0.262613	0.262545	0.256953	0.256943	0.244416	0.223697	0.223724	0.223767	0.210376
60	0.262916	0.262823	0.257228	0.257601	0.240929	0.220177	0.220211	0.220241	0.210394
70	0.263130	0.263054	0.257310	0.257514	0.243179	0.216651	0.216290	0.216343	0.210299
80	0.263429	0.263355	0.258157	0.258342	0.236856	0.207339	0.207366	0.207391	0.209376
90	0.263599	0.263521	0.258391	0.258571	0.235983	0.207579	0.207520	0.207567	0.210396
100	0.263750	0.263676	0.258650	0.258894	0.235988	0.205678	0.205690	0.205744	0.210770
110	0.263806	0.263737	0.258894	0.259038	0.235575	0.205196	0.205216	0.205240	0.210856
120	0.264111	0.264046	0.259364	0.259517	0.235825	0.204489	0.204547	0.204577	0.211265
$\Delta$ RMS	-0.00192	-0.00193	-0.00399	-0.00387	0.013084	0.019208	0.019177	0.019191	-0.00189

## Subject #2 (female)

Time (min)	Cond. #1	Cond. #2	Cond. #3	Cond. #4	Cond. #5	Cond. #6	Cond. #7	Cond. #8	No Micro
10	0.220678	0.242027	0.242109	0.258507	0.279862	0.287277	0.287089	0.286819	0.237962
20	0.223279	0.241948	0.242120	0.258697	0.279444	0.287913	0.287659	0.287554	0.237909
30	0.220506	0.241782	0.242295	0.258141	0.279580	0.288820	0.288629	0.288694	0.237971
40	0.223635	0.241889	0.242329	0.257368	0.279748	0.288434	0.288257	0.287529	0.237940
50	0.221997	0.241626	0.242008	0.257542	0.279151	0.290174	0.290001	0.289666	0.237979
60	0.225374	0.241413	0.241681	0.257930	0.279178	0.290803	0.290611	0.289832	0.237965
70	0.221959	0.241232	0.241557	0.257328	0.278830	0.291531	0.291317	0.291169	0.237911
80	0.221710	0.240985	0.241325	0.256771	0.278578	0.292904	0.292708	0.291809	0.237599
90	0.222706	0.240849	0.241245	0.256997	0.278572	0.293846	0.293543	0.293206	0.237317
100	0.224322	0.240781	0.241232	0.257573	0.278601	0.296027	0.295866	0.295200	0.237165
110	0.228793	0.240845	0.241244	0.257835	0.278804	0.296876	0.296628	0.295422	0.237119
120	0.226803	0.241067	0.241348	0.257440	0.278851	0.296689	0.296528	0.295974	0.237118
<b>ΔRMS</b>	-0.00829	0.001245	0.001097	0.0017	0.00129	-0.0096	-0.00954	-0.00915	0.000861

### Subject #3 (female)

Time (min)	Cond. #1	Cond. #2	Cond. #3	Cond. #4	Cond. #5	Cond. #6	Cond. #7	Cond. #8
10	0.209710	0.210576	0.207744	0.207841	0.207579	0.215221	0.216052	0.215488
20	0.210634	0.211270	0.207684	0.207752	0.207537	0.214160	0.214847	0.214328
30	0.210899	0.211295	0.207504	0.207557	0.207342	0.214196	0.214783	0.214337
40	0.211363	0.211782	0.207266	0.207325	0.207118	0.213255	0.213791	0.213374
50	0.212091	0.213485	0.206926	0.207061	0.206795	0.214027	0.214547	0.214137
60	0.212424	0.213613	0.206748	0.206853	0.206629	0.214446	0.214917	0.214541
70	0.213327	0.213746	0.206496	0.206561	0.206368	0.214505	0.215099	0.214697
80	0.214039	0.214426	0.206214	0.206263	0.206058	0.214429	0.215081	0.214648
90	0.216942	0.217302	0.206274	0.206355	0.206037	0.214618	0.215181	0.214794
100	0.219844	0.220178	0.206203	0.206258	0.206036	0.214376	0.215154	0.214532
110	0.214740	0.214977	0.206058	0.206182	0.205881	0.214449	0.215128	0.214728
120	0.214453	0.214770	0.205870	0.205940	0.205751	0.214715	0.215294	0.214749
ΔRMS	-0.01013	-0.0096	0.001874	0.001901	0.001828	0.001966	0.002261	0.002114

**Subject #4 (female)**

Time (min)	Cond. #1	Cond. #2	Cond. #3	Cond. #4	Cond. #5	Cond. #6	Cond. #7	Cond. #8
10	0.214274	0.214044	0.214739	0.219405	0.219456	0.219321	0.213836	0.214106
20	0.214230	0.214305	0.214484	0.219600	0.219676	0.219645	0.213796	0.213989
30	0.214480	0.214696	0.215083	0.219895	0.219957	0.219927	0.213969	0.214154
40	0.214606	0.214852	0.215334	0.220137	0.220211	0.220180	0.214039	0.214138
50	0.214930	0.215135	0.215105	0.220241	0.220337	0.220260	0.214393	0.214562
60	0.215509	0.215725	0.216402	0.220393	0.220431	0.220403	0.221903	0.222279
70	0.215612	0.215845	0.215832	0.220465	0.220559	0.220529	0.220002	0.220250
80	0.216018	0.216268	0.216282	0.220534	0.220591	0.220563	0.219045	0.219292
90	0.216213	0.216357	0.216344	0.220573	0.220615	0.220590	0.219154	0.219470
100	0.216560	0.216712	0.216686	0.220490	0.220541	0.220517	0.219431	0.219688
110	0.216984	0.217234	0.217522	0.220484	0.220530	0.220505	0.219596	0.219841
120	0.217301	0.217841	0.217538	0.220462	0.220544	0.220516	0.219871	0.220109
ARMS	-0.00307	-0.0038	-0.00305	-0.00117	-0.00116	-0.00127	-0.00811	-0.00829

## Subject #5 (male)

Time (min)	Cond. #1	Cond. #2	Cond. #3	Cond. #4	Cond. #5	Cond. #6	Cond. #7	Cond. #8
10	0.221445	0.225483	0.204566	0.201749	0.215313	0.214085	0.218317	0.218731
20	0.218431	0.221854	0.204408	0.202601	0.210917	0.209889	0.218531	0.220129
30	0.223711	0.226775	0.205182	0.203854	0.206626	0.206128	0.219058	0.219187
40	0.220821	0.224721	0.205959	0.205218	0.207294	0.205692	0.224113	0.225207
50	0.219795	0.223624	0.204527	0.201798	0.206752	0.205640	0.224098	0.224097
60	0.222295	0.223825	0.205567	0.206209	0.208046	0.206716	0.224943	0.224974
70	0.223529	0.227128	0.203577	0.203467	0.207797	0.206637	0.230117	0.230163
80	0.217203	0.223433	0.204919	0.204789	0.208388	0.206835	0.229545	0.229661
90	0.222512	0.224131	0.205727	0.205857	0.208096	0.205436	0.229698	0.229915
100	0.218036	0.225251	0.206164	0.205046	0.207893	0.206007	0.227605	0.227811
110	0.226260	0.229219	0.206928	0.206840	0.208223	0.204984	0.226994	0.226906
120	0.222697	0.229302	0.206498	0.206220	0.207474	0.207474	0.225880	0.225979
<b>ΔRMS</b>	-0.00906	-0.00745	-0.00335	-0.00509	0.008687	0.009101	-0.0118	-0.01143



## Subject #6 (male)

Time (min)	Cond. #1	Cond. #2	Cond. #3	Cond. #4	Cond. #5	Cond. #6	Cond. #7	Cond. #8
10	0.183463	0.183544	0.187275	0.186916	0.186738	0.186833	0.191835	0.189119
20	0.183515	0.183618	0.187250	0.186988	0.191281	0.191641	0.191664	0.189962
30	0.183608	0.183782	0.187269	0.187044	0.182428	0.182641	0.191546	0.189007
40	0.184014	0.184174	0.187314	0.187035	0.182138	0.182390	0.191829	0.188737
50	0.184302	0.184496	0.187366	0.187065	0.182390	0.182537	0.190876	0.189035
60	0.184642	0.184737	0.187681	0.187364	0.182420	0.182587	0.193399	0.189543
70	0.184914	0.185042	0.187927	0.187723	0.182433	0.182745	0.194152	0.190136
80	0.185383	0.185429	0.187635	0.187318	0.182591	0.182900	0.192499	0.190889
90	0.185452	0.185573	0.187776	0.187542	0.182755	0.183342	0.191732	0.190143
100	0.185867	0.186022	0.187863	0.187726	0.183010	0.183260	0.192675	0.189999
110	0.186197	0.186295	0.188148	0.188060	0.183106	0.183106	0.195729	0.191440
120	0.186352	0.186473	0.187877	0.187716	0.183188	0.183482	0.192180	0.189109
$\Delta$ RMS	-0.00289	-0.00293	-0.0009	-0.00114	0.009143	0.009251	-0.00485	-0.0027

## Subject #7 (female)

Time (min)	Cond. #1	Cond. #2	Cond. #3	Cond. #4	Cond. #5	Cond. #6	Cond. #7	Cond. #8
10	0.197767	0.197000	0.200917	0.200325	0.191214	0.191531	0.201864	0.203071
20	0.196976	0.196329	0.201181	0.201209	0.192528	0.192814	0.202562	0.203106
30	0.196811	0.195860	0.200642	0.200164	0.194374	0.194587	0.200777	0.202074
40	0.196597	0.195762	0.200736	0.200346	0.194527	0.196919	0.208526	0.208526
50	0.197204	0.196710	0.201167	0.201373	0.193560	0.194175	0.210282	0.210282
60	0.196793	0.195770	0.201387	0.201832	0.194374	0.194662	0.209858	0.210662
70	0.196984	0.196140	0.201285	0.202165	0.193342	0.193595	0.211208	0.211844
80	0.197363	0.196628	0.200726	0.200305	0.192310	0.192529	0.210000	0.209209
90	0.197934	0.197216	0.200975	0.201236	0.193081	0.193325	0.208239	0.208718
100	0.197498	0.196520	0.200394	0.199527	0.193566	0.193791	0.206889	0.207833
110	0.197881	0.197246	0.200718	0.200236	0.195297	0.195669	0.211669	0.210467
120	0.197770	0.196461	0.201157	0.201191	0.194572	0.194961	0.211047	0.210834
$\Delta$ RMS	-0.00134	-0.00148	0.000993	0.002638	-0.00408	-0.00539	-0.01089	-0.00977

**Subject #8 (male)**

Time (min)	Cond. #1	Cond. #2	Cond. #3	Cond. #4	Cond. #5	Cond. #6	Cond. #7	Cond. #8
10	0.231712	0.231838	0.234852	0.234896	0.227459	0.227256	0.227457	0.227400
20	0.231757	0.232023	0.235121	0.235268	0.227619	0.227436	0.227527	0.227482
30	0.231478	0.231834	0.234834	0.235074	0.227966	0.227725	0.227614	0.227411
40	0.231968	0.232204	0.235015	0.235251	0.228220	0.228098	0.227646	0.227639
50	0.232310	0.232446	0.235079	0.235244	0.228335	0.228320	0.227824	0.227786
60	0.232222	0.232465	0.235061	0.235236	0.228862	0.228657	0.227927	0.227877
70	0.231576	0.231829	0.235603	0.235674	0.228877	0.228673	0.227957	0.228034
80	0.232860	0.233101	0.235987	0.236010	0.229123	0.228989	0.228395	0.228364
90	0.233390	0.233657	0.236233	0.236294	0.229386	0.229263	0.230175	0.227906
100	0.233357	0.233560	0.236014	0.236108	0.229702	0.229821	0.228619	0.228487
110	0.233653	0.234082	0.236047	0.236218	0.229576	0.229347	0.228567	0.228536
120	0.233497	0.234000	0.236744	0.236709	0.229961	0.229796	0.228592	0.228541
$\Delta$ RMS	-0.00218	-0.00225	-0.00191	-0.00181	-0.0025	-0.00256	-0.00272	-0.00114

## Subject #9 (female)

Time (min)	Cond. #1	Cond. #2	Cond. #3	Cond. #4	Cond. #5	Cond. #6	Cond. #7	Cond. #8
10	0.201005	0.197450	0.200619	0.201412	0.200355	0.194868	0.200185	0.200616
20	0.200733	0.197348	0.200709	0.201445	0.200732	0.193405	0.200588	0.200915
30	0.200458	0.196964	0.200393	0.200927	0.200891	0.189328	0.200737	0.201046
40	0.200738	0.196922	0.200457	0.200976	0.196325	0.189488	0.194539	0.197246
50	0.200161	0.197553	0.200354	0.201064	0.198684	0.188750	0.197461	0.199824
60	0.200611	0.197039	0.200527	0.200922	0.197011	0.188628	0.196091	0.197946
70	0.200630	0.197166	0.200336	0.200885	0.195348	0.188525	0.195006	0.196735
80	0.200406	0.197201	0.200301	0.200647	0.198080	0.188524	0.196441	0.196259
90	0.200959	0.197343	0.200900	0.201210	0.198533	0.188305	0.197082	0.199295
100	0.200704	0.197495	0.200659	0.200960	0.198345	0.188062	0.197032	0.199146
110	0.200745	0.197820	0.200527	0.200990	0.199004	0.187702	0.197782	0.199768
120	0.200738	0.197940	0.200599	0.200991	0.199967	0.187509	0.199517	0.200767
ARMS	0.000844	-0.00102	0.000408	0.000798	0.005543	0.00736	0.005178	0.004656

## Subject #10 (male)

Time (min)	Cond. #1	Cond. #2	Cond. #3	Cond. #4	Cond. #5	Cond. #6	Cond. #7	Cond. #8
10	0.254839	0.254576	0.243928	0.254288	0.252112	0.251972	0.254504	0.251981
20	0.254521	0.254381	0.244702	0.254114	0.252313	0.252188	0.254306	0.252200
30	0.254637	0.254519	0.244986	0.255004	0.252383	0.252253	0.255190	0.252091
40	0.254691	0.254566	0.245366	0.254619	0.252427	0.252317	0.254818	0.252441
50	0.254537	0.254410	0.245752	0.254879	0.252395	0.252297	0.255050	0.252493
60	0.254597	0.254481	0.245887	0.255410	0.251964	0.251859	0.255549	0.252022
70	0.254745	0.254617	0.245930	0.255487	0.252128	0.252018	0.256296	0.251988
80	0.254872	0.254714	0.246334	0.255496	0.251931	0.251819	0.255657	0.252003
90	0.255000	0.254811	0.246522	0.255237	0.251615	0.251516	0.255389	0.251500
100	0.254553	0.254380	0.246137	0.255277	0.251610	0.251509	0.255445	0.251575
110	0.258795	0.254475	0.246348	0.255198	0.251375	0.251272	0.255349	0.251200
120	0.255012	0.254888	0.246465	0.255058	0.251012	0.250914	0.255221	0.250859
$\Delta$ RMS	-0.00427	-0.00051	-0.00259	-0.00138	0.001415	0.001402	-0.00199	0.001634

**APPENDIX G**  
**Results of Questionnaires**

## PART A: PRE-EXPERIMENT

### Neck and Shoulders:

- (1) Have you at any time during the past 12 months experienced pains, stiffness, cramps, and/or fatigue in your neck and/or shoulders?

**n = 10**

[ 1 | 10% ] Daily  
[ 1 | 10% ] Occasionally  
[ 5 | 50% ] Seldom  
[ 3 | 30% ] Never

If your response is **NEVER**, do not answer question (2).

- (2) Are you currently experiencing pains, stiffness, cramps, and/or fatigue in your neck and/or shoulders?

**n = 80**

[ 7 | 8.75% ] Yes  
[ 73 | 91.25% ] No

### Back:

- (3) Have you at any time during the past 12 months experienced aches, pains, and/or discomforts in your back?

**n = 10**

[ 1 | 10% ] Daily  
[ 1 | 10% ] Occasionally  
[ 4 | 40% ] Seldom  
[ 4 | 40% ] Never

If your response is **NEVER**, do not answer question (4).

- (4) Are you currently experiencing aches, pains, and/or discomforts in your back?

**n = 80**

[ 7 | 8.75% ] Yes  
[ 73 | 91.25% ] No

Lower Extremities:

- (5) Have you at any time during the past 12 months experienced tingling sensations, numbness, swelling, and/or pain in your lower extremities?

**n = 10**

[ 0 | 0% ] Daily  
[ 2 | 20% ] Occasionally  
[ 1 | 10% ] Seldom  
[ 7 | 70% ] Never

If your response is **NEVER**, do not answer question (6).

- (6) Are you currently experiencing tingling sensations, numbness, swelling, and/or pain in your lower extremities?

**n = 80**

[ 7 | 8.75% ] Yes  
[ 73 | 91.25% ] No



## PART B: DURING EXPERIMENT

- (1) For each body part indicate your perceived level of comfort using the following scale:

1 Very Comfortable

2 Comfortable

3 Fairly Comfortable

4 Uncomfortable

5 Very Uncomfortable

	1/2 hr	1 hr	1 1/2 hr	2 hr
Neck and Shoulders	2.04375 n=80	1.99375 n=80	2.0625 n=80	2.05 n=80
Upper Back	2.06875 n=80	2.025 n=80	1.91875 n=80	2.03125 n=80
Lower Back	2.29375 n=80	2.125 n=80	2.16875 n=80	2.225 n=80
Lower Extremities	1.9875 n=80	2.0625 n=80	2.06875 n=80	2.05625 n=80

### PART C: POST-EXPERIMENT

- (1) Are you currently experiencing pains, stiffness, cramps, and/or fatigue in your neck and/or shoulders? n = 80
- [ 14 | 17.5% ] Yes  
[ 66 | 82.5% ] No
- (2) Are you currently experiencing aches, pains, and/or discomforts in your back? n = 80
- [ 19 | 23.75% ] Yes  
[ 61 | 76.25% ] No
- (3) Are you currently experiencing tingling sensations, numbness, swelling, and/or pain in your lower extremities? n = 80
- [ 9 | 11.25% ] Yes  
[ 71 | 88.75% ] No
- (4) Does the seat back comfortably support the lumbar region of your spine? n = 10
- [ 8 | 80% ] Yes  
[ 2 | 20% ] No
- (5) Does the seat pan provide firm support and comfort? n = 10
- [ 8 | 80% ] Yes  
[ 2 | 20% ] No
- (6) In this experiment the seat back was fixed at 120°; estimate the angle of the seat back in the car you drive (ie. what is your preferred setting)? n = 10
- [ 0 | 0% ] Greater than 120°  
[ 1 | 10% ] 120°  
[ 9 | 90% ] Less than 120°, greater than 90°  
[ 0 | 0% ] 90°

(7) Did you feel the microadjustments?

n = 80

[ 80 | 100% ] Yes

[ 0 | 0% ] No

If your response is **NO**, do not answer question (8), (9), and (10).

(8) Would you have preferred more pronounced or less pronounced microadjustments?

n = 80

0.8 sec (n = 40)

[ 14 | 35% ] More pronounced

[ 5 | 12.5% ] Less pronounced

[ 21 | 52.5% ] Fine as is

1.1 sec (n = 40)

[ 12 | 30% ] More pronounced

[ 6 | 15% ] Less pronounced

[ 22 | 55% ] Fine as is

(9) In your estimation, was the period of time between successive microadjustments acceptable?

n = 80

15 sec (n = 40)

[ 24 | 60% ] Yes

[ 16 | 40% ] No

30 sec (n = 40)

[ 20 | 50% ] Yes

[ 20 | 50% ] No

If your response is **YES**, do not answer question (10).

(10) Would you have preferred more frequent or less frequent microadjustments?

n = 36

15 sec (n = 16)

[ 11 | 68.75% ] More frequent

[ 5 | 31.25% ] Less frequent

30 sec (n = 20)

[ 15 | 75% ] More frequent

[ 5 | 25% ] Less frequent

(11) What do you think of the car seat (ie. micro-adjuster lumbar support system)? Is it:

n = 10

[ 3 | 30% ] Excellent

[ 5 | 50% ] Good

[ 1 | 10% ] Fair

[ 1 | 10% ] Poor

(12) Are there things about the car seat (ie. lumbar support system) that you would change?

n = 10

[ 9 | 90% ] Yes

[ 1 | 10% ] No

If your response is **NO**, do not answer question (13).

(13) What would you recommend be changed?

1. Microadjustment for lower extremities / upper back . . . . .	n = 7
2. Anthropometry / seat design . . . . .	n = 7
3. Cycle, wait, and/or pulse . . . . .	n = 3
4. Noise . . . . .	n = 1
5.	

(14) Based on your participation in this study, would you purchase an automobile with a micro-adjuster lumbar support system built into the seat?

n = 10

[ 8 | 80% ] Yes

[ 2 | 20% ] No

## REFERENCES

- Andersson, B.J.G. (1981). Epidemiologic aspects on low back pain in industry. Spine, 6, 53-60.
- Andersson, B.J.G., Murphy, R.W., Ortengren, R., and Nachemson, A.L. (1979). The influence of backrest inclination and lumbar support on lumbar lordosis. Spine, 4, 52-58.
- Andersson, B.J.G., Ortengren, R., Nachemson, A., and Elfstrom, G. (1974a). Lumbar disc pressure and myoelectric back muscle activity during sitting. I. Studies on an experimental chair. Scandinavian Journal of Rehabilitation and Medicine, 6, 104-114.
- Andersson, B.J.G. and Ortengren, R. (1974b). Lumbar disc pressure and myoelectric back muscle activity during sitting. II. Studies on an office chair. Scandinavian Journal of Rehabilitation and Medicine, 6, 115-121.
- Andersson, B.J.G. and Ortengren, R. (1974c). Lumbar disc pressure and myoelectric back muscle activity during sitting. III. Studies on a wheelchair. Scandinavian Journal of Rehabilitation and Medicine, 6, 122-127.
- Andersson, B.J.G., Ortengren, R., Nachemson, A., and Elfstrom, G. (1974d). Lumbar disc pressure and myoelectric back muscle activity during sitting. IV. Studies on a car driver's seat. Scandinavian Journal of Rehabilitation and Medicine, 6, 128-133.
- Andersson, B.J.G., Ortengren, R., Nachemson, A., Elfstrom, G., and Broman, H. (1975). The sitting posture: An electromyographic and discometric study. Orthopedic Clinics of North America, 6, 105-120.
- Basmajian, J. and DeLuca, C. (1985). Muscles Alive: Their Functions Revealed by Electromyography. Baltimore, MD: Williams & Wilkins.
- Bergstrom, J., Harris, R.C., Hultman, E., and Nordesjo, L.-O. (1971). Energy-rich phosphagens in dynamic and static work. In B. Perrow and B. Saltin (Eds.), Muscle Metabolism During Exercise (pp. 341-355). New York: Plenum Press.

- Bianchi, C.P. and Narayan, S. (1982). Muscle fatigue and the role of transverse tubules. Science, 215, 295-296.
- Bridger, R.S. (1995). Introduction to Ergonomics. New York: McGraw-Hill, Inc..
- Bush, T.R., Mills, F.T., Thakurta, K., Hubbard, R.P., and Vorro, J. (1995). The use of electromyography for seat assessment and comfort evaluation. Society of Automotive Engineers International, 950143, 27-32.
- Chaffin, D.B. and Andersson, G.B.J. (1991). Occupational Biomechanics (2nd ed.). New York: Wiley & Sons.
- Clemente, C.D. (1985). Gray's Anatomy (30th ed.). Philadelphia: Lea & Febiger.
- Coventry, M.B. (1968). Introduction to symposium, including anatomy, physiology, and epidemiology. Journal of Bone and Joint Surgery, 50A, 167-169.
- Dainoff, M. and Dainoff, M. (1986). People and Productivity: A Manager's Guide to Ergonomics in the Electronic Office. Toronto: Holt, Rinehart & Winston.
- Damkot, D.K., Pope, M.H., Lord, J., and Frymoyer, J.W. (1984). Relationship between work history, work environment and low back pain in men. Spine, 9, 395-398.
- Fitts, R.H. and Holloszy, J.O. (1976). Lactate and contractile force in frog muscle during development of fatigue and recovery. American Journal of Physiology, 231, 430-433.
- Fitts, R.H. and Holloszy, J.O. (1978). Effects of fatigue and recovery on contractile properties of frog muscle. Journal of Applied Physiology, 45, 899-902.
- Frymoyer, J.W., Pope, M.H., Clements, J.H., Wilder, D.G., MacPherson, B., and Ashikaga, T. (1983). Risk factors in low-back pain: An epidemiological survey. Journal of Bone and Joint Surgery, 65A, 213-218.
- Giroux, B. and Lamontagne, M. (1990). Comparison between surface electrodes and intramuscular wire electrodes in isometric and dynamic conditions. Electromyography and Clinical Neurophysiology, 30(7), 397-405.

- Gollnick, P.H. and Hermansen, L. (1973). Biochemical adaptations to exercise: anaerobic metabolism. Exercise and Sports Sciences Reviews, 1, 1-43.
- Grandjean, E. (1980). Sitting posture of car drivers from the point of view of ergonomics. In Proceedings of the International Conference on Ergonomics and Transportation (pp.205-213). London: Academic Press.
- Greiff, H. and Guth, V. (1994). Seat comfort studies with EMG. Automotive Seating Review, 38-43.
- Grieco, A. (1986). Sitting posture: An old problem and a new one. Ergonomics, 29(3), 345-362.
- Holewijn, M. and Hues, R. (1992). Effects of temperature on electromyogram and muscle function. European Journal of Applied Physiology, 65, 541-545.
- Hosea, T.M., Simon, S.R., Delatizky, J., Wong, M.A., and Hsieh, C.-C. (1986). Myoelectric analysis of the paraspinal musculature in relation to automobile driving. Spine, 11, 928-936.
- Hubberd, R., Haas, W., Boughner, R., Canole, R., and Bush, N. (1994). Biomechanical factors for... Automotive Seating Review, 44-51.
- Information Graphics Corporation (1991). BODYWORKS (Version 2.0) (Computer program). Phoenix, AZ: Software Marketing Corporation.
- Karlsson, J. (1971). Muscle ATP, CP, and lactate in submaximal and maximal exercise. In B. Perrow and B. Saltin (Eds.), Muscle Metabolism During Exercise (pp. 383-395). New York: Plenum Press.
- Karlsson, J. (1972). Localized muscular fatigue: Role of muscle metabolism and substrate depletion. Exercise and Sport Sciences Reviews, 7, 1-42.
- Karlsson, J., Nordesjo, L.-O, Jorfeldt, L., and Saltin, B. (1972). Muscle lactate, ATP, and CP levels during exercise after physical training in man. Journal of Applied Physiology, 33, 199-203.

- Katsuraki, M., Hanai, T., Takatsuji, K., and Suwa, A. (1995). Development of the new generation ergonomic seat based on occupant posture analysis. Society of Automotive Engineers International, 950140, 1-8.
- Keegan, J.J. (1953). Alterations of the lumbar curve related to posture and seating. Journal of Bone and Joint Surgery, 35A, 589-603.
- Keegan, J.J. and Radke, A.O. (1964). Designing vehicle seats for greater comfort. Society of Automotive Engineers Journal, 72, 50-55.
- Keithley ASYST (1992). VIEWDAC (Revision 2.10) (Computer program). Taunton, MA: Keithley Instruments Inc..
- Kelsey, J.L. (1975). An epidemiological study of the relationship between occupations and acute herniated lumbar intervertebral discs. International Journal of Epidemiology, 4, 197-205.
- Kelsey, J.L. and Hardy, R.J. (1975). Driving of motor vehicles as a risk factor for acute herniated lumbar intervertebral disc. American Journal of Epidemiology, 102(1), 63-73.
- Lamb, D.R. (1984). Physiology of Exercise: Responses and Adaptations (2nd ed.). New York: MacMillan Publishing Company.
- Lee, J. and Ferraiuolo, P. (1993). Seat comfort. Society of Automotive Engineers International, 931005, 1-5.
- Lee, J., Grohs, T., and Milosic, M. (1995). Evaluation of objective measurement techniques for automotive seat comfort. Society of Automotive Engineers International, 950142, 21-25.
- Magora, A. (1972). Investigation of the relation between low-back pain and occupation. 3. Physical requirements: sitting, standing and weight lifting. Industrial Medicine and Surgery, 41, 5-9.
- Mohamed, A.I. (1996). Effect of Seat Massage System on Back Muscles, Unpublished master's thesis, University of Windsor, Windsor, Ontario, Canada.



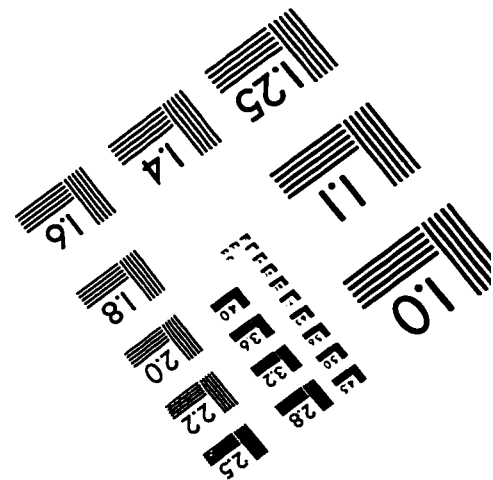
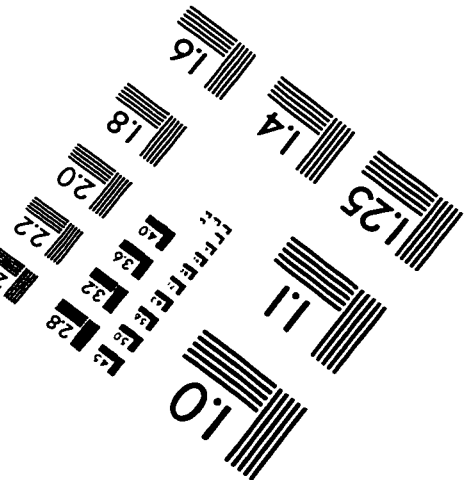
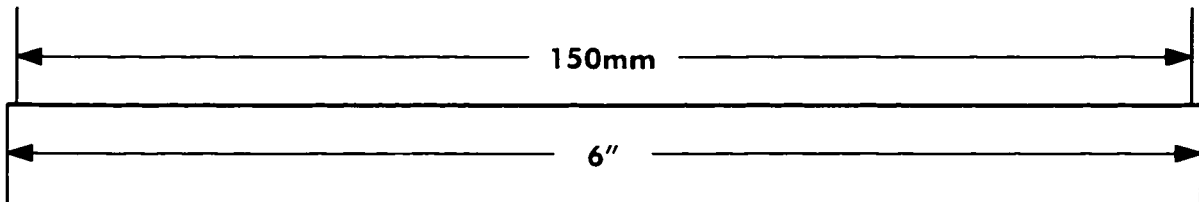
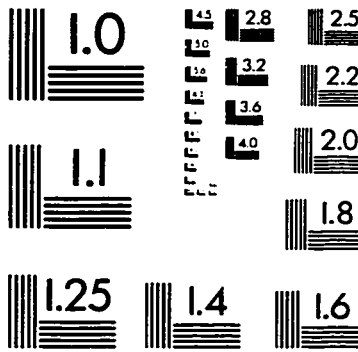
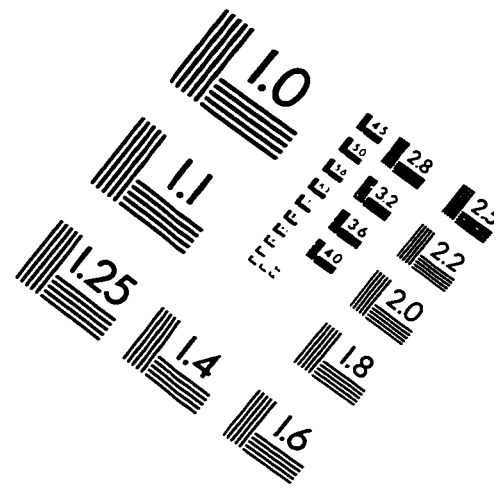
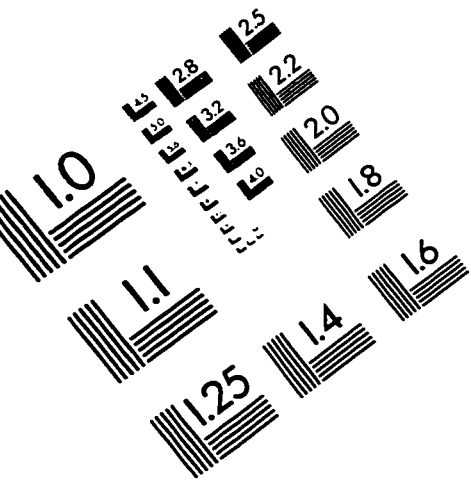
- Nieman, D.C. (1990). Fitness and Sports Medicine. Palo Alto, CA: Bull Publishing Company.
- Osborne, D.J. (1978). Techniques available for the assessment of passenger comfort. Applied Ergonomics, 9, 45-49.
- Porter, J.M. (1994). Seating design: Current problems and future strategies. Automotive Interiors International, 6-16.
- Reed, M.P., Schneider, L.W., and Eby, B.A.H. (1995). Some effects of lumbar support comfort on driver seated posture. Society of Automotive Engineers International, 950141, 9-20.
- Revicki, D.A. and Israel, R.G. (1986). Relationship between body mass indices and measures of body adiposity. American Journal of Public Health, 76, 992-994.
- Reynolds, H.M. (1993). Automotive seat design for sitting comfort. In B. Peacock and W. Karwowski (Eds.), Automotive Ergonomics (pp. 99-116). London: Taylor & Francis.
- Saltin, B. and Karlsson, J. (1971). Muscle glycogen utilization during work of different intensities. In B. Perrow and B. Saltin (Eds.), Muscle Metabolism During Exercise (pp. 289-299). New York: Plenum Press.
- Sanders, M.S. and McCormick, E.J. (1993). Human Factors in Engineering and Design (7th ed.). New York: McGraw-Hill, Inc..
- Sandover, J. (1983). Dynamic loading as a possible source of low-back disorders. Spine, 8, 652- 658.
- Sheridan, T.B., Meyer, J.E., Roy, S.H., Decker, K.S., Yanagishima, T., and Kishi, Y. (1991). Physiological and psychological evaluations of driver fatigue during long term driving. Society of Automotive Engineers International, 910116, 1-8.
- Simonsen, E. (1971). Physiology of Work Capacity and Fatigue. Springfield, IL: C.C. Thomas Publisher.
- Thakurta, K., Koester, D., Bush, N., and Bachle, S. (1995). Evaluating short and long term seating comfort. Society of Automotive Engineers International, 950144, 33-37.

- Troup, J.D.G. (1978). Driver's back pain and its prevention: A review of the postural, vibratory and muscular factors, together with the problem of transmitted road shock. *Applied Ergonomics*, 9(4), 207-214.
- Wilder, D.G., Woodworth, B.B., Frymoyer, J.W., and Pope, M.H. (1982). Vibration and human spine. *Spine*, 7, 243-252.

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