ABSTRACT

NON-INVASIVE INTERVENTIONS TO REDUCE LOW BACK DYSFUNCTION

by
Nadi Atalla

This study aims to quantitatively evaluate the low back condition so that low back dysfunction can be identified and classified when measurements show a variance from the normal. The evaluation is done by using the hysteresis concept. In this study, subjects received two different types of treatment: massaging using a mechanical massager for ten minutes and manual massaging by a professional physician. Using the Automated Anatomic Torsion Monitor (A-ATM), the low back of the subject was evaluated before and after treatment. The change in Hysteresis Loop Area (HLA) was -12.5% for mechanical massaging and -15.7% for manual massaging. The negative sign indicates improvement due to the treatments.

This study also theoretically measured the stiffness of the low back due to these treatments to see their effect before and after treatment.

In addition, this research also provides mathematical modeling of the preventive measures for low back pain, such as finding the reactive force at the fifth lumbar vertebra (L5) versus the inclination of the back from the vertical. Also, the ideal position of the cushion support while sitting on the chair is investigated.

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by
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NON-INVASIVE INTERVENTIONS TO REDUCE LOW BACK DYSFUNCTION

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“Hope is a good thing, maybe the best of things, and no good thing ever dies”

This thesis is dedicated to the people who stood by me during my ups and downs during the course of working on this thesis. I am thankful to all my family, teachers and friends who were there for me and gave me hope to reach this point in my life.

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CHAPTER 1

INTRODUCTION

1.1 Low Back Dysfunction

Low back dysfunction is considered to be a very serious problem that affects people at some point in their life time, whether it is caused by an accident or just by old age. While any type of pain in the body can be healed, low back pain is probably one of the most difficult pains to be healed. Back pain ranks second only to upper respiratory illness as a symptomatic reason for office visits to physicians [1]. About 70% of adults have low back pain at some time, but only 14% have an episode that lasts more than two weeks. About 1.5% of the people have such episodes with features of sciatica [2]. Not only is low back pain one of the top common reasons for physicians' visits in the United States, but it is also a top reason for limited activity for people who are younger than 45 years of age [3]. Many causes of low back pain respond to symptomatic and physical measures, but some are surgically remediable. Still others are systemic diseases such as cancer or disseminated infections which require specific therapy [1].

1.2 Anatomy of the Back

The spine is made up of small bones called vertebrae, which are arranged on top of one another. These bones are connected together to create a canal that protects the spinal cord. The spinal column is made up of three sections that create three natural curves in the back: the curves of the neck area are called the cervical area, the chest area that is called the thoracic area, and the lower back, the lumbar region. The lowest section of the spine, the sacrum and coccyx, is made up of vertebrae that are fused together [4]. There are five lumbar vertebrae that connect the upper spine to the pelvis.

Figure 1.1 shows the four regions of the spine: starting on the top are the seven cervical or neck vertebrae that are labeled C1-C7. The twelve thoracic vertebrae are labeled T1-T12, while the five lumbar vertebrae are labeled L1-L5. The sacrum and coccyx, which is a group of bones that are fused together, are at the base of the spine. The lumbar region is the lowest region of the back, and this is where most back pain is felt; this is what supports the weight of the upper body [5]. At birth, the spinal cord is almost vertical, forming a straight line. After the age of 12, it goes from straight to curved, as seen in the figure below, to permit better movement of the spine.

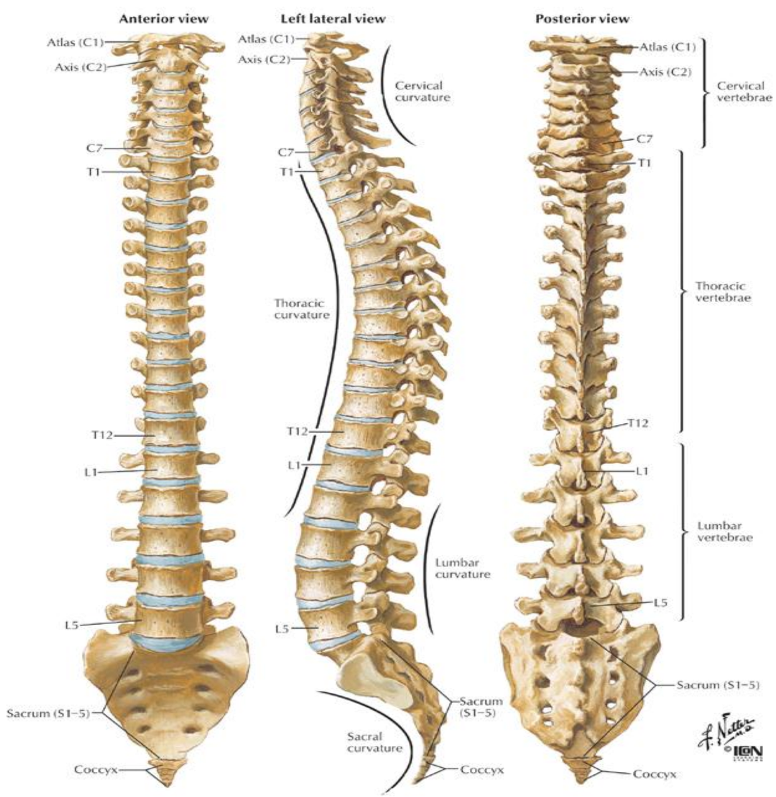

Figure 1.1 Anatomy of the Back [6]

As seen in figure 1.2, in addition to the vertebrae, the muscles, ligaments, nerves, and intervertebral disks are also parts of the spine.

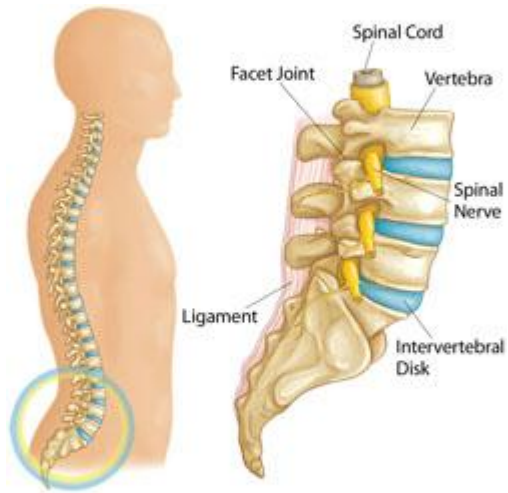

Figure 1.2 The Spine

The Spinal Cord:

The spinal cord and nerves act like electrical cables that travel through the spinal canal carrying messages between the human brain and the muscles to allow movement. The nerves branch out from the spinal cord through openings in the vertebrae [4].

Muscles and ligaments:

The main job of muscles and ligament is to provide the support and stability for the spine and the upper body. Such strong ligaments help the spinal column stay in position by connecting the vertebrae together [4].

Facet Joints and Intervertebral Disks:

Between the vertebrae, facet joints can be found; these joints help the spine move smoothly. Also in between the vertebrae sit the intervertebral disks. These disks act as shock absorbers and prevent the vertebrae from bumping against one another when walking or running. These disks work with the facet joints to help the spine move, twist, and bend. The intervertebral disks are flat and round, and about a half inch thick. There are two components that make up the intervertebral disks: the annulus fibrosus and nucleus pulposus. Annulus fibrosus is the tough, flexible outer ring of the disk. It helps the vertebrae connect to each other, while nucleus pulposus is the soft, jelly-like center of the annulus fibrosus [4]. In patients with low back pain with a disk mediated component, manipulation and mobilization therapies should avoid flexion to minimize stress on the disks. This is particularly relevant for high velocity manipulations where the stress on the disk is doubled for both flexion and rotation. It has been found that bending stress in the annulus fibrosus is 450 times greater than twisting stress for the same degree of bending or twisting which can help guide manual therapists to adjust their treatments to minimize stress on the intervertebral disk [7].

1.3 Symptoms/Types of Low Back Problems

Strain in the lumbar muscles causes symptoms to the low back. However, most of the time, such strain does not cause problems in the legs, such as sciatica pain. The most common symptom of lumbar strain is the pain around the low back and upper buttocks. Low back muscle spasm, such as sudden contraction, and pain associated with activities are generally relieved with rest [8]. There are three different types of low back pain: lumbago, sciatic pain, and Pseudoclaudication.

Lumbago (Low back pain):

Lumbago or low back pain is related to a mechanical problem in the lower back and it is not usually associated with a ruptured disk or a pinched nerve. The main causes of lumbago can be non-mechanical, such as inflammation of the facet joint or arthritis. It can also be due to strain of the supporting muscles or to local conditions which cause stress on the supporting structure or bone [9].

Sciatic Pain:

The sciatic nerve is the main nerve in the leg; it is also the largest nerve in the body. Irritation of the sciatic nerve can produce pain that starts in the lower-back or buttock area and radiates all the way down the back of the leg to the foot and toes. The sciatic pain or leg pain is caused by compression of a nerve root due to the herniation or rupture of an intervertebral disk [9].

Pseudoclaudication:

Pseudoclaudication involves cramping or heaviness in the legs associated with prolonged standing and walking which quickly diminishes with sitting or resting. Such pain is due to spinal stenosis or narrowing of the spinal canal and the foramen which are small passageways through which nerve roots exit [9].

1.4 Causes of Low Back Pain

The causes can be broadly categorized as mechanical spine disorders, non-mechanical spine disorders, and visceral diseases resulting in low back pain. The non-mechanical spine disorders are often systemic, including neoplastic, infectious, and inflammatory conditions [10]. The main causes of low back pain can be summarized in figure 1.3 and they are as follows: bad posture, intervertebral disk herniation, spinal stenosis, congenital defects of the spine, spondylolysis, osteoporosis, and arthritis.

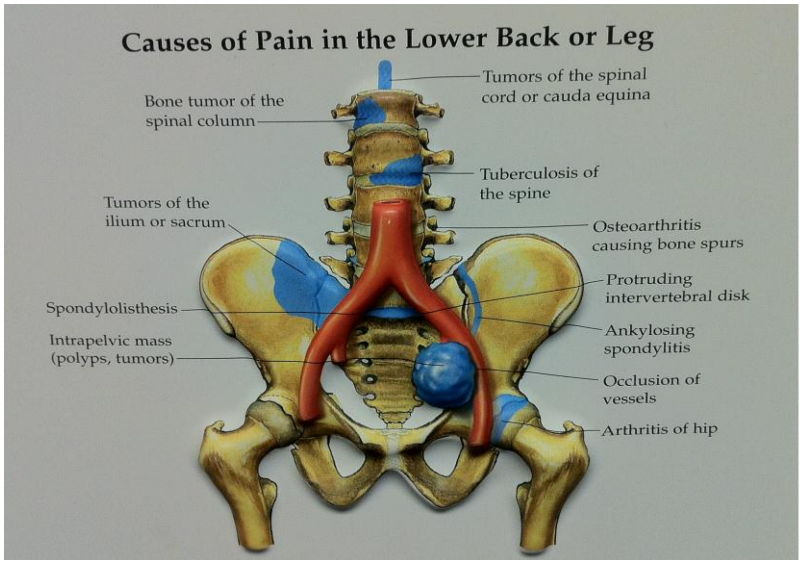

Figure 1.3 Some of the Causes of Low Back Pain

Bad Posture:

As shown in figure 1.4, good posture is when the weight of the whole body is equally distributed over all the parts of the body and not concentrated in one place [11]. Bad posture might be the most common cause of low back pain, since postural habits can start early in life and continues into adulthood. Any changes in lifestyle or activity level can greatly change one's posture at any time during his or her life. The most common cause of bad posture is fatigue. The tired back muscles simply cannot support the skeleton as they are designed to do. As the person gets older, it influences postural back pain development [12].

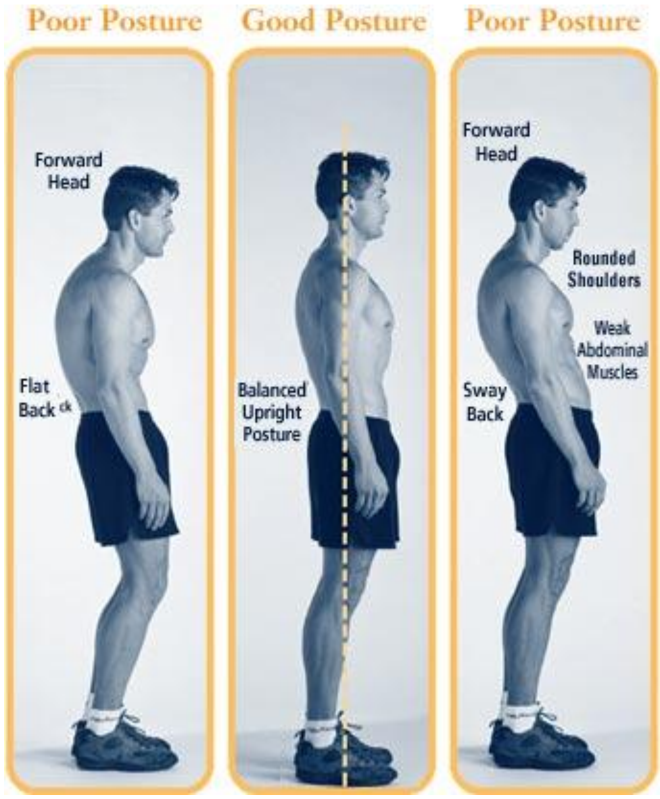

Figure 1.4 Good Posture (Center) vs. Bad Posture (Sides) [13]

Intervertebral Disk Herniation:

The spinal vertebrae are separated by disks filled with a soft, gelatinous substance which is in the middle of the disk. These disks cushion both the spinal column and space between the vertebrae. As seen in figure 1.5, a herniated or a slipped disk occurs when all or part of a spinal disk is forced through a weakened part of the disk. This places pressure on nearby nerves. Trauma or strain may cause these disks to herniate, or move out of place, and sometimes even rupture. When such an event happens, the spinal nerves may become compressed, resulting in pain, numbness, or weakness [14].

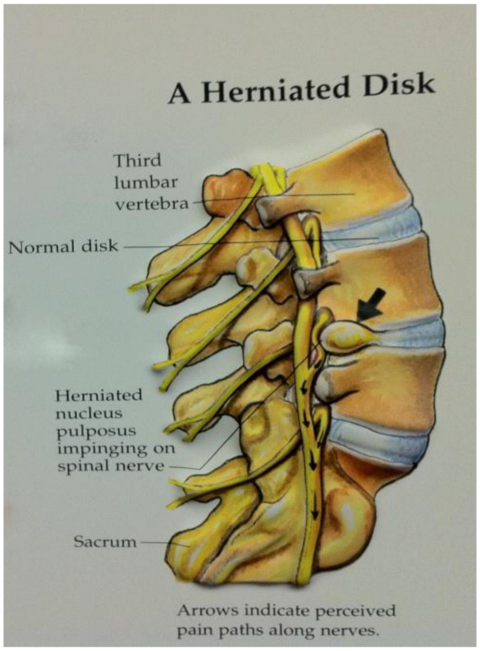

Figure 1.5 Disk Herniation

Spinal Stenosis:

Spinal stenosis happens when the spinal canal in the lumbar area squeezes the nerve roots and causes low-back pain, or sciatic-type pain, pseudoclaudication, cramping in the legs. Spinal stenosis is generally the result of a buildup of arthritis and degenerating bulging disks. This can occur locally just at the L4-L5 level, or it can extend from the L1 level to the sacrum [9].

Congenital Defects:

Congenital defects of the spine are caused by anomalous vertebral development in the embryo. Minor malformations of the spine are seldom apparent and often are identified only on routine chest films. The more severe congenital malformations which result in progressive scoliosis are even less common than are idiopathic scoliosis. Congenital anomalies of the spine may be simple and benign, causing no spinal deformity, or they may be complex, producing severe spinal deformity or even corpulmonale or paraplegia [15].

Spondylolysis:

Spondylolysis refers to the break of a vertebral bone; the break occurs in the bone bridge between the superior and the inferior facet joints. Spondylolysis is typically caused by stress fracture of the bone, and is especially common in adolescents who overtrain in activities such as tennis, diving, martial arts and gymnastics [16]. Pars interarticularis is especially vulnerable when the spine is in an extended position and a force suddenly presses the vertebrae together, as in landing on one's feet after a jump [9].

Osteoporosis:

Osteoporosis (figure 1.6) is a disease in which bones become fragile and more likely to break. If not prevented or treated, osteoporosis can progress painlessly until a bone breaks. Any bone of the body can be affected, but of special concern is a fracture of the hip and spine. Spinal or vertebral fractures also have serious consequences, including loss of height, severe back pain, and deformity [17].

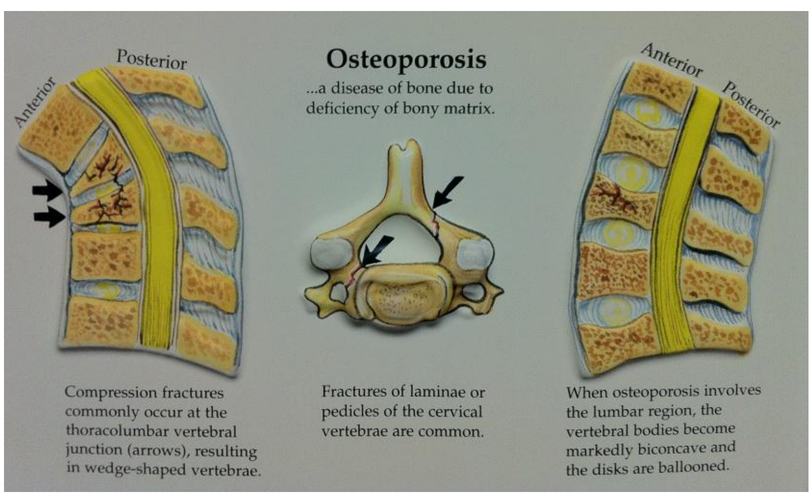

Figure 1.6 Osteoporosis

Arthritis:

Arthritis is the inflammation of one or more joints, which results in pain, swelling, stiffness, and limited movement. Arthritis involves the breakdown of cartilage. Cartilage normally protects the joint, allowing for smooth movement. It also absorbs shock when pressure is placed on the joint, as in walking. Without the usual amount of cartilage, the bones rub together, causing pain, swelling, inflammation, and stiffness [18].

In addition to the causes discussed above, there are additional, less common causes for low back pain such as fractures, infections and tumors.

Figure 1.7 shows the fractures of the vertebrae: In a compressive fracture, sudden downward force shatters the body of the vertebra presented by the arrow in the figure. In a dislocation, the ligaments are stretched or torn, presented by the arrows in the figure, allowing the vertebra to come out of alignment. While in a fracture-dislocation, both the vertebrae and ligaments are disrupted, as presented by the arrows in the figure [19].

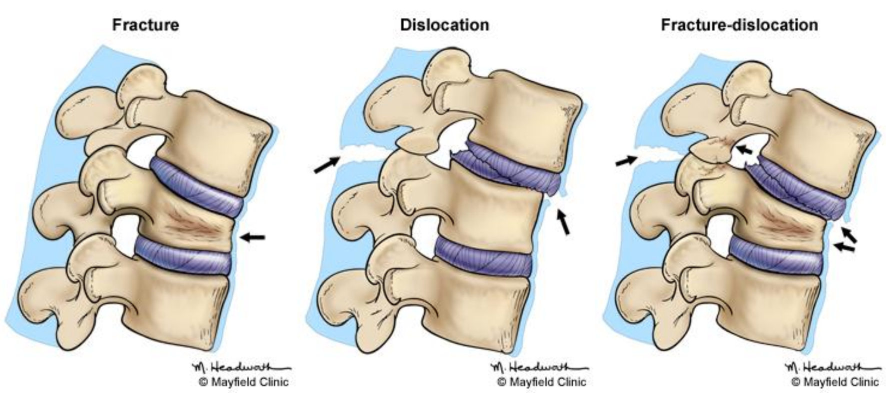

Figure 1.7 Fracture of the Vertebrae

An infection such as tuberculosis might be caused by bacteria which would destroy the vertebral bones, resulting in large collection of pus, and in irreversible destruction of the spinal cord [9].

Any type of tumor may occur in the spine, including: leukemia, lymphoma, and myeloma. A small number of spinal tumors occur in the nerves of the spinal cord itself. Most often, these are ependymomas and other gliomas. Tumors that start in spinal tissue are called primary spinal tumors. Tumors that spread to the spine from some other place (metastasis) are called secondary spinal tumors [20].

1.5 Diagnosis

Low back dysfunction is one of the hardest issues to diagnose due to the variety of pains. However, there are several methods that can help confirm the causes of low back pain. Such methods are imaging tests which include X-ray Imaging, Discogram, Computerized Axial Tomography (CAT), Magnetic Resonance Imaging (MRI), Electrodiagnostic/Electromyography (EMG), Bone Scans, Bone Density Scan, Myelogram, and Ultrasound Imaging [9].

X-ray Imaging:

X-ray imaging is the most basic type of imaging – it only visualizes bones, not disks, muscles or nerves. A simple X-ray can help determine if the patient has the most obvious causes of back pain such as broken bones, aging changes, curves, or deformities [4].

Discogram:

A discogram is an enhanced X-ray examination of the intervertebral discs. A dye is injected into the center of the injured disc which makes it clearly visible on X-ray film and on fluoroscope. The main role of this test is to determine which disc has structural damage and whether it is causing pain or not. Discograms can also show if a disc has begun to rupture and if it has tears in the annulus [21].

Computerized Axial Tomography (CAT) scan:

CAT scan is a three-dimensional X-ray test that focuses on the bones [4].

Magnetic Resonance Imaging (MRI):

MRI is a test that can create better images of soft tissues, such as muscles, nerves, and spinal disks. With an MRI scan, conditions such as herniated disk or an infection can be more visible [4].

Electrodiagnostic/Electromyography (EMG):

EMG is a test that measures the electrical activity of muscles and nerves. It determines if there is nerve damage, the cause of damage and whether the damaged nerves are responding to treatment or not [5].

Bone Scan:

Bone scan is a nuclear scanning test that identifies new areas of bone growth or breakdown. It can be done to evaluate damage to the bones, find cancer that has spread (metastasized) to the bones, and monitor conditions that can affect the bones (including infection and trauma). Bone scan is more advanced than X-ray and can predict a problem days to months earlier than a regular X-ray test [22].

Bone Density Test:

Bone density scanning, also called dual-energy X-ray absorptiometry (DXA) or bone densitometry. It is an enhanced form of X-ray testing which is used to measure bone loss. DXA is today's established standard for measuring bone mineral density (BMD), and is mostly performed on the lower spine and hips, or if osteoporosis is a concern [23].

Myelogram:

Myelogram uses a special dye and X-rays to make pictures of the bones and the fluid-filled space between the bones in the spine. Myelogram may be done to find a tumor, an infection, problems with the spine such as a herniated disc, or narrowing of the spinal canal caused by arthritis [24].

Ultrasound Imaging:

Ultrasound Imaging is also called ultrasound scanning or sonography, which involves exposing part of the body to high-frequency sound waves to produce pictures of the inside of the body. Unlike X-rays, ultrasound exams do not use ionizing radiation, therefore it is non-invasive. Ultrasound is captured in real-time, and has the ability to show the structure and movement of the body's internal organs, as well as blood flowing through blood vessels [25].

While these tests are very important, they are expensive. In order to diagnose the overall functions of the low back, a non-invasive and cheap device is needed.

1.6 Current Treatment

Throughout history, many researchers have been trying to find a cure to low back dysfunctions. Sometimes the cure can just be easing the pain, so that one can go on with his or her normal daily activities.

1.6.1 Exercises

One of the most common non-invasive treatments to any type of pain, not just low back pain, is exercising. Exercising does not necessarily completely heal the low back pain, but it helps relieve the pain. In his book “No More Aching Back,” Dr. Leon Root presents a back exercise program that help treating the low back:

Exercise 1: Lower-Back Stretch:

As seen in figure 1.8, lower-back stretch is an exercise designed to stretch the low back and to improve the mobility of one’s hips.

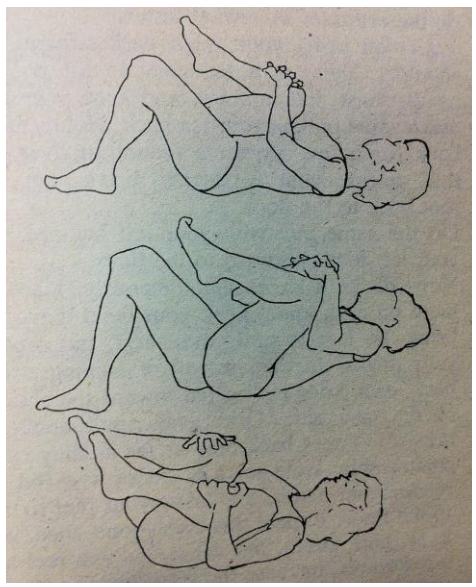

Figure 1.8 Lower-Back Stretch Exercise

By bringing the knees up to the chest, it reverses the lordosis of the lumbar spine and stretches those ligaments that tend to cause an exaggeration of that posture.

Exercise 2: Pelvis Roll or Tuck:

The main goal of the Pelvis Roll or Tuck exercise that is shown in figure 1.9 is to strengthen the buttock muscles while stretching the lumbar spine.

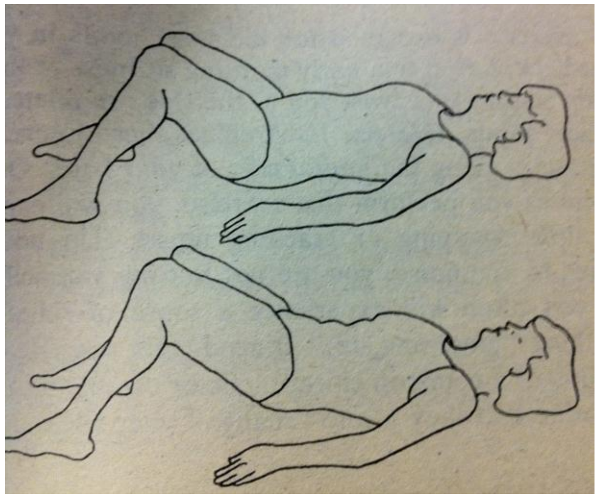

Figure 1.9 Pelvis Roll or Tuck Exercise

Exercise 3: Lumbar Spine Twist:

The Lumbar Spine Twist exercise, shown in figure 1.10, is designed for the facet joints in the low back which are stretched, as well as the muscles along the lateral side of the back.

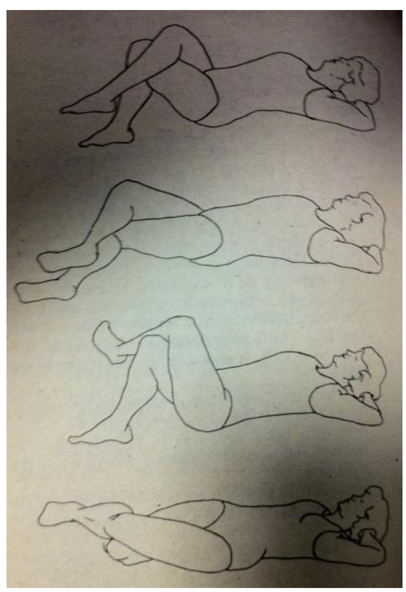

Figure 1.10 Lumbar Spine Twist Exercise

Exercise 4: Modified Sit-Up:

Strong stomach muscles are critical for a healthy back. The best way to strengthen the stomach muscles is by doing sit-ups. However, regular set-ups can aggravate back problems. Figure 1.11 shows the Modified Sit-Up exercise, where one would do them while the knees are bent.

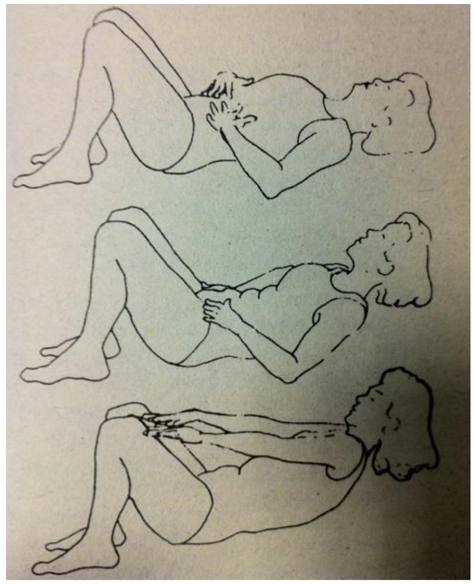

Figure 1.11 Modified Sit-Up Exercise

1.6.2 Inverted Decompression, Mobilization and Oscillation:

There are six basic human postural categories [26]. Three of the six are common and most people spend their lives, twenty-four hours a day, in them, as seen in figure 1.8a, b, and c. The other three postures are not as common, as seen in figure 1.8d, e, and f. Under the unidirectional and relentless force of gravity, the common postures produce compression and shortening of stature while the uncommon postures decompress and elongate [26]. While the common posture is used in work, play and rest, the uncommon posture is used to counter and correct adverse effects of gravity produced by the common postures [27].

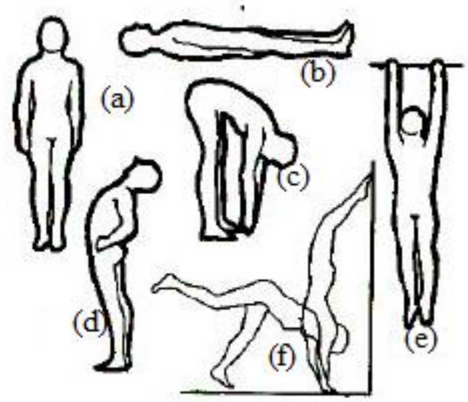

Figure 1.12 The Six Basic Human Postural Categories

Figure 1.12a shows the erect posture, which happens while standing, and the posture in this case is dominate [26]. Figure 1.12b shows the horizontal posture where the posture is at neutrality, which happens when one is lying on the side, front or back. The flexed posture is the third common posture; it happens when one is bending forward, to lift an object. On the other hand, figure 1.12d shows the extended posture, which is a type of uncommon posture. This happens when one is bending backward. Figure 1.12e shows the posture of hanging by the upper or lower limbs; this is called the brachiated posture. Figure 1.12f shows the inverted posture which includes hand stands, forearm stands, shoulder stands, and hanging by the lower limbs [26].

Many devices were built to exercise and achieve such uncommon postures such as inversion boots and tables. Such devices are found to be helpful since, for example, hanging from the limbs is a practical way to employ the natural pull of gravity to realign and elongate the entire organism [27]. This is commonly achieved in the head downward position through: decompression, mobilization, and oscillation.

Decompression helps anchoring the lower limbs and allowing gravity to stretch the body by moving to an inverted position. On the other hand, mobilization means moving the body while in the inverted position. And finally, oscillation is done on an inversion table that involves rocking gently from the inverted to the erect posture [27]. Many benefits are found to be due to decompression, mobilization, and oscillation. Such benefits include reduced pain and muscle spasm in common back problems [27].

The most recent study using oscillation was done by Vishal Singh, where he observed that by providing oscillation to the low back, using an Automated Anatomical Torsion Monitor (A-ATM), improves the viscoelasticity of the low back [28]. Such device is non-invasive and cost-effective.

1.6.3 Massaging

There are several solutions in an attempt to treat the low back; some are invasive such as injections and acupunctures, and some are not. While the invasive treatment might sound like a faster way to treat the low back – an easy fix – but it might be just a temporary fix. The goal of this study is to find non-invasive ways to treat low back pain in the long run, not just temporarily. Hence, all the focus of this study will be on current non-invasive treatments such as massage.

Massage has proved to be a very accurate way to relieve the pain, not just of the low back but of any part of the body. Massage might be thought of an instantaneous pain relief, but it is not. Constant massage helps not just to relieve the pain instantaneously but to treat an injury in the long run. A massage makes access to one’s inner pharmacy; since the skin, on which massage is done, is a rich source of age-reversing hormones that can be released through massage [29].

Manual Massaging

Manual massage is probably the most common and well-known way of massage. It can be done by a professional, non-professional or even by oneself. Through a slow, calming massage, the skin releases natural relaxing chemicals and while during a brisk, invigorating massage, it releases natural energizing chemicals [29]. But this statement needs to be scientifically proved which will be done in this study.

Mechanical Massaging

Mechanical massaging is the alternative to manual massaging; since the back is a tough spot to reach to self-massage. There are several types of mechanical massagers; the most simple and least expensive one is the one used in this study. It is a simple, extendable arm percussion massager that has different speeds and heat option, as seen in figure 1.9

Figure 1.13 Simple Mechanical Massager Used in the Study [30]

1.7 Objective and Goals

The goal of this study is to quantitatively evaluate the low back condition so that low back dysfunction can be identified and classified when measurements show a variance from the normal. In this study, the subject will receive two different types of treatment: massaging using a mechanical massager for ten minutes and manual massaging by a professional physician. Using the Automated Anatomic Torsion Monitor (A-ATM), the low back of the subject will be evaluated before and after treatment. The efficacy of the treatment will then be determined.

In addition to the above, it is intended to determine the viscoelastic constants of the low back such as stiffness, damping, and friction before and after the treatment.

The mathematical modeling of the preventive measures for the low back pain will also be presented in this study.

CHAPTER 2

HYSTERESIS CONCEPT

2.1 Introduction

In a nonlinear system, there can be a hysteretic reaction when the output response of a system lags behind the input stimulus.

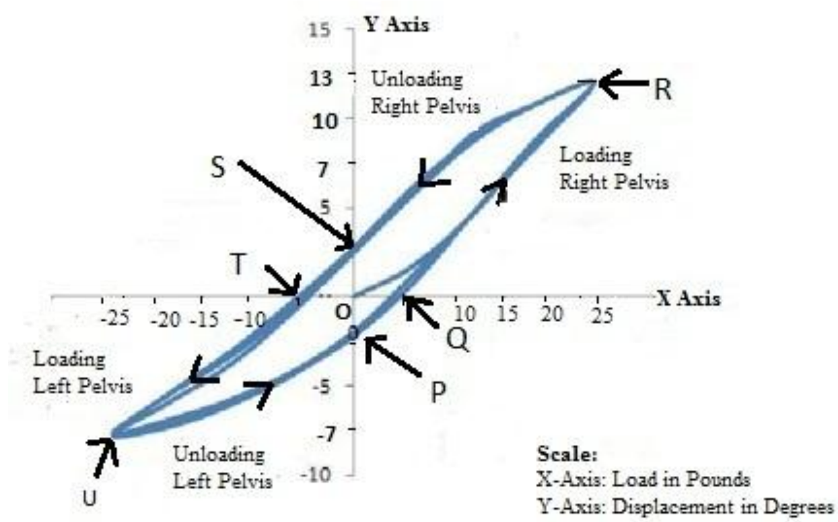

Figure 2.1 Hysteresis Loop Area

As seen in figure 2.1, when the right pelvis is loaded, the curve starts at the origin and goes to the point “R” in the first quadrant for a maximum applied force. This corresponds to the maximum deflection for the right pelvis. While unloading the right pelvis, the curve returns to the point “S” on the y-axis. That point on the y-axis gives the information for residual displacement that is known as *retentivity* for the right pelvis. Therefore, retentivity is measured by “OS” while the coercive force for the right pelvis is measured by “OT”. This is the required force that brings the right pelvis to its original position.

The negative values in figure 2.1 show the loading and the unloading of the left pelvis. This is where the curve starts at "S" and goes to the point "U" in the third quadrant for a maximum applied force. This corresponds to the maximum deflection for the left pelvis. While unloading, the curve returns to the point "P" on the negative y-axis. That point on the negative y-axis gives the information for residual displacement that is the retentivity for the left pelvis. Therefore, retentivity is measured by "OP" while the coercive force is measured by "OQ". This is the required force that brings the left pelvis to its original position.

Figure 2.1 also defines the energy dissipation concept which is given by the area enclosed by the curve "QRTUQ". This shows the inelasticity of the low back because if the low back were perfectly elastic then the "QRTUQ" curve would not be formed. Loading and unloading will follow a straight line path. The area that is included in the curve "QRTUQ" is called the Hysteresis Loop Area (HLA). The greater this area, the more inelastic the low back is and vice versa.

2.2 Definitions

The concept of hysteresis is applied in this study for the evaluation of low back dysfunction. Using this concept, the elasticity and stiffness can be evaluated. Elasticity is the physical property of a system that returns the system to its original shape after removing the load from the system. The stiffness is the property of the material to undergo a certain displacement subjected to a specific load. If the displacement is less under a given load, then the material is stiffer; but if it is more under the same load, then the material is less stiff. For example, steel is considered to be stiffer and more elastic than rubber. Since Young's Modulus of steel is much higher than that of rubber, the higher the Young's Modulus, the stiffer the material is.

The Range of Motion (ROM) is defined as the maximum deflection of the low back under a given applied force. As it was seen in figure 2.1, "R" and "U" are the maximum ranges of motion for the right and the left pelvis respectively.

2.3 Static Model

Figure 2.2, given below, shows the hysteresis loop when a steel rod is subjected to torques on A-ATM. It can be seen that the HLA is nearly equal to zero since the steel is almost perfectly elastic.

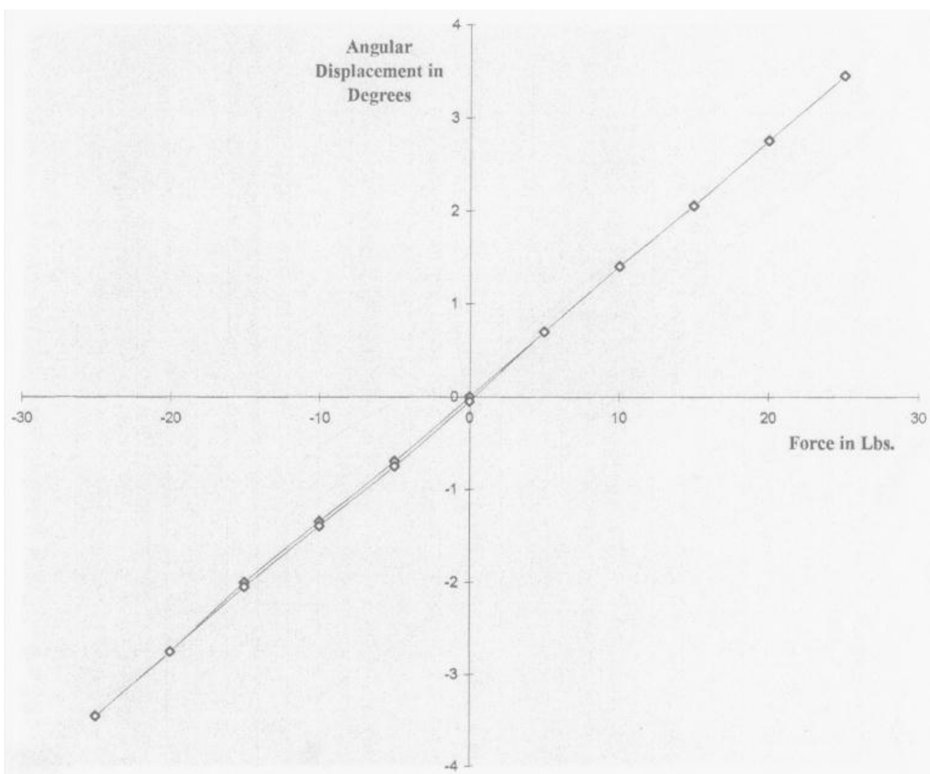

Figure 2.2 Static Model on A-ATM

CHAPTER 3

EXPERIMENTAL METHODS AND PROTOCOLS

The experiment is divided into two parts: the evaluation part and the treatment part. The evaluation part is done with the use of the A-ATM. The treatment part is divided into two sections: treatment using a mechanical massager and treatment using manual massaging.

3.1 Methods for Using the A-ATM for Evaluating the Low Back

The following procedure has been performed on all subjects:

1. The subject is asked for the date of birth, height, and weight to calculate his/her body mass index (BMI).
2. The subject is then asked to locate his/her Posterior Superior Iliac Spine (PSIS) spots on his/her back as it is shown by the two crosses in figure 3.1.

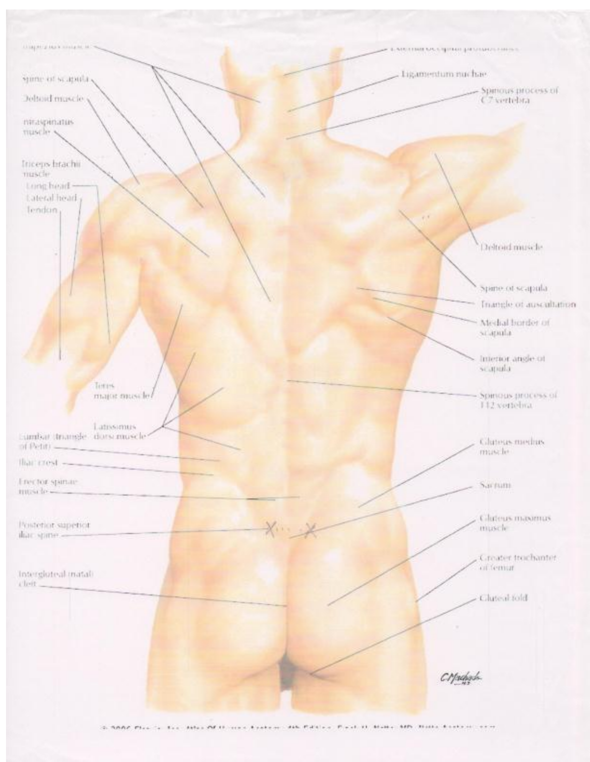

Figure 3.1 The Two Posterior Superior Ilian Spine Spots

3. The subject is asked to place a piece of tape on the located two spots of his low back to confirm that he/she places himself/herself at the correct position.

4. The subject is then asked to lie supine on the A-ATM as seen in figure 3.2

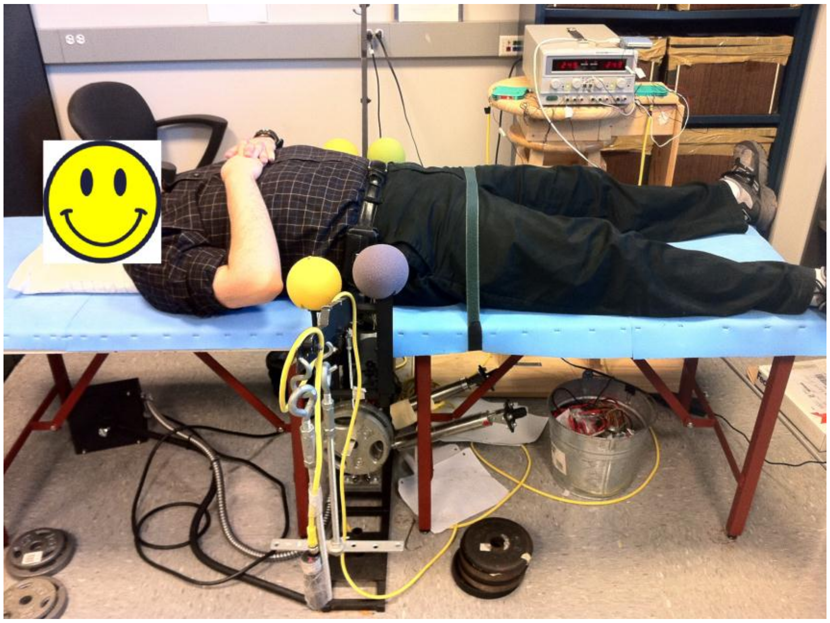

Figure 3.2 The Subject Lying Supine on the A-ATM

5. Starting on the right side, the right lever arm is at zero vertical displacement without any weight.

6. The weights are added to the right lever arm weight carrier in the increments of five pounds up to twenty five pounds.

    a. This results in the rise of the right pad displacing the right PSIS.

    b. The right Anterior Superior Iliac Spine (ASIS) also rises.

7. Optical Ultrasound transducers are attached to the lever arms to measure the displacement in terms of voltage.

a. The vertical displacement for each of the applied weights is recorded by the ultrasound sensor through DAQ card and software installed on the computer by the operator.

b. One volt on the ultrasound is equivalent to a displacement of 3.5687 in, meaning that the resolution of the transducer is $3.5687X10^{-4}$ in.

c. On the computer that was used in this study, 1 pixel equals 1.085 in^2 which is equivalent to HLA of 1.085 lb-in.

8. The weights are removed from the lever arm weight carrier in five pound decrements for unloading measurements.
9. The vertical displacement for each of the removed weights is recorded by the ultrasound sensors down to zero load weight.
10. Steps 3 through 9 are repeated for the left pelvis lever arm
    a. Application of the weight to the left lever arm weight carrier raises the left pad.
    b. This displaces the left PSIS and consequently the left ASIS.
11. The weight vs. the displacement is plotted for loading and unloading.
12. The final reading is recorded after 45 seconds when the displacement settles down due to the creep effect encountered in viscoelastic tissues of the low back
    a. The HLA is calculated using the MATLAB software. The area under the curve is calculated using the trapezoidal rule for loading and unloading curves.

13. The above procedure is performed before and after treatment, whether the treatment is with the mechanical massager or by manual massaging.

3.2 Protocol for Using the Mechanical Massager

The mechanical massager that is used in this study is the HOMEDICS HHP-300 which is a well-known, non-invasive, commonly used massager for treating the low back pain. The heat feature in the massager is not used, and only the normal frequency option is used. Appendix D gives the details of the mechanical components of this device.

1- The subject is asked to lie down prone on the table.

2- The investigator applies the mechanical massager along the spine of the subject for ten minutes without applying any extra pressure on the back. During massaging, subject is asked if he or she feels any pain or uncomfortable at any point in time; if so, the massaging is stopped.

3.3 Protocol For Manual Massaging

The manual massaging on the subject was performed by a professional physician. The focus of this treatment is to align the head, shoulder, hip, knee and ankle from the lateral aspect of the body and to create space between the iliac crest and the lower ribs. Then, the shoulder girdle is raised and the pelvic girdle is lowered while releasing the pelvis from the ribs and thorax by working on the quadratus. This is achieved by the activation and inhibition of muscles using exercises for the patient as well as direct pressure on muscle, golgi tendon organs, and fascia between the greater trochanter of the femur and the head of the humerus, with emphasis at the iliac crest on the thoracolumbar fascia. The session is directed to release the shoulder girdle from the rib cage by working on the teres, subscapularis, serratus anterior, latissimus dorsi and pectoralis major muscles. It is also directed to distinguish fascia of the trapezius from the levator, splenius and SCM; to separate the Iliotibial band from the vastus or biceps femoris between the greater trochanter and iliacus. In addition to ensuring easy movement of the quadratus lumborum fascia [35].

The goal of this session is to increase the breath path from the chin to the pubis symphysis, to lengthen the anterior thorax, and to achieve balance between the iliopsoas and rectus abdominus. This is achieved by the activation and inhibition of muscles using exercises for the patient as well as applying direct pressure on muscle, golgi tendon organs, and fascia. Specific myofascial work using myofascial and osteopathic techniques is performed on the intermediate deep fascial layer, at the rectus abdominus fascia, and is directed towards the midline. Finally, working down towards the pubic crest and on to the fascia of the psoas and adductors, inguinal ligament as well as the anterior part of the spine and pectoral arch [35].

CHAPTER 4

EXPERIMENTAL SECTION

The table and the pads were covered with closed cell foam for the subject's comfort. The thickness of the foam padding did not exceed 0.375 in to minimize the effect on the hysteresis. The sensors were located on each lever arm.

To make sure that the change in HLA is due to treatment only and not due to any other factors, the investigator made sure that the subject was in the same exact position as in the first evaluation before the treatment.

The methods described in section 3.1 were applied on normal subjects and patients.

4.1 Reproducibility Test

The main goal of the reproducibility test is to make sure that the apparatus is as accurate as possible. For this part of the experiment, there was no treatment given. The reproducibility test implies that the readings are reproduced after one hour duration.

The variables that were tested were the time intervals between the applied loads i.e. 30-second vs. 45-second vs. 60-second time intervals. The main purpose of these time intervals is to consider the creep effect so that the readings settle down under a given load. It was found that 45-second time interval was better compared to 30-second and 60-second time interval since the change in HLA between two tests (taken at one hour duration) is the least for 45-second time interval. Hence when evaluating the back before and after applying the mechanical massager and/or the manual massaging, the 45-second time interval is applied.

The following figures show the 45-second time interval results of five normal subjects (two females and three males) that were tested. The time in between each evaluation was one hour.

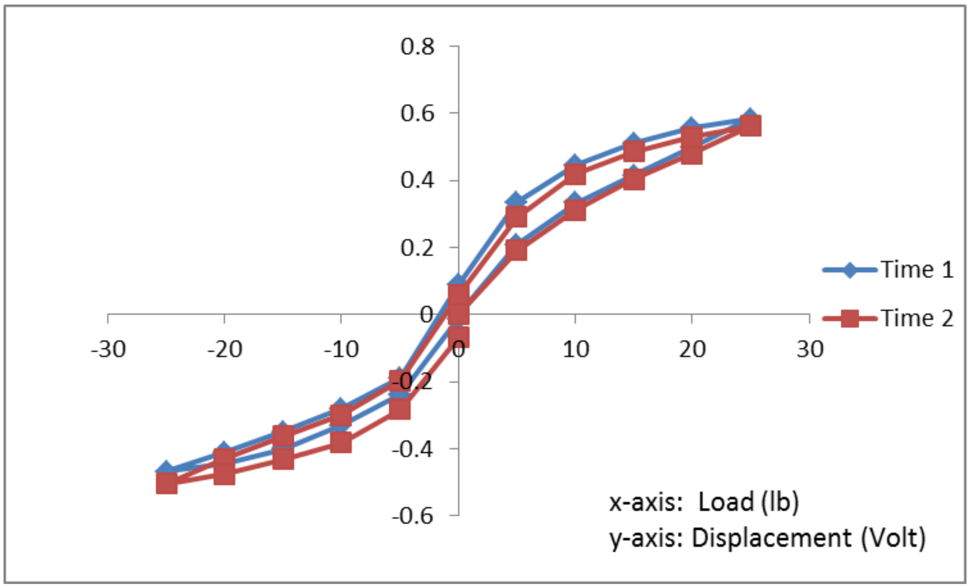

Figure 4.1 Reproducibility for Subject 1

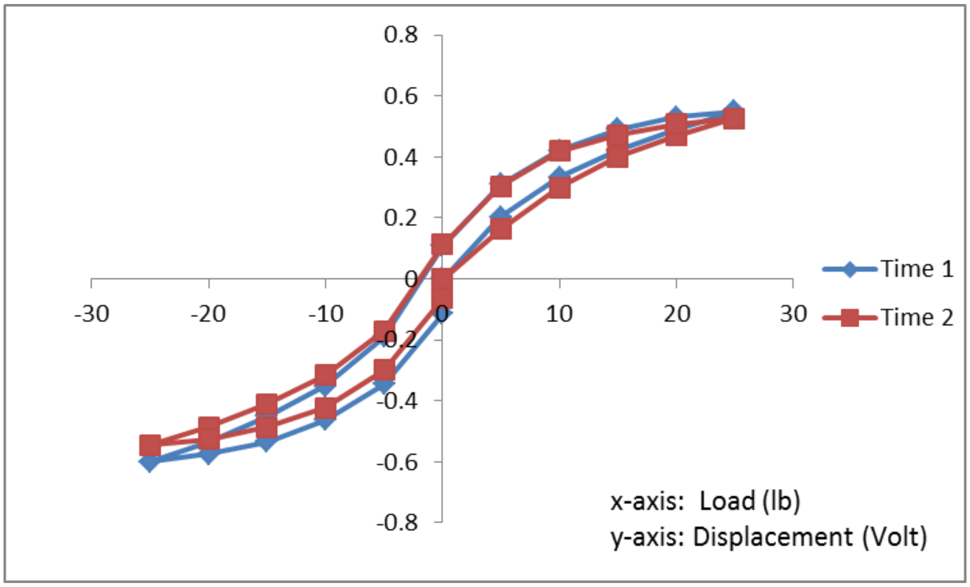

Figure 4.2 Reproducibility for Subject 2

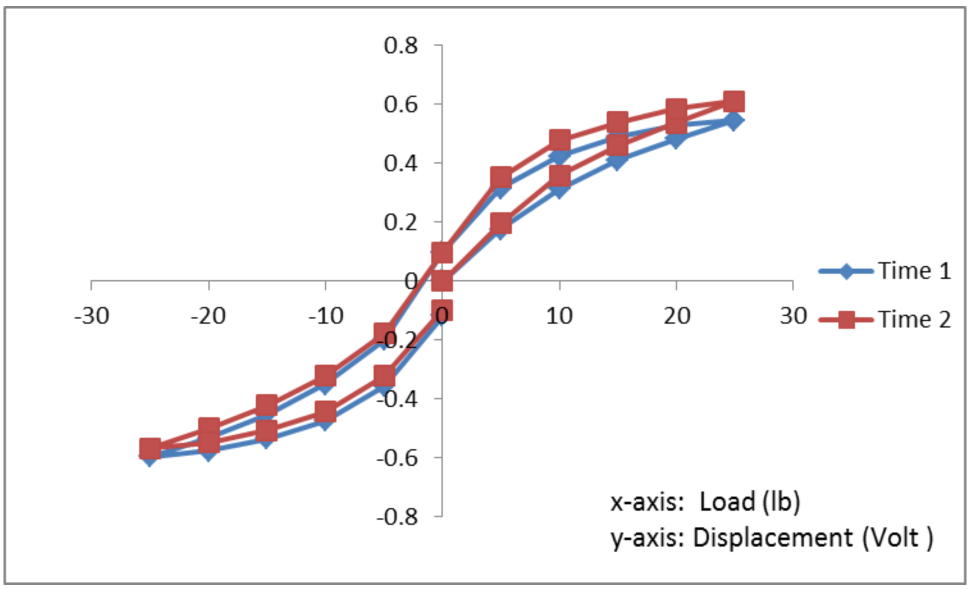

Figure 4.3 Reproducibility for Subject 3

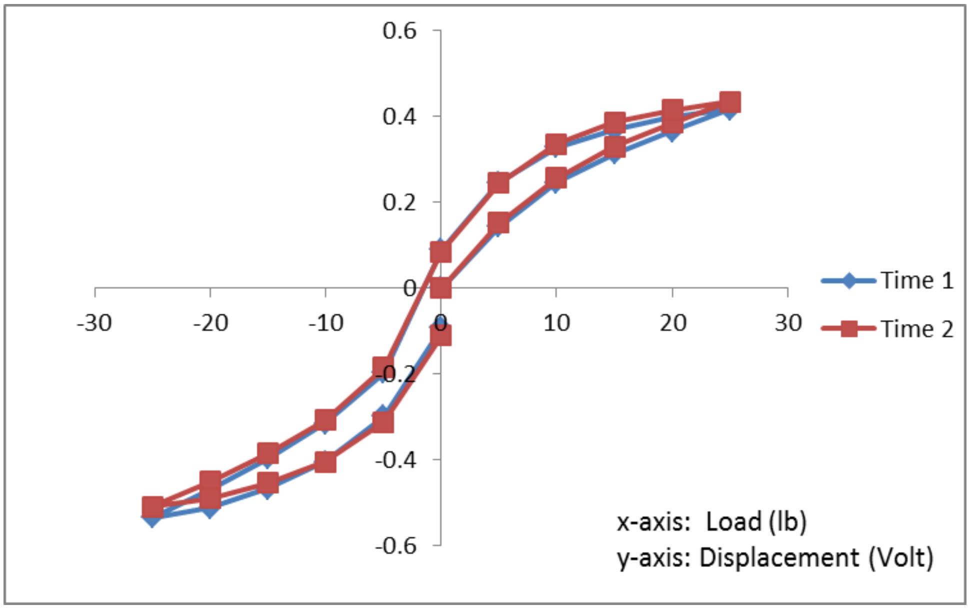

Figure 4.4 Reproducibility for Subject 4

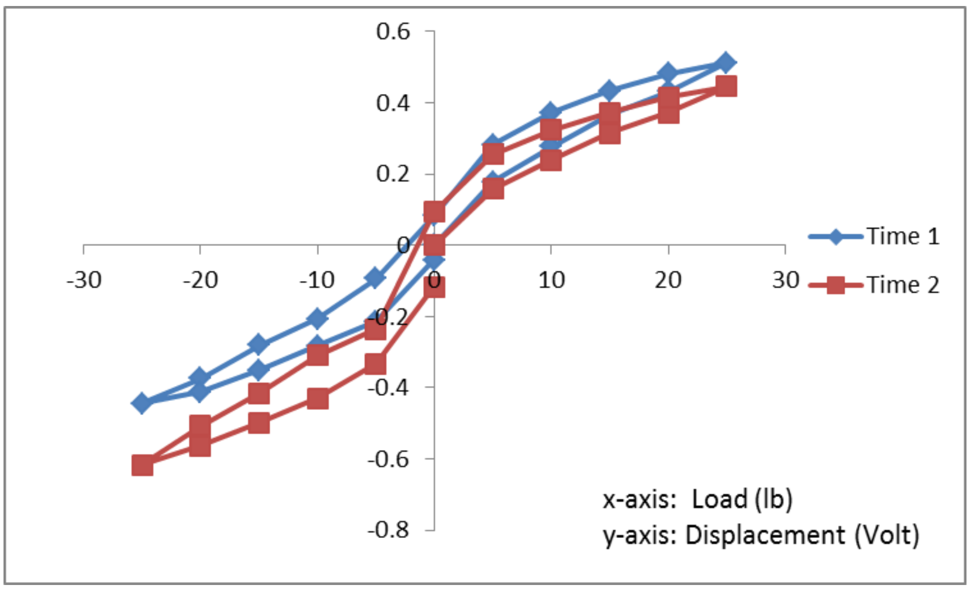

Figure 4.5 Reproducibility for Subject 5

4.2 Effects of Mechanical Massager Applied on the Low Back for 10 minutes

In addition to the methods described in section 3.1, the methods described in section 3.2 were also applied. The results of the effects of the mechanical massager when applied on five patients (four females and one male) who suffer from different kinds of low back dysfunctions are described as follows:

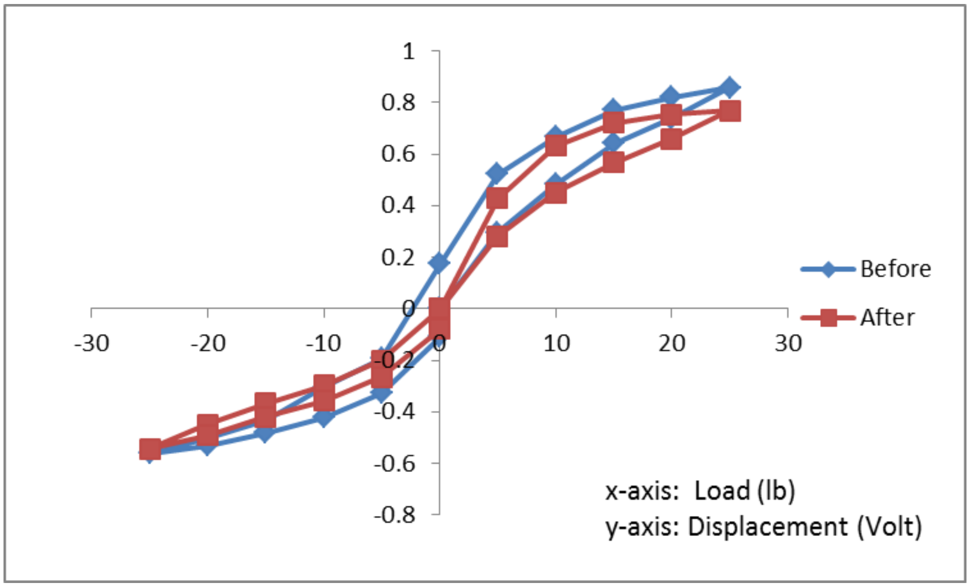

Figure 4.5 The Effect of the Mechanical Massager on Patient 1

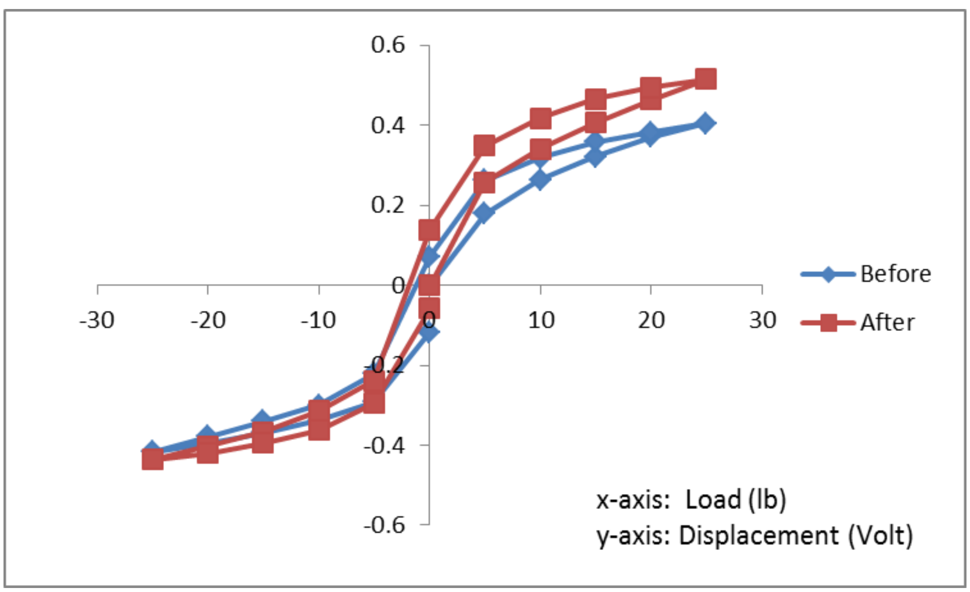

Figure 4.6 The Effect of the Mechanical Massager on Patient 2

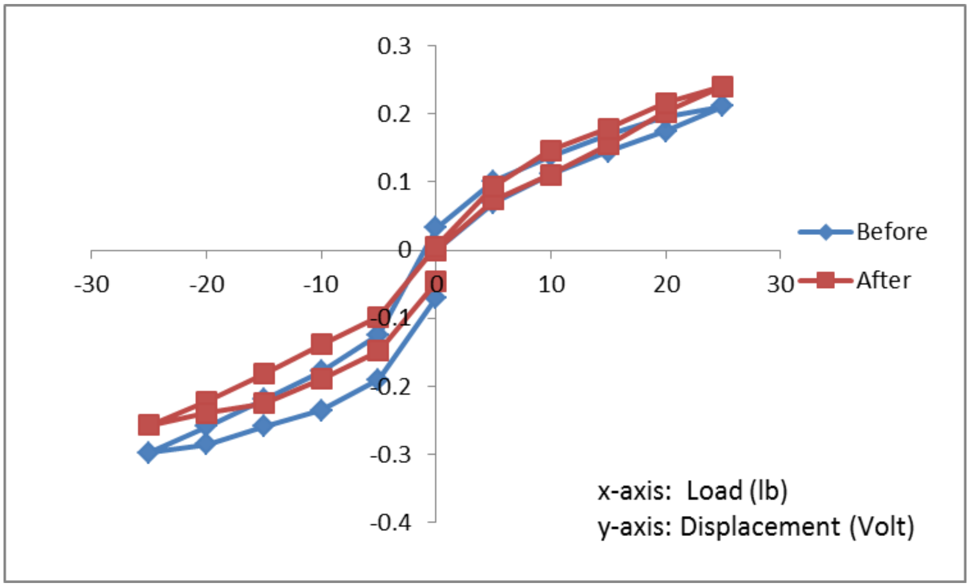

Figure 4.7 The Effect of the Mechanical Massager on Patient 3

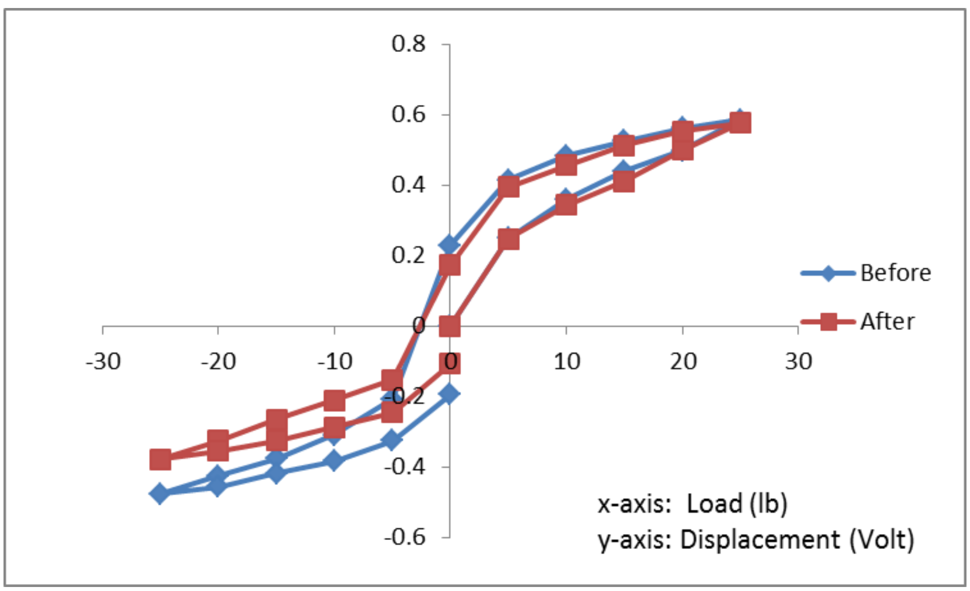

Figure 4.8 The Effect of the Mechanical Massager on Patient 4

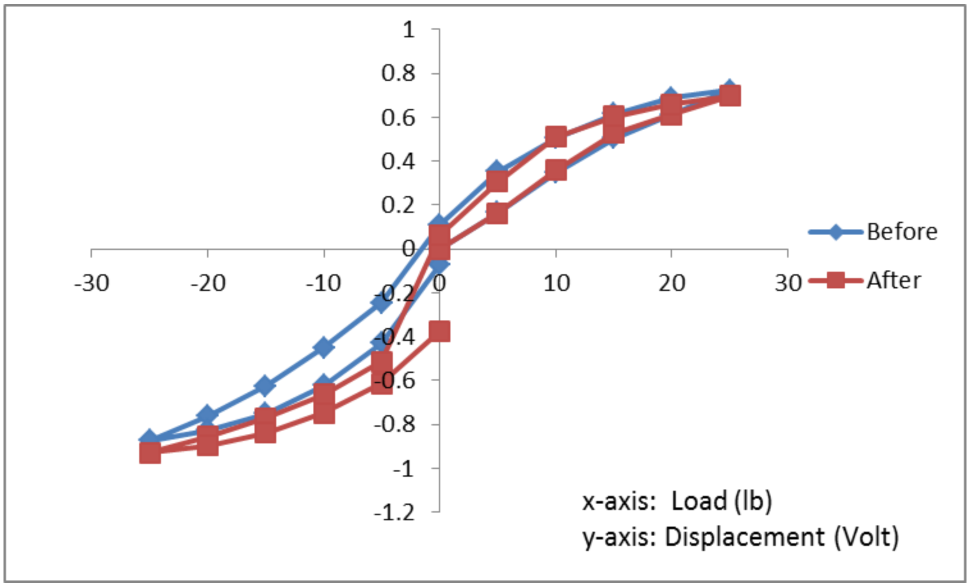

Figure 4.9 The Effect of the Mechanical Massager on Patient 5

4.3 Effects of Manual Massaging Applied on the Low back

The methods described in section 3.3, as well as the methods described in 3.1, were applied in this part of the experiment. The same patients were given the manual massaging treatment on the low back by the professional physician the following week. The stiffness and elasticity of their low back were evaluated before and after the treatment. The effects of the manual massaging are described as follows:

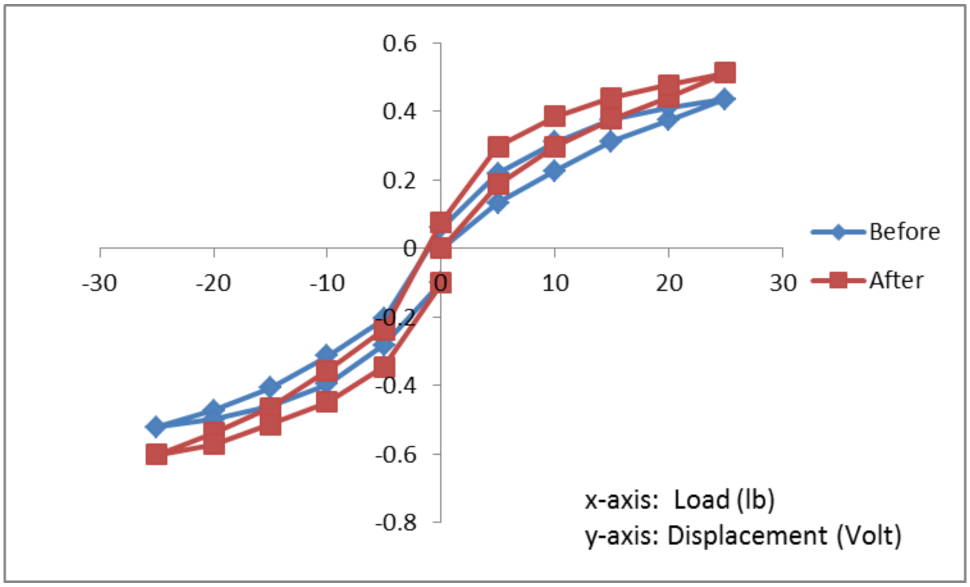

Figure 4.10 The Effect of Manual Massaging for Patient 1

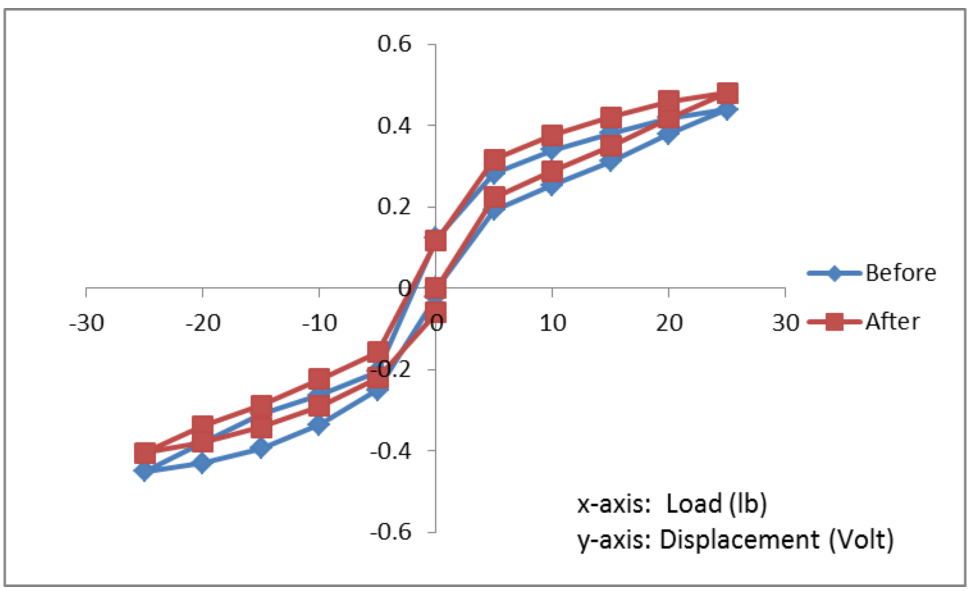

Figure 4.11 The Effect of Manual Massaging for Patient 2

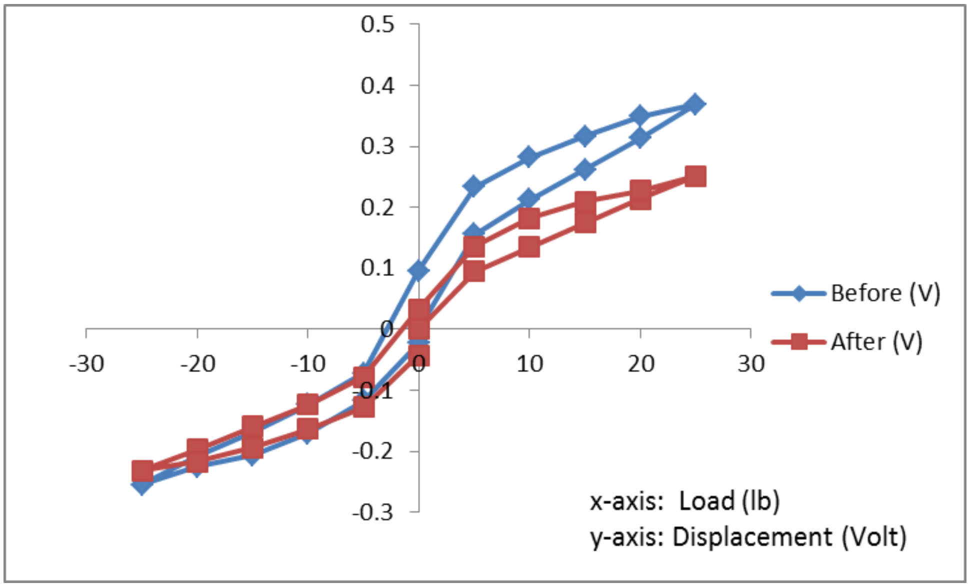

Figure 4.12 The Effect of Manual Massaging for Patient 3

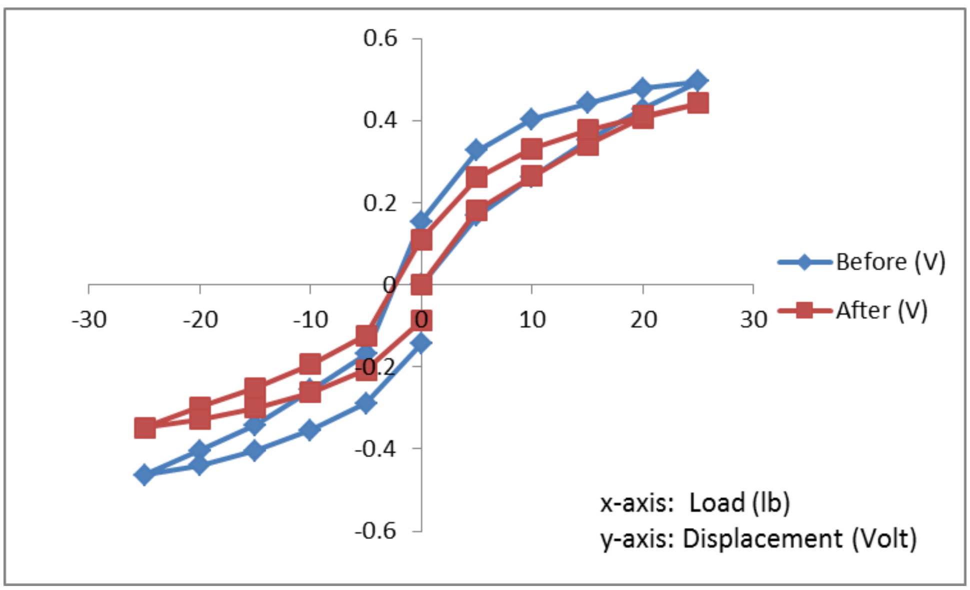

Figure 4.13 The Effect of Manual Massaging for Patient 4

The test for the fifth patient could not be performed because she was not avaialable.

CHAPTER 5

RESULTS

5.1 Reproducibility Test

The reproducibility test results are summarized in tables 5.1, 5.2 and 5.3, and they reflect the effects of the time intervals while taking the creep effect into consideration. After one hour duration, the mean percent change in HLA for the 30-second, 45-second and 60-second time intervals for five subjects are found to be 4.0, 3.9, and 5.0 respectively.

Table 5.1 HLA for 30-second Time Interval

Subject #	***Age***	***Sex***	***BMI***	***Time 1 HLA (Pixel)***	***Time 2 (1 Hour) HLA(Pixel)***	***% Change in HLA***
1	23	F	17.5	0.7	0.8	6.1
2	24	M	28.3	0.9	0.9	0.2
3	24	M	28.3	1.0	1.0	1.9
4	24	M	19.4	0.7	0.8	3.9
5	19	F	19.1	0.8	0.9	7.8
Mean	***23***	***-***	***22.5***	***0.8***	***0.9***	***4.0***
StDev	***1.9***	***-***	***4.8***	***0.1***	***0.1***	***2.7***
				t-test: 0.0253		

Table 5.2 HLA for 45-second Time Interval

Subject #	***Age***	***Sex***	***BMI***	***Time 1 HLA (Pixel)***	***Time 2 (1 Hour) HLA(Pixel)***	***% Change in HLA***
1	23	F	17.5	0.7	0.7	7.0
2	24	M	28.3	0.9	0.9	0.0
3	24	M	28.3	0.9	0.9	1.6
4	24	M	19.4	0.7	0.7	1.9
5	19	F	19.1	0.7	0.8	8.7
Mean	***23***	***-***	***22.5***	***0.8***	***0.8***	***3.9***
StDev	***1.9***	***-***	***4.8***	***0.1***	***0.1***	***3.4***
				t-test: 0.0379		

Table 5.3 HLA for 60-seconds Time Interval

Subject #	***Age***	***Sex***	***BMI***	***Time 1 HLA (Pixel)***	***Time 2 (1 Hour) HLA(Pixel)***	***% Change in HLA***
1	23	F	17.5	0.6	0.7	10.3
2	24	M	28.3	0.8	0.8	1.9
3	24	M	28.3	0.9	0.9	3.5
4	24	M	19.4	0.7	0.7	0.8
5	19	F	19.1	0.7	0.8	8.6
Mean	***23***	**-**	***22.5***	***0.7***	***0.8***	***5.0***
StDev	***1.9***	**-**	***4.8***	***0.1***	***0.1***	***3.8***
				t-test: 0.0663		

When considering the creep effect, the 45-second time interval proved to be the most reliable interval to use since the percent change in HLA is the lowest i.e. 3.9. 1-tailed, type 1 t-test was performed on the HLA at time 1 and at time 2 for all time intervals. The results for the t-test, for 30-second, 45-second, and 60-second time intervals were 0.0253, 0.0379, and 0.0663 respectively.

In addition to the HLA, the stiffness of the low back was calculated at maximum deflection at the right and the left pelvis. Table 5.3 shows the maximum stiffness of the right and left pelvis of the five normal subjects taken at the 45-second time interval after one hour.

Table 5.4 Maximum Stiffness for Right and Left Pelvis for Normal Subjects at 45-second Time Interval

Subject	***Maximum Time 1***	***Stifness (Nm/rad)***	***Maximum Time 2***	***Stifness (Nm/rad)***	***% of***	***Change Stiffness***
#	***Right Pelvis***	***Left Pelvis***	***Right Pelvis***	***Left Pelvis***	***Right Pelvis***	***Left Pelvis***
1	1411	1755	1463	1630	4	-7
2	1497	1371	1560	1507	4	10
3	1510	1377	1349	1447	-11	5
4	1980	1541	1895	1617	-4	5
5	1605	1854	1846	1334	15	-28
Mean	***1600***	***1580***	***1623***	***1507***	***2***	***-3***

As seen in the table above, the mean stiffness at the right pelvis is 1600 Nm/rad while it is 1580 Nm/rad for the left pelvis. The mean percent change of stiffness for the five normal subjects after one hour wait is 2 for the right pelvis and 3 for the left pelvis. The stiffness calculated at 5, 10, 15, and 20 lbs for both pelvises are given in Appendix B. It is observed that the stiffness increases as the load applied increases.

5.2 Effect of the Mechanical Massager Applied on the Low Back for Ten Minutes

The effect of the mechanical massager applied on the low back for ten minutes on patients with low back problems are summarized in table 5.5.

Table 5.5 Change of HLA for Patients Using the Mechanical Massager (45-second time interval)

Patient #	***Age***	***Sex***	***BMI***	***HLA Before (Pixel)***	***HLA After (Pixel)***	***% Change in HLA***
1	46	F	21.7	1.2	0.8	-29.3
2	53	F	22.0	0.5	0.6	22.6
3	23	M	26.4	0.4	0.3	-22.2
4	46	F	23.8	1.0	0.9	-12.4
5	55	F	24.9	1.2	1.0	-21.3
Mean	***45***	**-**	***23.8***	***0.9***	***0.7***	***-12.5***
StDev	***11***	**-**	***1.8***	***0.4***	***0.3***	***18.4***
				t-test: 0.0716		

The negative values of the percent change in HLA indicate that the HLA after treatment decreased; hence, there was improvement due to the treatment. Such improvement was three times or more than the mean percent change that was found in the reproducibility test with no treatment on normal subjects. Patient #2 is the only patient that did not show any improvement after the mechanical massaging treatment.

The mean percent change in HLA for the five patients was found to be -12.5 which is considered an improvement. 1-tailed, type 1 t-test was performed on the HLA before and after the treatment for all patients. The result for the t-test is 0.0716.

Table 5.6 shows the mean stiffness for the right and the left pelvis to be 1886 Nm/rad, and 1775 Nm/rad respectively.

Table 5.6 Maximum Stiffness for Right and Left Pelvis of Patients Before and After Mechanical Massaging Treatment

Patient	***Maximum Before***	***Stiffness (Nm/rad)***	***Maximum After***	***Stiffness (Nm/rad)***	***% of***	***Change Stiffness***
#	***Right Pelvis***	***Left Pelvis***	***Right Pelvis***	***Left Pelvis***	***Right Pelvis***	***Left Pelvis***
1	955	1463	1068	1508	12	3
2	2031	1975	1595	1886	-21	-5
3	3908	2770	3433	3204	-12	16
4	1405	1728	1424	2175	1	26
5	1134	939	1178	881	4	-6
Mean	***1886***	***1775***	***1739***	***1931***	***-3***	***7***

It is observed that the stiffness for the patients is noticeably higher compared to that of the normal subjects that were presented in table 5.4.

5.3 Effect of Manual Massaging Applied on the Low back

The effect of manual massaging applied on the low back on the same patients with low back problems are summarized in table 5.7.

Table 5.7 Change of HLA for Patients Using Manual Massaging (45-second time interval)

Patient #	***Age***	***Sex***	***BMI***	***HLA Before (Pixel)***	***HLA After (Pixel)***	***% Change in HLA***
1	46	F	21.7	0.6	0.7	13.3
2	53	F	22.0	0.7	0.7	-1.9
3	23	M	26.4	0.5	0.3	-32.7
4	46	F	23.8	1.0	0.6	-41.5
5	55	F	24.9	-	-	-
Mean	***45***	***-***	***23.8***	***0.7***	***0.6***	***-15.7***
StDev	***11***	***-***	***1.8***	***0.2***	***0.1***	***22.3***
				t-test:	***0.1635***	

Improvement after the treatment was seen; such improvement was three times or more than the mean percent change that was found in the reproducibility test with no treatment on normal subjects. Patient #5 was not available to be evaluated using manual massaging treatment.

The mean percent change in HLA for the five patients was found to be -15.7, which is an improvement even higher than when using the mechanical massager. 1-tailed, type 1 t-test was performed on the HLA before and after the treatment for all patients. The result for the t-test is 0.1635; which implies that more patients are needed to reach a definite conclusion.

Table 5.8 Maximum Stiffness for Right and Left Pelvis of Patients Before and After Manual Massaging Treatment

Patient	***Maximum Before Stiffness (Nm/rad)***		***Maximum After Stiffness (Nm/rad)***		***% of Change Stiffness***	
#	***Right Pelvis***	***Left Pelvis***	***Right Pelvis***	***Left Pelvis***	***Right Pelvis***	***Left Pelvis***
1	1889	1579	1605	1367	-15	-13
2	1874	1828	1711	2035	-9	11
3	2230	3230	3277	3545	47	10
4	1661	1774	1860	2364	12	33
5	-	-	-	-	-	-
Mean	***1914***	***2103***	***2114***	***2328***	***9***	***10***

The mean maximum stiffness for the right pelvis is 1914 while it is 2103 for the left pelvis. The above table shows the mean percent change of stiffness for the four tested patients which came out to be 9 and 10 respectively.

CHAPTER 6

PREVENTIVE MEASURES

6.1 Angle of Inclination for Standing and Lifting a Load

As mentioned in previous chapters, there are many causes for low back dysfunction or any type of back pain. Low back pain does not result from just lifting a heavy weight; rather, it is the result of lifting any amount of weight, be it heavy or light, the wrong way. One always sees the box labels for the weights indicating the ‘wrong’ or the ‘correct’ way of lifting the weight, as seen in figure 6.1 a, and b. The question is why lifting the weight in figure 6.1a is wrong while it is correct in figure 6.1b?

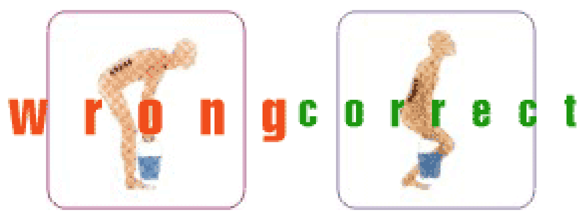

Figure 6.1 (a) Wrong Way of Lifting a Load. (b) Correct Way of Lifting a Load [36]

The following mathematical model shows the physical and mechanical differences between both cases presented in figure 6.2.

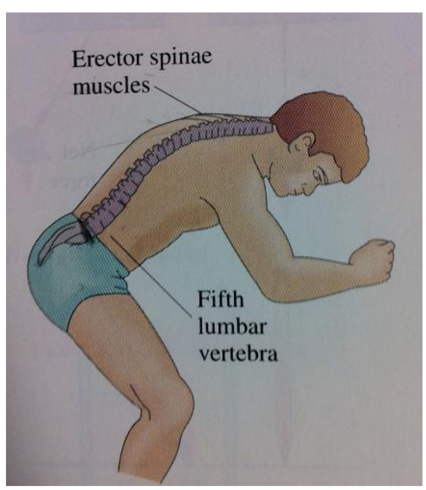

Figure 6.2 Person Standing at Angle of Inclination

Figure 6.3a, b and c show the detailed free body diagrams of three different cases that are analyzed.

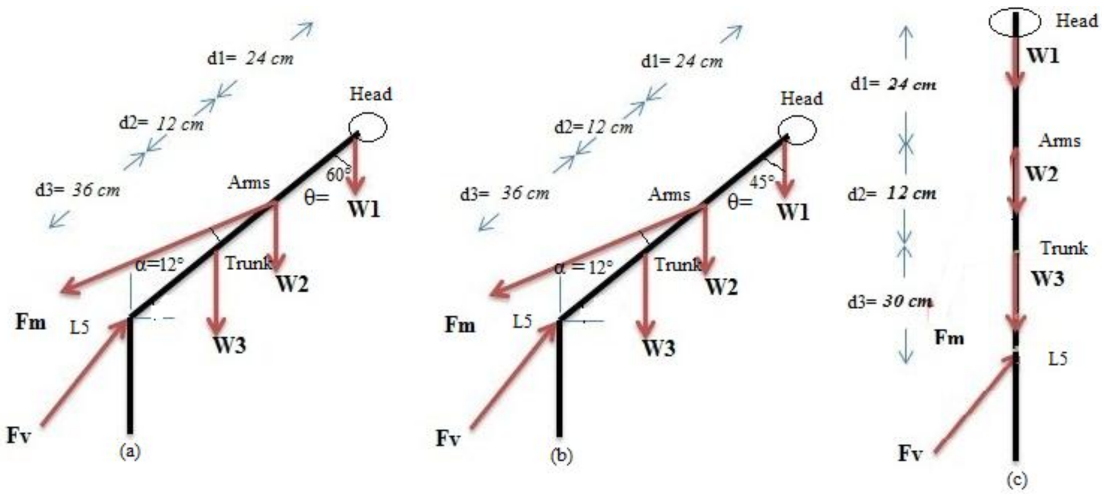

Figure 6.3 Detailed Free Body Diagrams for Three Different Case of Different Angle For Standing (a) θ =60°, (b) θ =45°, (c) θ =0°

Here, W_1, W_2, W_3 are the normalized weights of the head, arms, and trunk, respectively, with respect to the total weight (W) of the subject. d_1, d_2, and d_3 are the normalized distances. In this case these are taken to be, 24 cm, 12 cm, and 36 cm respectively [37]. The muscle force F_M due to Erector Spinae Muscles is acting at the shoulders (near the arms) making an angle α = 12° to the trunk. The reaction force F_V, is acting on L5. θ is the angle of bending of the person from the vertical.

Using the equations below, one can calculate the reactive force (F_V) at the fifth lumbar vertebra (L5). The muscle force F_M is calculated by taking the sum of the moments about L5. F_V is calculated by breaking down the F_V force into the F_{vx} and F_{vy} along x and y directions.

$$F_M = \frac{W_1(d_1+d_2+d_3)\times\sin\theta + W_2(d_2+d_3)\times\sin\theta + W_3(d_3)\times\sin\theta}{(d_2+d_3)\times\sin\alpha} \qquad (6.1)$$

$$F_{Vx} = F_{Mx} = F_M \times \sin(\theta + \alpha) \tag{6.2}$$

$$F_{Vy} = F_M \times \cos(\theta + \alpha) + W_1 + W_2 + W_3 \tag{6.3}$$

$$\mathrm{F}_V = \sqrt{\mathrm{F}_{Vx}{}^2 + \mathrm{F}_{Vy}{}^2} \tag{6.4}$$

Case #1: Angle θ =60° bending from the vertical (Figure 6.3a)

The first case to look at is when the person is leaning forward at an angle θ =60° as seen in figure 6.3a. Using equation 6.1, the muscle force F_M is found to be F_M=2.37W (in terms of the total body weight of the person). Using equations 6.2-6.4, F_V is calculated to be F_V =2.65W.

Case #2: Angle θ =45° bending from the vertical (Figure 6.3b)

In this case, figure 6.3b shows the inclination of the same person, at an angle θ =45° instead of 60° as it was in the first case. Similar to the first case, using the equations above the muscle force F_M in terms of the total body weight of the person, is calculated to be F_M=1.94W. Similarly, the magnitute of the F_V force is calculated to be F_V =2.36W, which is less than the F_V in case 1.

Case #3: No inclination (θ =0° angle from the vertical) (Figure 6.3c)

As seen in figure 6.3c, this is the case where it is assumed that the person is not leaning at all. In this case the muscle force F_M is calculated to be zero. This means that there are no forces exerted by the erector spinae muscles. F_V is calculated to be F_V=0.65.

These results are summarized in the table below.

Table 6.1 The Reactive Forces in Three Different Cases

Force	Case #1 60° Inclination	Case #2 45° Inclination	Case #3 0° Inclination
F_M	2.37W	1.94W	0
F_V	2.65W	2.36W	0.65W

As seen in Table 6.1, one can see that the more the bending (with respect to the vertical direction), the more the reactive force at L5.

A MATLAB code has been generated by which one can input any angle (with respect to the vertical), and the program will output the corresponding F_M and F_V in terms of body weight. Figure 6.4 shows how the F_M and F_V values increase dramatically with the increase of angle of inclination of the subject ranging from 0° to 75° from the vertical.

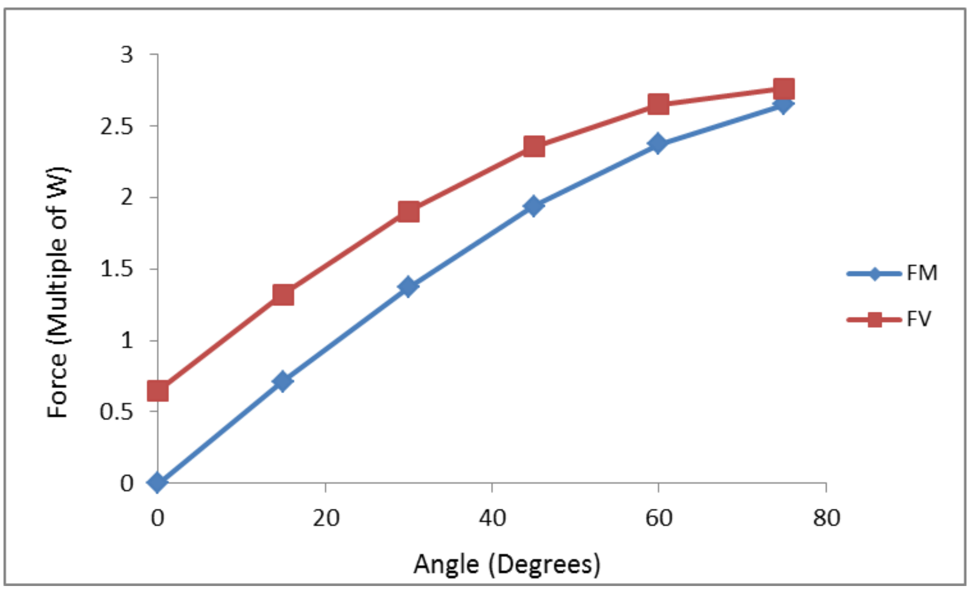

Figure 6.4 F_M and F_V at 0°-75° Inclination Angles for Standing

If the person has a mass of 90 kg, and is lifting 20kg load at 60° angle of inclination, then F_V is increased to nearly four times the person's weight (4W). For this 90 kg person, the force F_V on L5 would be 3223N, which is a strong force and is likely to cause low back pain at one time or another [37]. Therefore the weight should be lifted at an angle of 0° of inclination, with bending the knees instead of the back.

6.2 Cushion Support

It was mentioned earlier that bad posture is one of the main causes of low back dysfunction. There are many methods to prevent such bad posture habits that people have been using during the course of their lives. One of these techniques is using a cushion to support the back while sitting down to achieve good posture. Good posture helps relieve strain on the back. It distributes the forces that act upon one's spine over a greater area, thus dissipating the pressure on specific regions. Good posture also allows the muscles to relax in between moments of work. Smooth movement puts less stress on the muscles than awkward and sudden movements [4]. Mechanically, the position of the cushion support makes a great difference on how the back is relieved by reducing the reaction at L5. The following model shows the difference between three different positions of a cushion support and the effect of each position on L5.

In this model, the person is sitting down on a chair with cushion support placed at normalized distances of an individual, i.e. 36cm, 10cm, and 1 cm from L5 [37]. It is desired to calculate the reactive force F_V at L5 for all these distances separately.

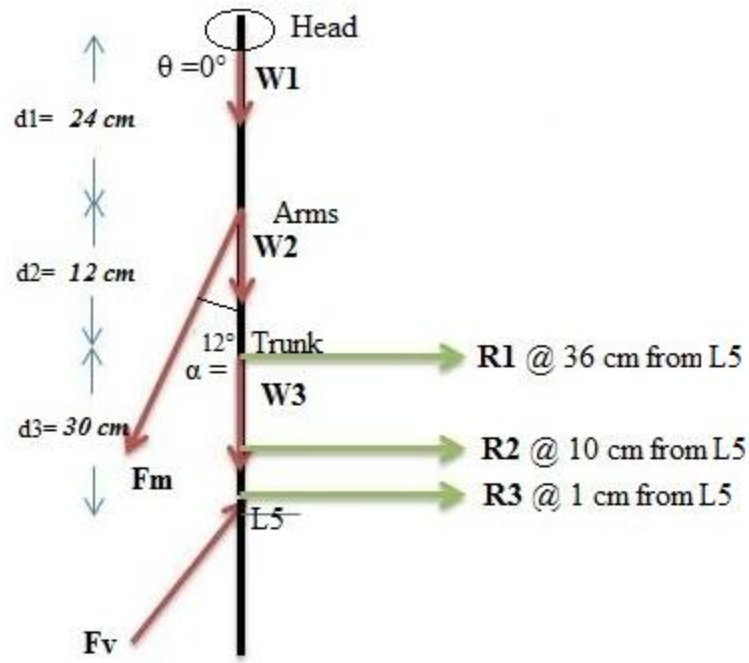

Figure 6.5 Free Body Diagrams for Three Different Cases of Different Positions of Cushion Support

In the above figure, W_1, W_2, W_3 are the normalized weights with respect to the total body weight (W). The muscle force F_M is a force at the arms at an angle α of 12° to the trunk [37].

Using the equations below, one can calculate the reactive forces at L5 F_V.

$$F_M = \frac{d_c \times R}{\sin \alpha \times (d_2 + d_3)} \tag{6.5}$$

$$F_{Vx} = (F_M \times \sin \alpha) - R \tag{6.6}$$

$$F_{Vy} = F_M \times \cos \alpha + W \tag{6.7}$$

$$F_V = \sqrt{{F_{Vx}}^2 + {F_{Vy}}^2} \tag{6.8}$$

Where R can vary as R_1, R_2, R_3.

Case #1: Support at the middle of the trunk (36 cm from L5)

The first case is when the cushion support is placed exactly at the middle of trunk which is at a distance of 36cm from L5. As seen in the free body diagram in figure 6.5, the cushion is producing a reaction force R_1, that is assumed to be $R_1 = k_1 W$, where k_1 is a variable and W is the total weight of the person. Using a pressure mat, in this case, k_1 was measured to be equal to 0.1. Using the above equations, F_M and F_V are calculated to be $F_M = 0.361W$, and $F_V = 1.003W$.

Case #2: Support at 10 cm from L5

This case is when the cushion is placed exactly at 10cm above from L5. The support at this position is producing a force R_2 that is assumed to be $R_2 = k_2 W$. k_2 was calculated in this case, using the pressure mat, and is equal to 0.13. Using the above procedure, F_M and F_V are calculated to be $F_M = 0.1303W$ and $F_V = 0.7842W$.

Case#3: The support is at 1 cm from L5

This is the case when the cushion support is placed at a 1 cm distance from L5. The support at this position is producing a reaction force R_3 that is assumed to be $R_3 = k_3 W$. In this case, k_3 equals 0.14. F_M and F_V are calculated to be $F_M = 0.014W$ and $F_V = 0.6777W$. The above results are summarized in table 6.2.

Table 6.2 Three Different Cases For Cushion Support

	Case #1	Case #2	Case #3
	36 cm from L5	10 cm from L5	1 cm from L5
Force	*k=0.10*	*k=0.13*	*k=0.14*
F_M	0.3607W	0.1303W	0.014W
F_V	1.0032W	0.7842W	0.6777W

As seen in table 6.2, the closer the cushion support is to L5, the lower the reactive force is at L5. From table 6.2, one can conclude that the best position for the cushion support to have the least reactive force on the low back is to be as near L5 as possible.

A MATLAB code has been developed by which the forces F_M and F_V can be calculated by varying the position of the cushion suppor. Figure 6.4 visually shows the reactive force on L5 for various positions of the cushion support from L5.

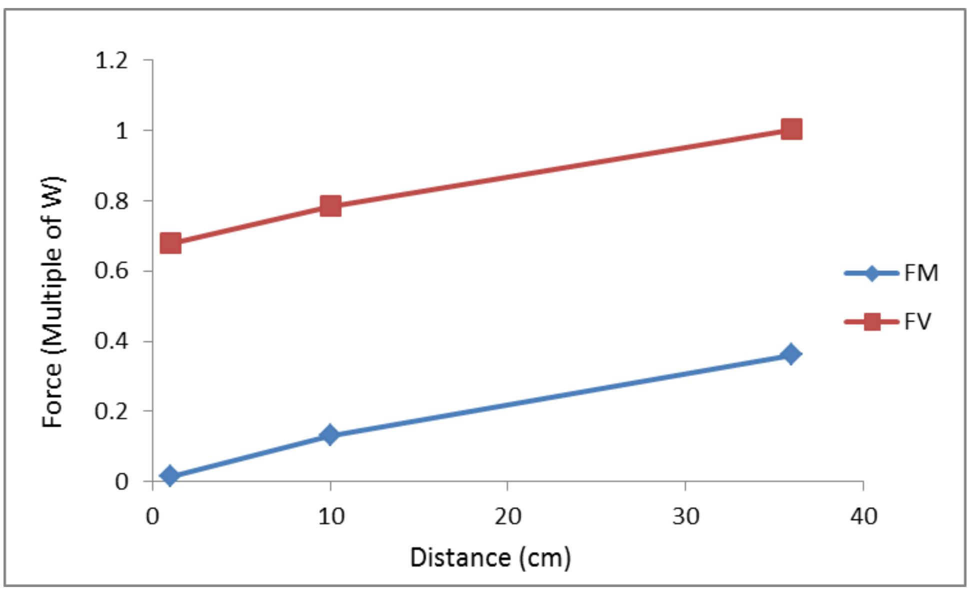

Figure 6.4 F_M and F_V at Different Distances from L5

CHAPTER 8

CONCLUSION

This study was done to quantitatively evaluate the low back condition. Using the A-ATM a low back dysfunction was identified and classified when measurements showed a variance from the normal.

The reproducibility tests showed that the mean percent change in HLA after one hour duration was 3.9 for 45-second time interval between two consecutive readings. The mean percent change in stiffness was found to be 3 for both the pelvises at maximum load.

Non-invasive treatment such as massaging, whether manual massaging or using a mechanical massager, showed an improvement in the percent change of HLA. Mechanical massager showed -12.5% change of HLA for patients after treatment, while manual massaging showed -15.7% change of HLA for the same patients. This implies that both treatments were equally effective, taking into consideration the allowance of the reproducibility results.

A mathematical model was developed to evaluate the reactive forces at L5 for various angles of inclination from the vertical. The best way to carry a load to minimize the reactive force at L5 is to use the bending of the knees while lifting a weight. It was also found that a cushion support at a distance of 1 cm from L5, while sitting on a chair, produces minumum reactive force at L5. This induces better posture, which helps prevent low back pain.

Such results are very useful since they show that treating and preventing low back problems can be solved via non-invasive procedures such as massaging. However, more subjects are needed to arrive at more accurate results.

CHAPTER 8

FUTURE WORK

As a preventive measure, a suitable device that would alarm the person to keep his/her back at a specific angle from the vertical, while sitting or standing, needs to be built. This device can be attached at a proper position on the back. This would prevent the person from having bad postural habits and can be used by children in schools at earlier stages to prevent bad postural habits.

It is advisable to use pressure mat to *accurately* locate the two PSIS positions before and after the treatment since it would give better, more accurate results when evaluating the HLA of the low back.

The effectiveness of using a cushion support under the knees while lying down can be determined by evaluating the HLA and the stiffness of the low back by using this strategy over time.

The effect of manual and mechanical massaging can be determined by evaluating the change in thickness of the lumbar fascia using the ultrasound techniques. It is documented that the thickness of the lumbar fascia increases by 25% for patients suffering from low back pain [38].

The A-ATM can be also used to evaluate the effects of prescribed pain killers. Such drugs do not just relief the pain but also might have a positive effect on the HLA and stiffness of the low back.

The protocol of bending instead of twisting may be used in finding the hysteresis loop area on the A-ATM.

In an attempt to make the A-ATM more accurate, sliding of the incremental weights may be designed instead of manually adding the incremental loads.

Finally, the study of low back dysfunction is a field with infinite possibilities. There is a different case for each individual, since the pain level and severance of the injury can be different from one patient to another. Finding a cure or a way to treat the low back requires ongoing research.

APPENDIX A

LOAD VS. DISPLACEMENT TABLES FOR 45-SECONDS TIME INTERVAL

APPENDIX A.1 Displacement for Normal Subjects

A.1.1 Subject 1

Name:	Subject 1	**Age:**	23
Weight:	50.35 kg	**Height:**	1.6968 m
Sex:	F	**BMI:**	17.47834704

Load (lb)	Time 1 Displacement (V)	Time 2 Displacement (1 Hour) (V)
Right 0	0	0
Pelvis 5	0.209237609	0.192055818
10	0.332063834	0.312113987
15	0.414919967	0.403249082
20	0.498013332	0.479695435
25	0.582772952	0.561975499
20	0.555292317	0.529535097
15	0.509592778	0.486216071
10	0.444393135	0.418632991
5	0.334734509	0.289747001
0	0.087171087	0.058256907
Left -5	-0.188904042	-0.196990009
Pelvis -10	-0.280530711	-0.299466368
-15	-0.350443312	-0.362601689
-20	-0.410676553	-0.429993023
-25	-0.468960069	-0.50483334
-20	-0.444250801	-0.476107179
-15	-0.401418881	-0.431383706
-10	-0.329783857	-0.381934075
-5	-0.239034046	-0.283563416
0	-0.012609855	-0.069251041

A.1.2 Subject 2

Name:	Subject 2	**Age:**	24
Weight:	87.09 kg	**Height:**	1.753 m
Sex:	M	**BMI:**	28.33905482

Load (lb)	Time 1 Displacement (V)	Time 2 Displacement (1 Hour) (V)
Right 0	0	0
Pelvis 5	0.202043685	0.163485648
10	0.333690983	0.298931474
15	0.421654971	0.400075766
20	0.488531023	0.470726953
25	0.549305905	0.52734362
20	0.52971343	0.507690776
15	0.4911712	0.471133994
10	0.422264087	0.418292405
5	0.310544087	0.303289134
0	0.108635127	0.112397459
Left -5	-0.190702332	-0.171339873
Pelvis -10	-0.351506518	-0.316092377
-15	-0.450600235	-0.409834548
-20	-0.534180445	-0.485147914
-25	-0.599476725	-0.545551292
-20	-0.575171134	-0.525682712
-15	-0.533581341	-0.485873839
-10	-0.463745918	-0.423781247
-5	-0.34549582	-0.300171525
0	-0.114715716	-0.064586783

A.1.3 Subject 3

Name:	Subject 3	**Age:**	24
Weight:	87.09 kg	**Height:**	1.753 m
Sex:	M	**BMI:**	28.33905482

Load (lb)	Time 1 Displacement (V)	Time 2 Displacement (1 Hour) (V)
Right 0	0	0
Pelvis 5	0.174634462	0.194897592
10	0.312843721	0.357518508
15	0.410469545	0.460437384
20	0.480278506	0.536355808
25	0.544641545	0.609082797
20	0.526015071	0.583313913
15	0.488713695	0.538081125
10	0.422593939	0.477650127
5	0.313833199	0.351922018
0	0.096195291	0.097372699
Left -5	-0.201725857	-0.177958218
Pelvis -10	-0.351367761	-0.321420717
-15	-0.45315279	-0.423283564
-20	-0.532141641	-0.500630078
-25	-0.596719023	-0.568224537
-20	-0.577309184	-0.547345315
-15	-0.534405136	-0.507540639
-10	-0.474305777	-0.445052968
-5	-0.356936414	-0.323030093
0	-0.118955772	-0.099038915

A.1.4 Subject 4

Name:	Subject 4	**Age:**	24
Weight:	61.23 kg	**Height:**	1.7779 m
Sex:	M	**BMI:**	19.36287

Load (lb)	Time 1 Displacement (V)	Time 2 Displacement (1 Hour) (V)
Right 0	0	0
Pelvis 5	0.142879206	0.151942983
10	0.24609312	0.256130873
15	0.312463709	0.329222883
20	0.365106691	0.385144586
25	0.415745903	0.434361529
20	0.397662623	0.414790234
15	0.368529903	0.386105832
10	0.328342416	0.334506293
5	0.245585981	0.243984735
0	0.089655758	0.084574131
Left -5	-0.196607664	-0.185376899
Pelvis -10	-0.314854176	-0.306832103
-15	-0.396600306	-0.384295569
-20	-0.468827199	-0.450567069
-25	-0.533606488	-0.508881369
-20	-0.510853887	-0.489651848
-15	-0.466842848	-0.453343545
-10	-0.403986522	-0.403479973
-5	-0.298916297	-0.311248306
0	-0.092625664	-0.110051904

A.1.5 Suject 5

Name:	Subject 5	**Age:**	19
Weight:	50 kg	**Height:**	1.62 m
Sex:	F	**BMI:**	19.11

Load (lb)	Time 1 Displacement (V)	Time 2 Displacement (1 Hour) (V)
Right 0	0	0
Pelvis 5	0.177856989	0.158004608
10	0.276169545	0.238590657
15	0.365899583	0.313883244
20	0.431285141	0.372537184
25	0.512670803	0.44585728
20	0.481253985	0.415148665
15	0.433782273	0.372177861
10	0.372844415	0.323621024
5	0.282668678	0.256087509
0	0.083353565	0.093314794
Left -5	-0.094328497	-0.236452134
Pelvis -10	-0.206281319	-0.309835186
-15	-0.279887642	-0.415986212
-20	-0.374424169	-0.507135651
-25	-0.444029712	-0.616250937
-20	-0.411039193	-0.562759331
-15	-0.351172298	-0.498738747
-10	-0.28263393	-0.429593193
-5	-0.213303153	-0.332325548
0	-0.041292668	-0.11716982

APPENDIX A.2 Displacement for Patients Using Mechanical Massaging Treatment

A.2.1 Patient 1

Weight:	52.16 kg	**Height:**	1.5493 m
Sex:	F	**BMI:**	21.72088
Type of Treatment:	Mechanical Massager		

Load (lb)	Displacement Before Treatment (V)	Displacement After Treatment (V)
Right 0	0	0
Pelvis 5	0.296036129	0.279879473
10	0.482413673	0.449159972
15	0.641336451	0.567081074
20	0.739296064	0.659897001
25	0.857887847	0.768140031
20	0.821173673	0.753153858
15	0.770408059	0.720849704
10	0.667233137	0.631182557
5	0.52328226	0.427424261
0	0.173750994	0.000689593
Left -5	-0.193075836	-0.201422503
Pelvis -10	-0.305409318	-0.298836161
-15	-0.434052481	-0.368539426
-20	-0.501883094	-0.448775978
-25	-0.562165079	-0.545174877
-20	-0.532242913	-0.491093083
-15	-0.481378469	-0.42069115
-10	-0.422039172	-0.357763654
-5	-0.328025586	-0.265722587
0	-0.109486831	-0.079553668

A.2.2 Patient 2

Name:	Patient 2	**Age:**	53
Weight:	65.77 kg	**Height:**	1.7273 m
Sex:	F	**BMI:**	22.03339
Type of Treatment:	Mechanical Massager		

Load (lb)	Displacement Before Treatment (V)	Displacement After Treatment (V)
Right 0	0	0
Pelvis 5	0.178771471	0.257970078
10	0.263887453	0.340306086
15	0.320812658	0.407082966
20	0.370476663	0.463457225
25	0.405327086	0.515831295
20	0.381596656	0.495067242
15	0.358511506	0.466161439
10	0.318001998	0.41683572
5	0.262685838	0.349294921
0	0.072294886	0.139068252
Left -5	-0.222293895	-0.239681567
Pelvis -10	-0.299826059	-0.315094186
-15	-0.339713537	-0.36670752
-20	-0.379247912	-0.403261212
-25	-0.416727377	-0.436420407
-20	-0.394191216	-0.420988566
-15	-0.369411793	-0.39517952
-10	-0.338197127	-0.36300471
-5	-0.291704309	-0.295647844
0	-0.117794695	-0.058555075

A.2.3 Patient 3

Name:	Patient 3	**Age:**	23
Weight:	87.54	**Height:**	1.829
Sex:	M	**BMI:**	26.43333
Type of Treatment:	Mechanical Massager		

Load (lb)	Displacement Before Treatment (V)	Displacement After Treatment (V)
Right 0	0	0
Pelvis 5	0.068907723	0.074141292
10	0.111208996	0.111018833
15	0.14435855	0.154408553
20	0.174032386	0.202714369
25	0.210886287	0.240014077
20	0.194702258	0.215607242
15	0.168761393	0.178190285
10	0.138015246	0.146560424
5	0.101184925	0.093696095
0	0.032829369	0.005817617
Left -5	-0.123849285	-0.098095201
Pelvis -10	-0.178013994	-0.138608469
-15	-0.218837451	-0.181375557
-20	-0.258950344	-0.221590644
-25	-0.297374225	-0.257188113
-20	-0.285386781	-0.238861978
-15	-0.258777456	-0.224541293
-10	-0.234966601	-0.189315549
-5	-0.190145011	-0.147413674
0	-0.069923392	-0.046588414

A.2.4 Patient 4

Name:	Patient 4	**Age:**	46
Weight:	58.97	**Height:**	1.5749 m
Sex:	F	**BMI:**	23.76218
Type of Treatment:	Mechanical Massager		

Load (lb)	Displacement Before Treatment (V)	Displacement After Treatment (V)
Right 0	0	0
Pelvis 5	0.248384006	0.247188785
10	0.360305844	0.342989596
15	0.440706921	0.411026648
20	0.499176011	0.500582189
25	0.585105922	0.577331981
20	0.562027028	0.553346203
15	0.525339883	0.512153721
10	0.483573567	0.457375238
5	0.414026326	0.39468636
0	0.229703239	0.173346034
Left -5	-0.207090787	-0.151786307
Pelvis -10	-0.308572554	-0.211437855
-15	-0.376472921	-0.266050108
-20	-0.426055704	-0.325995384
-25	-0.476207506	-0.378506696
-20	-0.456090554	-0.355310215
-15	-0.418649689	-0.32537394
-10	-0.382726554	-0.286233315
-5	-0.325457975	-0.245742244
0	-0.194981975	-0.107772033

A.2.5 Patient 5

Name:	Patient 5	**Age:**	55
Weight:	65.77 kg	**Height:**	1.6255 m
Sex:	F	**BMI:**	24.87967
Type of Treatment:	Mechanical Massager		

Load (lb)	Displacement Before Treatment (V)	Displacement After Treatment (V)
Right 0	0	0
Pelvis 5	0.16502	0.1640585
10	0.347059501	0.357705994
15	0.505020765	0.526829131
20	0.61139193	0.614192633
25	0.724123111	0.697266177
20	0.689861369	0.66023668
15	0.615416847	0.60463224
10	0.504937778	0.512050988
5	0.354076444	0.306710014
0	0.109696	0.062992236
Left -5	-0.245950153	-0.513912626
Pelvis -10	-0.44977026	-0.662039514
-15	-0.625171033	-0.770664396
-20	-0.762865293	-0.857061741
-25	-0.872591881	-0.929443683
-20	-0.827573779	-0.89827767
-15	-0.750080164	-0.838584357
-10	-0.622373953	-0.748479287
-5	-0.429370203	-0.613362355
0	-0.07181131	-0.374239392

APPENDIX A.3 Displacement for Patients Using Manual Massaging Treatment

A.3.1 Patient 1

Name:	Patient 1	**Age:**	46
Weight:	52.16 kg	**Height:**	1.5493 m
Sex:	F	**BMI:**	21.72088
Type of Treatment:	Manual Massaging		

Load (lb)	Displacement Before Treatment (V)	Displacement After Treatment (V)
Right 0	0	0
Pelvis 5	0.133255693	0.186759612
10	0.226063843	0.298384935
15	0.313413915	0.377855788
20	0.374238052	0.441224046
25	0.43565632	0.512507163
20	0.411133471	0.477100382
15	0.376620439	0.438861145
10	0.311745342	0.386146607
5	0.219969993	0.298079473
0	0.061223693	0.076492866
Left -5	-0.205488917	-0.237023592
Pelvis -10	-0.313821481	-0.356557062
-15	-0.40587737	-0.463828352
-20	-0.472066971	-0.537036934
-25	-0.52093228	-0.601328801
-20	-0.49850103	-0.570930245
-15	-0.46022793	-0.512811284
-10	-0.395486283	-0.447940618
-5	-0.281875551	-0.344497012
0	-0.098721374	-0.10111538

A.3.2 Patient 2

Name:	Patient 2	**Age:**	53
Weight:	65.77 kg	**Height:**	1.7273 m
Sex:	F	**BMI:**	22.03339
Type of Treatment	Manual Massaging		

Load (lb)	Displacement Before Treatment (V)	Displacement After Treatment (V)
Right 0	0	0
Pelvis 5	0.191809887	0.223566556
10	0.252852571	0.287856047
15	0.311935721	0.349840526
20	0.380332465	0.418366165
25	0.439248211	0.480785523
20	0.419630893	0.460198304
15	0.38149746	0.420999499
10	0.340738396	0.376084859
5	0.28147039	0.315873786
0	0.122760141	0.116280784
Left -5	-0.204615058	-0.158225929
Pelvis -10	-0.26347156	-0.223629722
-15	-0.309137105	-0.288422005
-20	-0.379720216	-0.338803171
-25	-0.450310952	-0.404640617
-20	-0.430102502	-0.378861515
-15	-0.394307827	-0.341309371
-10	-0.336490438	-0.289256014
-5	-0.249933574	-0.220382831
0	-0.02061584	-0.059737546

A.3.3 Patient 3

Name:	Patient 3	**Age:**	23
Weight:	87.54	**Height:**	1.829
Sex:	M	**BMI:**	26.43333
Type of Treatment:	Manual Massaging		

Load (lb)	Displacement Before Treatment (V)	Displacement After Treatment (V)
Right 0	0	0
Pelvis 5	0.155956548	0.095074728
10	0.212805991	0.135095441
15	0.26139216	0.17458201
20	0.312768392	0.213705938
25	0.369311157	0.25139708
20	0.348927907	0.226616575
15	0.316474575	0.20878839
10	0.282065674	0.181861454
5	0.23317546	0.135746295
0	0.095831102	0.032448787
Left -5	-0.072575011	-0.078447274
Pelvis -10	-0.124059362	-0.123954326
-15	-0.167556707	-0.159487524
-20	-0.208858434	-0.196876871
-25	-0.255082857	-0.232447247
-20	-0.22571686	-0.217083597
-15	-0.207106943	-0.194460509
-10	-0.17119068	-0.163456737
-5	-0.117725149	-0.127922116
0	-0.023498777	-0.043070979

A.3.4 Patient 4

Name:	Patient 4	**Age:**	46
Weight:	58.97	**Height:**	1.5749 m
Sex:	F	**BMI:**	23.76218
Type of Treatment;	Manual Massaging		

Load (lb)	Displacement Before Treatment (V)	Displacement After Treatment (V)
Right 0	0	0
Pelvis 5	0.167641227	0.182198741
10	0.263216217	0.263948068
15	0.352235005	0.340245826
20	0.427730116	0.406609684
25	0.495210951	0.442445684
20	0.477492511	0.411183018
15	0.441674136	0.377069952
10	0.403002135	0.330833618
5	0.327241924	0.260790361
0	0.154441308	0.110302573
Left -5	-0.168725539	-0.123923577
Pelvis -10	-0.25660102	-0.19381649
-15	-0.342146521	-0.250879503
-20	-0.403939378	-0.297682795
-25	-0.463894285	-0.348323426
-20	-0.439103573	-0.328056759
-15	-0.403878012	-0.300375588
-10	-0.354303664	-0.261744336
-5	-0.288919945	-0.208384995
0	-0.143401291	-0.087257204

APPENDIX B

LOAD VS. STIFFNESS TABLES FOR 45-SECONDS TIME INTERVAL

APPENDIX B.1 Stiffness for Normal Subjects

B.1.1 Subject 1

Name:	Subject 1	**Age:**	23
Weight:	50.35 kg	**Height:**	1.6968 m
Sex:	F	**BMI:**	17.47834704

Load (lb)	Time 1 Stiffness (Nm/rad)	Time 2 Stiffness (1 Hour) (Nm/rad)
Right 0	0	0
Pelvis 5	787.6908236	858.2078279
10	992.1298717	1055.655932
15	1190.413128	1224.961677
20	1321.57187	1372.238831
25	1410.643254	1463.132803
20	1184.666104	1242.57344
15	968.5640731	1015.324584
10	740.8216227	786.5500467
5	492.0999401	568.6360042
0	0	0
Left -5	872.535164	836.6984126
Pelvis -10	1174.685205	1100.309755
-15	1410.000115	1362.625103
-20	1603.663665	1531.419672
-25	1754.710849	1629.556687
-20	1482.119481	1382.619652
-15	1230.561471	1144.850847
-10	999.0013063	862.3340575
-5	689.4273208	581.0528803
0	0	0

B.1.2 Subject 2

Name:	Subject 2	**Age:**	24
Weight:	87.09 kg	**Height:**	1.753 m
Sex:	M	**BMI:**	28.33905482

Load (lb)	Time 1 Stiffness (Nm/rad)	Time 2 Stiffness (1 Hour) (Nm/rad)
Right 0	0	0
Pelvis 5	815.7568448	1008.268634
10	987.2833095	1102.281475
15	1171.345043	1234.7035
20	1347.326325	1398.48064
25	1497.051872	1559.70101
20	1242.153198	1296.2774
15	1005.041827	1047.951025
10	779.76698	787.1923104
5	530.5005348	543.2103194
0	0	0
Left -5	864.3024999	962.0289522
Pelvis -10	937.1511413	1042.348029
-15	1095.875297	1205.22559
-20	1231.718011	1356.758216
-25	1371.115724	1507.405588
-20	1143.512062	1251.721031
-15	924.8305715	1016.042503
-10	709.8042024	776.9672306
-5	476.7438182	548.8605722
0	0	0

B.1.3 Subject 3

Name:	Subject 3	**Age:**	24
Weight:	87.09 kg	**Height:**	1.753 m
Sex:	M	**BMI:**	28.33905482

Load (lb)	Time 1 Stiffness (Nm/rad)	Time 2 Stiffness (1 Hour) (Nm/rad)
Right 0	0	0
Pelvis 5	943.8709034	845.6868431
10	1053.18961	921.3600753
15	1203.355988	1072.383669
20	1370.56663	1226.699036
25	1509.935738	1349.363191
20	1250.926566	1127.462211
15	1010.115567	917.060393
10	779.1565672	689.0684135
5	524.9318607	468.0212266
0	0	0
Left -5	817.0429603	926.2332197
Pelvis -10	937.5219732	1025.040145
-15	1089.681838	1166.82516
-20	1236.459084	1314.636073
-25	1377.489423	1446.958472
-20	1139.254138	1201.952572
-15	923.398289	972.4968529
-10	693.9451078	739.7197402
-5	461.4328829	509.9623202
0	0	0

B.1.4 Subject 4

Name:	Subject 4	**Age:**	24
Weight:	61.23 kg	**Height:**	1.7779 m
Sex:	M	**BMI:**	19.36287

Load (lb)	Time 1 Stiffness (Nm/rad)	Time 2 Stiffness (1 Hour) (Nm/rad)
Right 0	0	0
Pelvis 5	1153.743328	1084.896045
10	1339.265409	1286.7268
15	1581.708781	1501.059834
20	1804.341316	1710.257155
25	1980.069261	1894.963735
20	1656.287451	1587.715329
15	1340.65835	1279.491744
10	1003.39474	984.8725749
5	671.0168708	675.4249997
0	0	0
Left -5	838.326577	889.1463469
Pelvis -10	1046.453852	1073.856885
-15	1245.551512	1285.533549
-20	1404.16795	1461.274975
-25	1541.311308	1616.539756
-20	1288.217184	1344.230223
-15	1057.618391	1089.221791
-10	815.1464548	816.1725551
-5	551.1687617	529.2983536
0	0	0

B.1.5 Subject 5

Name:	Subject 5	**Age:**	19
Weight:	50 kg	**Height:**	1.62 m
Sex:	F	**BMI:**	19.11

Load (lb)	Time 1 Stiffness (Nm/rad)	Time 2 Stiffness (1 Hour) (Nm/rad)
Right 0	0	0
Pelvis 5	926.7606662	1043.25956
10	1193.259015	1381.419444
15	1350.317141	1574.544096
20	1526.817712	1768.273493
25	1604.540264	1845.952475
20	1367.778078	1586.340676
15	1138.501191	1327.488417
10	883.4065501	1018.059088
5	582.8945089	643.4724588
0	0	0
Left -5	1747.736948	696.9624182
Pelvis -10	1597.974993	1063.432448
-15	1766.081427	1187.353306
-20	1759.341694	1297.702315
-25	1853.574785	1333.571765
-20	1602.244933	1168.867493
-15	1407.067275	989.7313872
-10	1165.932531	766.4246463
-5	772.6666702	495.6735703
0	0	0

APPENDIX B.2 Stiffnes for Patients Using Mechanical Massaging Treatment

B.2.1 Patient 1

Name:	Patient 1	**Age:**	46
Weight:	52.16 kg	**Height:**	1.5493 m
Sex:	F	**BMI:**	21.72088
Type of Treatment:	Mechanical Massager		

Load (lb)	Stiffness After Treatment (Nm/rad)	Stiffness After Treatment (Nm/rad)
Right 0	0	0
Pelvis 5	556.5389197	588.7110135
10	682.2387912	732.9339539
15	768.6474563	869.9349064
20	888.0805267	995.8406273
25	955.1579163	1068.035094
20	798.694194	871.5923256
15	638.9162379	683.2555276
10	492.4064962	520.7302367
5	314.3722309	385.1627495
0	0	0
Left -5	853.6711902	818.2742901
Pelvis -10	1078.867237	1102.633557
-15	1137.790269	1340.623631
-20	1311.340456	1467.126304
-25	1462.636839	1508.451436
-20	1236.222729	1340.269769
-15	1025.567275	1174.036424
-10	780.1837462	920.7274259
-5	502.1827961	620.114785
0	0	0

B.2.2 Patient 2

Name:	Patient 2	**Age:**	53
Weight:	65.77 kg	**Height:**	1.7273 m
Sex:	F	**BMI:**	22.03339
Type of Treatment:	Mechanical Massager		

Load (lb)	Stiffness After Treatment (Nm/rad)	Stiffness After Treatment (Nm/rad)
Right 0	0	0
Pelvis 5	922.0174932	638.7715983
10	1248.864307	968.056613
15	1540.479371	1213.394291
20	1778.130507	1420.495801
25	2031.108188	1594.66691
20	1726.196746	1329.468172
15	1378.204171	1059.169858
10	1036.078435	789.9510973
5	627.291756	471.5483675
0	0	0
Left -5	741.3922731	687.5630344
Pelvis -10	1098.98782	1045.65547
-15	1454.622515	1347.33559
-20	1736.91269	1633.232977
-25	1975.392639	1885.996358
-20	1670.91087	1564.272806
-15	1337.45072	1250.04111
-10	974.1046742	907.4060129
-5	564.8152695	557.2708864
0	0	0

B.2.3 Patient 3

Name:	Patient 3	**Age:**	23
Weight:	87.54	**Height:**	1.829
Sex:	M	**BMI:**	26.43333
Type of Treatment:	Mechanical Massager		

Load (lb)	Stiffness After Treatment (Nm/rad)	Stiffness After Treatment (Nm/rad)
Right 0	0	0
Pelvis 5	2392.576125	2223.672705
10	2964.809416	2969.88883
15	3425.748456	3202.698108
20	3788.551618	3252.224401
25	3907.641803	3433.048038
20	3386.143196	3057.613611
15	2930.203884	2775.078937
10	2388.834141	2249.509043
5	1629.290123	1759.535007
0	0	0
Left -5	1331.075496	1680.616628
Pelvis -10	1851.885718	2378.607117
-15	2259.33482	2726.318251
-20	2545.403505	2974.988338
-25	2770.15536	3203.579245
-20	2309.342365	2759.697692
-15	1910.329452	2201.897365
-10	1402.745677	1741.274936
-5	866.8372972	1118.242007
0	0	0

B.2.4 Patient 4

Name:	Patient 4	**Age:**	46
Weight:	58.97	**Height:**	1.5749 m
Sex:	F	**BMI:**	23.76218
Type of Treatment:	Mechanical Massager		

Load (lb)	Stiffness After Treatment (Nm/rad)	Stiffness After Treatment (Nm/rad)
Right 0	0	0
Pelvis 5	663.4504467	666.6616184
10	914.2174851	960.4682866
15	1120.556988	1201.720478
20	1318.481181	1314.762355
25	1404.987345	1424.011134
20	1170.398371	1188.853533
15	939.4061801	963.7003193
10	680.5961524	719.7253986
5	397.6632493	417.2023378
0	0	0
Left -5	795.8622765	1086.016312
Pelvis -10	1067.790651	1558.976289
-15	1312.309092	1858.05154
-20	1545.614545	2021.262853
-25	1727.909106	2175.402499
-20	1443.519174	1854.196675
-15	1179.777878	1518.847519
-10	860.5442413	1151.251704
-5	506.1515556	670.5897637
0	0	0

B.2.5 Patient 5

Name:	Patient 5	**Age:**	55
Weight:	65.77 kg	**Height:**	1.6255 m
Sex:	F	**BMI:**	24.87967
Type of Treatment:	Mechanical Massager		

Load (lb)	Stiffness After Treatment (Nm/rad)	Stiffness After Treatment (Nm/rad)
Right 0	0	0
Pelvis 5	998.8896732	1004.746471
10	949.1833005	920.8761514
15	977.3696407	936.7386583
20	1075.388689	1070.454882
25	1133.567497	1177.597929
20	952.2705047	995.3246325
15	801.2342474	815.6133643
10	651.6872945	642.5963304
5	465.1677162	537.1425004
0	0	0
Left -5	670.0223358	320.1292732
Pelvis -10	731.9361658	496.2974201
-15	788.6549576	638.7016534
-20	860.392894	764.8717624
-25	938.8662558	880.6958982
-20	792.4487757	729.3431421
-15	656.3978324	586.4446189
-10	528.147973	438.5431336
-5	383.4119409	267.9782105
0	0	0

APPENDIX B.3 Stiffness for Patients Using Manual Massaging Treatment

B.3.1 Patient 1

Name:	Patient 1	**Age:**	46
Weight:	52.16 kg	**Height:**	1.5493 m
Sex:	F	**BMI:**	21.72088
Type of Treatment:	Manual Massaging		

Load (lb)	Stiffness After Treatment (Nm/rad)	Stiffness After Treatment (Nm/rad)
Right 0	0	0
Pelvis 5	1237.091612	882.5596691
10	1458.036839	1104.303417
15	1576.90572	1307.495208
20	1760.218655	1492.319334
25	1889.314438	1605.054783
20	1601.876505	1379.730718
15	1311.793886	1125.284776
10	1056.906248	852.9042054
5	749.231086	552.7183566
0	0	0
Left -5	802.0706682	695.2805256
Pelvis -10	1049.902986	923.849671
-15	1217.008227	1064.516414
-20	1394.496499	1225.135888
-25	1578.983647	1366.867859
-20	1320.273696	1152.051893
-15	1072.87341	962.4592942
-10	832.712687	734.9356618
-5	584.5367617	478.1287403
0	0	0

B.3.2 Patient 2

Name:	Patient 2	**Age:**	53
Weight:	65.77 kg	**Height:**	1.7273 m
Sex:	F	**BMI:**	22.03339
Type of Treatment:	Manual Massaging		

Load (lb)	Stiffness After Treatment (Nm/rad)	Stiffness After Treatment (Nm/rad)
Right 0	0	0
Pelvis 5	859.3088489	737.1684603
10	1303.427291	1144.753053
15	1584.39027	1412.434452
20	1731.948082	1574.106256
25	1873.816757	1711.394797
20	1569.348472	1430.590289
15	1294.98499	1173.174049
10	966.8260744	875.7775498
5	585.3792593	521.535265
0	0	0
Left -5	805.4984612	1041.79969
Pelvis -10	1250.837891	1473.920143
-15	1598.756406	1713.755572
-20	1734.747208	1944.717924
-25	1827.636048	2034.563177
-20	1531.028685	1738.688306
-15	1252.811601	1447.808414
-10	979.0545564	1139.20507
-5	659.3329571	747.8264608
0	0	0

B.3.3 Patient 3

Name:	Patient 3	**Age:**	23
Weight:	87.54	**Height:**	1.829
Sex:	M	**BMI:**	26.43333
Type of Treatment:	Manual Massaging		

Load (lb)	Stiffness After Treatment (Nm/rad)	Stiffness After Treatment (Nm/rad)
Right 0	0	0
Pelvis 5	1056.965441	1734.017157
10	1548.946256	2440.479645
15	1891.199469	2832.463872
20	2106.887342	3084.837183
25	2229.693303	3277.453676
20	1888.181378	2908.955259
15	1561.63074	2368.160368
10	1168.284502	1812.68678
5	706.7652756	1214.387473
0	0	0
Left -5	2271.667255	2101.603745
Pelvis -10	2657.641888	2659.894476
-15	2951.280977	3100.666082
-20	3156.487471	3348.718148
-25	3230.047502	3544.906982
-20	2920.56014	3036.8034
-15	2387.400448	2542.76653
-10	1925.735526	2016.894092
-5	1400.335756	1288.685462
0	0	0

B.3.4 Patient 4

Name:	Patient 4	**Age:**	46
Weight:	58.97	**Height:**	1.5749 m
Sex:	F	**BMI:**	23.76218
Type of Treatment;	Manual Massaging		

Load (lb)	Stiffness After Treatment (Nm/rad)	Stiffness After Treatment (Nm/rad)
Right 0	0	0
Pelvis 5	983.2641144	904.6646582
10	1252.052687	1248.577183
15	1402.813543	1452.34258
20	1539.546045	1619.747288
25	1661.351023	1860.232213
20	1378.593433	1601.682949
15	1118.095307	1310.226447
10	817.1428576	995.8257641
5	503.3875058	631.8561504
0	0	0
Left -5	976.9422795	1330.277319
Pelvis -10	1284.366722	1700.813938
-15	1444.259235	1970.533312
-20	1630.483689	2213.823798
-25	1773.940972	2364.330793
-20	1499.54874	2008.539973
-15	1223.049066	1645.461451
-10	929.7375742	1259.101354
-5	570.2659948	790.9159816
0	0	0

APPENDIX C

MATLAB SOURCE CODES

C.1 CALCULATING THE STIFFNESS OF THE LOW BACK BEFORE AND AFTER TREATMENT

```
% A code that will Theoritically Calculate the Stifness of the back
% Written by Nadi Atalla(c) 2010

% Load the text file with the data loads vs. displacements
loads=Subject3(:,1);
data1=Subject3(:,2);
data2=Subject3(:,3);
Lever=82/100; % Length of Lever arm in meter

% loads converted to kg then to Newton
W1=loads.*0.45359237.*9.8;
% Finding the angle theta (before) by converting displacement from
volts to
% cm then to meter
theta1=asin((data1.*0.090644)./Lever);
% Finding the angle theta (after) by converting displacement from volts
to
% cm then to meter
theta2=asin((data2.*0.090644)./Lever);

% Calculate the Moment before
M1=W1.*Lever.*cos(theta1);
% Calculate the Moment after
M2=W1.*Lever.*cos(theta2);
% Calculate the stiffness before
k1=M1./theta1
% Calculate the stiffness after
k2=M2./theta2
```

C.2 CALCULATING F_M AND F_V FOR A GIVEN ANGLE OF INCLINATION

```
% This program is designed to calculate: The The muscle force FM which
% is a force at the arms at an alpha angle of 12 degrees to the trunk,
% and the reaction force FV, acting on the fifth lumbar vertebrae, when
% it is given an inclination angle of the body from the horizontal
% possibly when lifting a 20 kg load
% Assumptions:w1, w2, w3 are the weights of the head, arms, trunk
% respectively.
% The total weight of the person is w.
% The distance between the head and the arms is 24 cm.
% The distance between the arms and the trunk is 12 cm.
% The distance between the trunk and the fifth lumbar vertebrae is 36
% cm. Made by Nadi Atalla (c) 2010 with the help of Darnell
% 11/1/10
clc
clear all
D_HA=0.24; %Distance between the head and the arms in m (d1)
D_AT=0.12; %Distance between the arms and the trunk in m. (d2)
D_T5LV=0.36; %Distance between the trunk and the fifth lumbar vertebrae
in m.(d3)

w1=0.07; %w1=0.07w of total weight of body
w2=0.12; %w2=0.12w of total weight of body + a possible 20kg load (that
is
% 2/9 of total weight of body
w3=0.46; %w3=0.45w of total weight of body

alpha=12*pi/180;% The angle that the muscle force FM is making with the
trunk. [Constant]
a=input('Please Enter the Angle of Inclination of the Body From the
Vertical (In Degrees)');
theta=a*pi/180;

% To find Muscle force FM:
%FM*(D_AT+D_T5LV)*sin(alpha)-w1*(D_HA+D_AT+D_T5LV)*sin(theta)-
w2*(D_AT+D_T5LV)*sin(theta)-w3*(D_T5LV)*sin(theta)=0;
FM=((w1*(D_HA+D_AT+D_T5LV)*sin(theta))+(w2*(D_AT+D_T5LV)*sin(theta))+(w
3*(D_T5LV)*sin(theta)))/((D_AT+D_T5LV)*sin(alpha));

% beta=(theta-alpha); % theta - The angle that the muscle force FM is
making with the trunk

% To find Reaction force FV acting on fifth lumbar vertebrae:
FVx= FM*sin(alpha+theta);
FVy=FM*cos(alpha+theta)+w1+w2+w3+(20);
FV=sqrt((FVx^2)+(FVy^2));
 disp('The Muscle Force in terms of w is Fm= ')
disp(FM)
disp('The Reaction Force Acting on the 5th Lumbar Verterbae in terms of
w is Fv=')
disp(FV)
```

C.3 CALCULATING F_M AND F_V FOR A GIVEN CUSHION SUPPORT POSITION FROM L5

```
% The following model shows the difference between three different
% positions of a cushion support and the effect of each on the low back
%(the fifth lumbar vertebra).
% This program is designed to calculate: The muscle force FM which is a
% force near the shoulder at an angle of 12 degrees from the trunk, and
% the force acting on the fifth lumbar vertebrae FV.
% Assuming the person is sitting down with no inclination from the
% horizontal (0 degree angle).
% w1, w2, w3 are the weights of the head, arms, trunk respectively.
% Total weight of the person is w.
% The distance between the head and the arms is 24 cm.
% The distance between the arms and the trunk is 12 cm.
% The distance between the trunk and the fifth lumbar vertebrae is
% 36cm. Made by Nadi Atalla (c) 2010
% 11/1/10

clc
clear all
D_HA=0.24; %Distance between the head and the arms in m
D_AT=0.12; %Distance between the arms and the trunk in m.
D_T5LV=0.36; %Distance between the trunk and the fifth lumbar vertebrae
in m.

w1=0.07; %w1=0.07w of total weight of body
w2=0.12; %w2=0.12w of total weight of body
w3=0.46; %w3=0.45w of total weight of body
totalw=w1+w2+w3; %Total w1+w2+w3 of total of body

alpha=12*pi/180;% The angle that the muscle force FM is making with the
trunk. [Constant]
d=input('Please Enter the Distance of the Cushion Support from the
Fifth Lumbar Vertebrae (in meters)');
k=input('Please Enter the Value of Variable K');

% To find Muscle force FM:
FM=(k*d)/(sin(alpha)*(D_AT+D_T5LV));

% To find Reaction force FV acting on fifth lumbar vertebrae:
FVx=(FM*sin(alpha))-k;
FVy=(FM*cos(alpha))+totalw;
FV=sqrt((FVx^2)+(FVy^2));

disp('The Muscle Force in terms of w is Fm= ')
disp(FM)
disp('The Reaction Force Acting on the 5th Lumbar Verterbae in terms of
w is Fv=')
disp(FV)
```

APPENDIX D

MECHANICAL COMPONENTS AND SPECIFICATIONS OF HOMEDICS HHP-300 MECHANICAL MASSAGER

Distributed by
HoMEDICS®

Extendable Percussion Massager

WITH HEAT

Instruction Manual and Warranty Information

HHP-300
HHP-300W

El manual en español empieza a la página 9

2 year limited warranty

HoMEDICS

IMPORTANT SAFEGUARDS

WHEN USING ELECTRICAL PRODUCTS, ESPECIALLY WHEN CHILDREN ARE PRESENT, BASIC SAFETY PRECAUTIONS SHOULD ALWAYS BE FOLLOWED, INCLUDING THE FOLLOWING:

READ ALL INSTRUCTIONS BEFORE USING

DANGER—TO REDUCE THE RISK OF ELECTRIC SHOCK:

- Always unplug the appliance from the electrical outlet immediately after using and before cleaning.
- **DO NOT** reach for an appliance that has fallen into water. Unplug it immediately.
- **DO NOT** use while bathing or in shower.
- **DO NOT** place or store appliance where it can fall or be pulled into a tub or sink.
- **DO NOT** place in or drop into water or other liquid.

WARNING—TO REDUCE THE RISK OF BURNS, ELECTRIC SHOCK, FIRE OR INJURY TO PERSONS:

- An appliance should never be left unattended when plugged in. Unplug from outlet when not in use and before putting on or taking off parts or attachments.
- Close supervision is necessary when this appliance is used by, on or near children, invalids or disabled persons.
- Use this appliance only for its intended use as described in this manual. Do not use attachments not recommended by HoMedics; specifically any attachments not provided with the unit.

Caution:
All servicing of this massager must be performed by authorized HoMedics service personnel only.

- **NEVER** operate this appliance if it has a damaged cord or plug, if it is not working
properly, if it has been dropped or damaged, or dropped into water. Return it to
HoMedics Service Center for examination and repair.
- Keep cord away from heated surfaces.
- **NEVER** drop or insert any object into any opening.
- **NEVER** operate the appliance with the air openings blocked. Keep the air openings free of lint, hair, and the like.
- **NEVER** operate on a soft surface such as a couch or bed where the air openings may be blocked.
- Use heated surfaces carefully. May cause serious burns. Do not use over insensitive skin areas or in the presence of poor circulation. The unattended use of heat by children or incapacitated persons may be dangerous.
- **DO NOT** operate where aerosol (spray) products are being used or where oxygen is being administered.
- **DO NOT** operate under a blanket or pillow. Excessive heating can occur and cause fire, electrocution or injury to persons.
- **DO NOT** carry this appliance by the power cord or use cord as handle.
- To disconnect, turn all controls to the "off" position, then remove plug from outlet.
- **DO NOT** use outdoors.

SAVE THESE INSTRUCTIONS

Caution—Please read all instructions carefully before operating.

- This product is not intended for medical use. It is intended only to provide a luxurious massage.
- Consult your doctor prior to using this product, if
  - You are pregnant
  - You have a pacemaker
  - You have any concerns regarding your health
- Not recommended for use by Diabetics.

- Never leave the appliance unattended, especially if children are present.
- Never cover the appliance when it is in operation.
- Do not use this product for more than 15 minutes at a time.
- Extensive use could lead to the product's excessive heating and shorter life. Should this occur, discontinue use and allow the unit to cool before operating.
- Never use this product directly on swollen or inflamed areas or skin eruptions.
- DO NOT use this product as a substitute for medical attention.
- DO NOT use this product before bed. The massage has a stimulating effect and can delay sleep.
- NEVER use this product while in bed.
- This product should NEVER be used by any individual suffering from any physical ailment that would limit the user's capacity to operate the controls or who has sensory deficiencies in the lower half of their body.
- This unit should not be used by children or invalids without adult supervision.
- This product is not for use in automobiles.

Instructions for Use

- This appliance has a polarized plug (one blade is wider than the other). This plug will fit in a polarized outlet only one way. If the plug does not fit fully in the outlet, reverse the plug. If it still does not fit, contact a qualified electrician to install the proper outlet. Do not change the plug in any way.

1. Always make sure the unit is set to the "OFF" position before inserting the plug into a 120 volt electrical outlet.
2. To turn the unit on, simply slide the switch located along the top of the units handle up one notch. To increse the intensity of the massage, slide the switch up another notch. To turn the unit off, return the switch to its lowest position. (See page 7)
3. Turn massage on. To activate heat function, press the heat button located below

the slide switch. To cancel heat function, press the heat button a second time. **NOTE: To eliminate the risk of being burned, never use the heat function without the attachments.** Do not use the heat continuously for more than 15 minutes. Do not use the heat if you have sensitive skin, poor circulation, discolored areas, swelling, burned, inflamed or where skin eruptions or sores are present. Heat should be pleasant and comfortable. Should pain or discomfort result, discontinue use and consult your physician. To use heat attachments, locate red massage heads. Turn black massage heads counter-clockwise to remove. Place red nodes on massage and turn clockwise to secure.

4. Apply massager head lightly to the area you wish to massage.
5. Move the unit slowly, holding on the targeted area. Massage the area for a short period of time and move to another area. Never massage the same spot longer than 3 minutes. CAUTION - as stated in the "IMPORTANT SAFETY INSTRUCTIONS" section of this manual, never use this appliance on or near eyes

Caution:
All servicing of this unit must be performed by authorized HoMedics service personnel only.

or other highly sensitive areas.

6. **Handle Extension Instruction:** To utilize the 3" handle extension, slide the locking switch to the unlock position (Fig. 1). Gently extend the head of the unit to the desired position. Slide the locking switch to the lock position (Fig.1).
7. Operation of longer than 15 minutes is not recommended and may cause overheating.
8. When massage is completed, turn unit off, unplug the power supply, allow to cool and store properly in a dry place.

Maintenance

TO CLEAN:
Be sure to unplug the unit and allow it to cool before cleaning. Use a soft, slightly damp cloth to wipe. Never allow water or any liquids to come into contact with the handle.

TO STORE:
Unplug the appliance from the outlet, retract extendable portion and allow it to cool before storing in its box or a clean, dry place. Coil the cord and secure it with the supplied fastener. Do not hang the unit by the powercord.

Figure 1


3" Handle Extension
Locking Switch
Variable Speed Control
For gentle to invigorating
massage at the slide
of a switch.
Off/Massage Low/
Massage High
Heat Button
Dual Pivoting Heads
For an invigorating massage
Ergonomic
Rubberized Handle
For easy grip
and handling
2 Custom Attachment Sets
Included
For heat or hard (red
shown on product), or soft
massage applications

HoMEDiCS

Mail To:
HoMedics Service Center
Dept. 168, Suite 3
43155 West Nine Mile Road
Novi, MI 48375

Phone:
1-800-466-3342
8:30-5:00 p.m. (EST) M-F

Email:
cservice@homedics.com

LIMITED TWO YEAR WARRANTY

HoMedics sells its products with the intent that they are free of defects in manufacture and workmanship for a period of two years from the date of original purchase, except as noted below. HoMedics warrants that its products will be free of defects in material and workmanship under normal use and service. This warranty extends only to consumers and does not extend to Retailers.

To obtain warranty service on your HoMedics product, mail the product and your dated sales receipt (as proof of purchase), postpaid, to the following address:

HoMedics Service Center
Dept. 168, Suite 3
43155 West Nine Mile Road
Novi, MI 48375

No COD's will be accepted.

HoMedics does not authorize anyone, including, but not limited to, Retailers, the subsequent consumer purchaser of the product from a Retailer or remote purchasers, to obligate HoMedics in any way beyond the terms set forth herein. This warranty does not cover damage caused by misuse or abuse; accident; the attachment of any unauthorized accessory; alteration to the product; improper installation; unauthorized repairs or modifications; improper use of electrical/power supply; loss of power; dropped product; malfunction or damage of an operating part from failure to provide manufacturer's recommended maintenance; transportation damage; theft; neglect; vandalism; or environmental conditions; loss of use during the period the product is at a repair facility or otherwise awaiting parts or repair; or any other conditions whatsoever that are beyond the control of HoMedics.

This warranty is effective only if the product is purchased and operated in the country in which the product is purchased. A product that requires modifications or adoption to enable it to operate in any other country than the country for which it was designed, manufactured, approved and/or authorized, or repair of products damaged by these modifications is not covered under this warranty.

THE WARRANTY PROVIDED HEREIN SHALL BE THE SOLE AND EXCLUSIVE WARRANTY. THERE SHALL BE NO OTHER WARRANTIES EXPRESS OR IMPLIED INCLUDING ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS OR ANY OTHER OBLIGATION ON THE PART OF THE COMPANY WITH RESPECT TO PRODUCTS COVERED BY THIS WARRANTY. HOMEDICS SHALL HAVE NO LIABILITY FOR ANY INCIDENTAL, CONSEQUENTIAL OR SPECIAL DAMAGES. IN NO EVENT SHALL THIS WARRANTY REQUIRE MORE THAN THE REPAIR OR REPLACEMENT OF ANY PART OR PARTS WHICH ARE FOUND TO BE DEFECTIVE WITHIN THE EFFECTIVE PERIOD OF THE WARRANTY. NO REFUNDS WILL BE GIVEN. IF REPLACEMENT PARTS FOR DEFECTIVE MATERIALS ARE NOT AVAILABLE, HOMEDICS RESERVES THE RIGHT TO MAKE PRODUCT SUBSTITUTIONS IN LIEU OF REPAIR OR REPLACEMENT.

This warranty does not extend to the purchase of opened, used, repaired, repackaged and/or resealed products, including but not limited to sale of such products on Internet auction sites and/or sales of such products by surplus or bulk resellers. Any and all warranties or guarantees shall immediately cease and terminate as to any products or parts thereof which are repaired, replaced, altered, or modified, without the prior express and written consent of HoMedics.

This warranty provides you with specific legal rights. You may have additional rights which may vary from country to country. Because of individual country regulations, some of the above limitations and exclusions may not apply to you.

For more information regarding our product line in the USA, please visit: www.homedics.com

IB-HHP300B

APPENDIX E

NJIT IRB APPROVED CONSENT FORM

NEW JERSEY INSTITUTE OF TECHNOLOGY
323 MARTIN LUTHER KING BLVD.
NEWARK, NJ 07102
CONSENT TO PARTICIPATE IN A RESEARCH STUDY

TITLE OF STUDY: Mechanical Stiffness Modeling to Evaluate the Low Back

RESEARCH STUDY:
I,______________________________________, have been asked to participate in a research study under the direction of Drs. Chaudhry and Findley.

PURPOSE:
The purpose of this research study is to obtain movement data from the low back of a human subject. A medical instrument called the Anatomic Torsion Monitor (ATM) will be employed to gather this data. This device consists of an exam table with a lever arm attached to its side. While I am lying down, a pad at the end of the lever will slowly and gently press into my lower back. If I am being treated for low back pain, a mechanical massager will be used to relieve me of my low back pain. When I have finished this treatment I will return for a second evaluation of my low back dysfunction. The study will determine if the elasticity of my soft tissues and stiffness have improved by using the mechanical massager.

DURATION:
My participation in this study will last for about **30** minutes each visit.

PROCEDURES:
I have been told that, during the course of this study, the following will occur:
I will be asked to wear appropriate clothing during my participation.
I will lie down on an exam table fitted with a leverage device. A trained medical practitioner will perform motion testing of my lower back and hip regions under the following procedure:
A force will be applied to my back in the region of my pelvis, first on one side and then on the other. The force will not exceed 25 pounds, roughly the same force that a skilled medical practitioner such as an osteopathic
physician or a physical therapist might apply. The amount of movement of the pelvis will be measured by means of displacement sensor under the pads. The sensors will be isolated from any part of my body. The ATM evaluates the low back before and after the treatments.

Again, I will be asked to lie down supine on the table for the treatment of using the mechanical massager on my low back for about 10 minutes. I am told that the heat feature of the massager will not be used. I am also told that the treatment will last 10 minutes and that the first 30 seconds of the treatment is to get used to the massager. I am also told that if I feel uncomfortable after 30 seconds of the start of the massaging, or at any time during the 10 minutes, the treatment will be stopped immediately. I will be asked for the repeated test of evaluation of my low back after the massaging treatment.
I am told that the investigator is not a licensed therapist in the State of New Jersey to perform massage therapy. I am also told that this study is not used for therapeutic treatment; it is mainly for evaluation purpose only to determine the effect of the massager on low back dysfunction.

PARTICIPANTS:
I will be one of about **20** participants in this study.

EXCLUSIONS:
I will inform the researcher if any of the following apply to me:

- I am outside the age range of less than 18 and greater than 55.
- I am not between the height range of 5' 2" and 6' 4" and have low body mass index
- (LBMI - thin waist).
- I have had injuries such as head, neck, trunk trauma and/or fracture.
- I have a major illness that required hospitalization; I have connective tissue (CNT) diseases; and/or I have a condition that would interfere with my participating comfortably in this study.
- I have had peripheral neuropathy and/or any type of neurotic disorder.
- I have had surgery of the back, legs, belly, surgeries to the axial skeleton, and/or any major surgeries.
- I am pregnant at this time.
- I have any injury/skin abrasion at my low back.
- I am diabetic
- I use pacemaker or any other electrically sensitive device.

If any of the above applies, I will not be able to be in the study at this time.

RISKS/DISCOMFORTS:
I have been told that the study described above may involve the following risks and/or discomforts:
I might briefly feel mild pressure to the low back, but no pain will be felt. Should I feel pain or feel any discomfort at any time during the study I may withdraw.
There also may be risks and discomforts that are not yet known.
I fully recognize that there are risks that I may be exposed to by volunteering in this study which are inherent in participating in any study; I understand that I am not covered by NJIT's insurance policy for any injury or loss I might sustain in the course of participating in the study.

CONFIDENTIALITY:
I understand confidential is not the same as anonymous. Confidential means that my name will not be disclosed if there exists a documented linkage between my identity and my responses as recorded in the research records. Every effort will be made to maintain the confidentiality of my study records.
If the findings from the study are published, I will not be identified by name. My identity will remain confidential unless disclosure is required by law.

PAYMENT FOR PARTICIPATION:
I have been told that I will receive no compensation for my participation in this study.

RIGHT TO REFUSE OR WITHDRAW:
I understand that my participation is voluntary and I may refuse to participate, or may discontinue my participation at any time with no adverse consequence. I also understand that the investigator has the right to withdraw me from the study at any time.

INDIVIDUAL TO CONTACT:
If I have any questions about my treatment or research procedures, I understand that I should contact the principal investigators at:

Thomas W. Findley MD, PhD
Co-Director, Center for Healthcare Knowledge Management
VA Medical Center mailstop 129
385 Tremont Ave, East Orange NJ 07018-1095
973-676-1000 x 2713 (phone)
973-395-7114 (fax)
tfindley@njneuromed.org

Hans R Chaudhry, Biomedical Engineering Department
New Jersey Institute of Technology
323 Martin Luther King Boulevard
Newark, NJ 07102
973-642-7835
Chaudhry@adm.njit.edu

If I have any addition questions about my rights as a research subject, I may contact:

Dawn Hall Apgar, PhD, IRB Chair
New Jersey Institute of Technology
323 Martin Luther King Boulevard
Newark, NJ 07102
(973) 642-7616
dawn.apgar@njit.edu

SIGNATURE OF PARTICIPANT
I have read this entire form, or it has been read to me, and I understand it completely. All of my questions regarding this form or this study have been answered to my complete satisfaction. I agree to participate in this research study.
Subject Name:____
Signature:____
Date:________

SIGNATURE OF READER/TRANSLATOR IF THE PARTICIPANT DOES NOT READ ENGLISH WELL
The person who has signed above, ___________________________, does not read English well, I read English well and am fluent in (name of the language) ___________________________, a language the subject understands well. I have translated for the subject the entire content of this form. To the best of my knowledge, the participant understands the content of this form and has had an opportunity to ask questions regarding the consent form and the study, and these questions have been answered to the complete satisfaction of the participant (his/her parent/legal guardian).
Reader/Translator Name:____
Signature:____
Date:______________

NJIT
New Jersey's Science & Technology University

Approved by the NJIT IRB on 5/14/10.
Modifications may not be made to this consent form without NJIT IRB approval.

SIGNATURE OF INVESTIGATOR OR RESPONSIBLE INDIVIDUAL

To the best of my knowledge, the participant, ________________________, has understood the entire content of the above consent form, and comprehends the study. The participants and those of his/her parent/legal guardian have been accurately answered to his/her/their complete satisfaction.

Investigator's Name:________________ ____

Signature:____

Date:___________

NJIT New Jersey's Science & Technology University

Approved by the NJIT IRB on 5/14/10.
Modifications may not be made to this consent form without NJIT IRB approval.

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