AN INVESTIGATION INTO THE IMMEDIATE EFFECT OF RIB MOBILIZATION AND SHAM LASER APPLICATION ON CHEST WALL EXPANSION AND LUNG FUNCTION IN HEALTHY ASYMPTOMATIC MALES – A PILOT STUDY.

By

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Dissertation submitted in partial compliance with requirements for the Masters Degree in Technology: Chiropractic, in the Faculty of Health at the Durban Institute of Technology, South Africa.

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DEDICATION

I dedicate this work especially to Mawlana Shaykh Muhammad Nazim Adil al-Qubrusi an-Naqshbandi al-Haqqani of Cyprus, the knower of knowers, the master of saints, and the torchbearer of Islam in the “West”, my beloved shaykh who has accepted me as a disciple and guided me along the spiritual path within the most distinguished Naqshbandi Order. I am truly grateful to The Almighty for this exceptional blessing.

This work is further dedicated to my lifelong teacher and mentor Professor Yusuf da Costa who has always inspired me in the pursuit of truth and knowledge, my parents Mohammed Sa’aid and Gadija, whose unwavering and unselfish support and understanding made a major contribution to my academic achievements.

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ABSTRACT

Optimal ventilation of the lungs is essential to the function of the human body. Our lungs can be expanded and contracted by the elevation and depression of the ribs. This causes an increase and decrease of the anteroposterior diameter of the chest cavity and the lungs are then expanded by raising the rib cage.

There are several different dysfunctions which the ribs are subjected to. These dysfunctions consist of restrictions in either inhalation or exhalation and are associated with increased tone of the intercostals muscles between the ribs. Therefore, if the chest wall movement is restricted in any way, this will cause decrements in pulmonary function and exercise capacity. Furthermore, there is a significant increase in oxygen cost associated with external chest wall restriction, which is directly related to the level of chest wall restriction.

Mobilization of the ribs aims to restore mobility and function but no investigations into the immediate effect of rib mobilization on chest wall expansion and lung function have been conducted.

Therefore this study aimed to test whether chest wall expansion and therefore lung function can be influenced in ten minutes following a mechanical intervention. This study was in the form of a randomized controlled clinical trial consisting of a population of sixty asymptomatic male participants, randomly allocated into three groups of twenty each. Chest wall expansion and lung function measurements were taken on the participants in order to determine the effect of rib mobilization and sham laser on these two parameters. Group a received rib mobilization; Group b (control) received no intervention, while Group c received sham laser application to the rib cage. Groups a and c had their measurements taken before and after the intervention, while in Group b there was a ten minute interval (the approximate time taken to carry out rib mobilizations or sham laser application) between the taking of the first and second measurements.

The results indicate that rib mobilization is effective in increasing chest wall expansion and lung function as compared to a control and sham intervention group. The findings of this study also demonstrate that in the clinical setting, rib mobilizations could be used as part of a treatment protocol to improve the lung function and chest expansion of people suffering from illnesses such as chronic obstructive pulmonary disease e.g. asthma.

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CHAPTER ONE

1.1 INTRODUCTION TO THE STUDY:

Guyton and Hall (2000: 311-313) in their description of muscles that cause lung expansion and contraction, state that the lungs can be expanded and contracted by elevation and depression of the ribs, thus increasing and decreasing the anteroposterior diameter of the chest cavity. The lungs are expanded due to the rising of the rib cage. This expands the lungs because, in the natural resting position, the ribs slant downward, thus allowing the sternum to fall backward toward the spinal column.

Bourdillon et al. (1992) states that there are several different dysfunctions to which the ribs are subjected to. These dysfunctions consist of restrictions in either inhalation or exhalation and are commonly known as ‘respiratory rib dysfunctions’ which are associated with increased tone of the intercostal muscles above or below.

Gonzalez et al. (1999: 188-194) also makes mention of the fact that chest wall restriction, whether caused by disease or mechanical constraints, can cause decrements in pulmonary function and exercise capacity. In an earlier study by Caro et al. (1959) the effects of restricting chest cage expansion on pulmonary function in man was tested. The results of this study showed that restricting chest wall expansion in normal man reduced the total lung capacity and its subdivisions. Following the release of chest restriction, the mechanical changes in the lungs were reversed via a hysteresis-like pathway. Thus, any abnormality that affects the muscles of respiration or rib biomechanics will have an effect on the optimal functioning of the lungs and respiratory system as a whole.

Myburgh (1998), Pillay (2001) and Dimopoulos (2002) all conducted different studies on joint mobilization and its effects. Although these studies concentrated on the effects of spinal mobilization, they do imply physiological and biomechanical effects, which we assume to be similar when mobilizing the rib cage.

A study by Hightower et al. (1999) tested the effects of rib cage mobilization and respiratory muscle stretching on vital capacity and chest wall expansion in fourteen elderly adults aged 58 to 83. Although the results indicated that the experimental group showed an improvement in xiphoid and axillary chest wall expansion measurements following manual stretching and rib mobilization compared to a control group, they are weakened due to various flaws in terms of design and methodology.

This study improved on the various methodological flaws of the above study by virtue of the following: the population and sample size was much larger, the participants were randomly allocated into three equal but separate groups each with its own intervention (or control), the study was more homogeneous in terms of age and sex and only healthy males were considered.

Thus, the aim of this study was to determine the objective response to rib mobilization of participants in order to ascertain to what extent these rib mobilizations would immediately impact on chest wall expansion and lung function. Immediate is defined in many ways, with differences in these definitions being reflected in the type of study, measurement tools and form of intervention utilised within the respective study (Etminan et al. 2003, Hoiness et al 2003, Macintosh et al 2003,Van Tulder et al. 2003, Webbe 2003) Therefore for the purposes of this study the following definition will be utilised: for the purposes of this study the following definition will be utilised: immediate is defined as a period of 10 minutes or less.

CHAPTER TWO

REVIEW OF THE RELATED LITERATURE

2.1 INTRODUCTION:

This chapter gives a review of the available information on the thoracic cage in terms of anatomy, biomechanics, mobilization, respiration, ventilation and mechanoreceptors.

2.2 RELEVANT ANATOMY AND BIOMECHANICS:

The thoracic cage is formed by part of the vertebral column (twelve thoracic vertebrae and their intervertebral discs), twelve pairs of ribs and costal cartilages, and the sternum. The ribs and costal cartilages form the largest part of the thoracic cage (Moore 1992: 33-34). Thus, stability of the thoracic spine is substantially enhanced by the rib cage and its articulations (Edmonston and Singer 1997).

Ribs are narrow, curved flat bones that form most of the chest wall. Ribs with their costal cartilages are separated by intercostal spaces that are occupied by intercostal muscles, vessels and nerves (Moore and Agur 1996: 32-33). Intercostal spaces contain three layers of intercostal muscles. The superficial layer is the external intercostal muscle, the middle layer is the internal intercostal muscle and the deepest layer is the innermost intercostal muscle. The external and innermost intercostals act to elevate the rib cage while the internal intercostals depress the ribs. These three muscles are assisted in varying degrees by the transversus thoracis, subcostal, levator costarum, serratus posterior superior and serratus posterior inferior muscles to either elevate or depress the ribs (Moore and Agur 1996: 41-42).

Moore and Agur (1996: 41-42) also stated that the role of individual intercostal muscles and accessory muscles of respiration in moving the ribs is difficult to evaluate. However, they do not elaborate on the reasons for this. Hence, it is difficult to isolate the specific intercostal muscle that is responsible for the rib cage movement.

Each rib possesses its own range and direction of movement. During inspiration, the upper ribs thrust upward like the movement of a ‘bucket handle’, increasing the anteroposterior diameter of the chest, while the lower ribs open like ‘callipers’ which increase the lateral diameter of the chest (Gatterman 1990: 182-186). This increase in rib cage size is due to the action of the diaphragm and intercostal muscles. The vertical diameter of the rib cage is increased during inspiration as the diaphragm contracts. On the other hand the transverse and anteroposterior diameters of the rib cage are increased as a result of contraction of the intercostal muscles. During expiration these muscles relax and the elastic recoil of the lungs causes much of the previously inspired air to be exhaled (Moore and Agur 1996: 41-42). These statements are shared by Guyton and Hall (2000: 311-315).

According to Gatterman (1990: 182-186) the mobility of the ribs varies considerably in that the first few ribs are more fixed than the others, due to the weight of the upper extremities and the strain of the ribs beneath. Mobility is increased down to the last two ribs which are freely moveable. This is supported by Moore and Agur (1996: 41-42) who state that the first seven ribs are joined to the sternum, the next three have their costal cartilages joined to the rib above them, while the eleventh and twelfth ribs are ‘floating’ or ‘free’ ribs as their costal cartilages end in the abdominal muscle wall.

Schultz, Benson and Hirsch (1974) studied the concept of rib stiffness, where differing loads were placed on the ribs in different directions i.e. in an anterior, posterior, medial, lateral, superior and inferior direction. It was found that rib stiffness decreased from the second rib which had the highest degree of stiffness, down to the tenth rib which had the least stiffness. This was true for all directions tested.

Taking into account the fact that mobility and stiffness of the ribs vary considerably when we move from the upper to lower ribs, the researcher assumes that considerable movement of the rib cage occurs at the lower levels rather than at the level of the first few ribs.

2.3 MOBILIZATION:

The Canadian Orthopractic Manual Therapy Association (2002) defines mobilization as a gentle, repetitive, passive movement of graded amplitude aimed at restoring mobility and function and reducing pain in a joint and surrounding tissue while Haldeman et al. (1993: 103-104) defined joint mobilization as a passive movement within the paraphysiological joint space administered by a clinician for the purposes of increasing overall range of motion. Maitland (2001: 3-4) is of the view that mobilization of a joint is a passive movement performed in such a manner (particularly in relation to speed of movement) that it is, at all times within the ability of the patient to prevent the movement if he or she chooses. Flynn (1996:173-174) with reference to the spine indicates that mobilization be used for restoring passive accessory motion, reducing pain and increasing segmental and total spinal range of motion.

Gatterman (1990: 50-51) describes three physical events that occur during spinal joint manipulation that differentiates it from joint mobilization: (1) as the elastic barrier of the joint is passed, the articular surfaces separate suddenly (2) a cracking noise is heard and (3) a radiolucent space appears within the joint (as seen on a radiograph).

Studies investigating the effect of mobilization include one by Cassidy et al. (1992) who conducted a randomised, controlled clinical trial in order to compare the immediate results of spinal manipulation versus mobilization on pain and range of motion in the cervical spine. Fifty two subjects formed the manipulation group while forty eight subjects were allocated to the mobilization group. Cervical spine range of motion was measured objectively using an analogue goniometer. Objective and subjective measurements were taken prior to and immediately after the treatments. The authors concluded that both treatments increased cervical spinal range of motion to a similar degree (p values not stated).

Myburgh (1998) conducted a randomised clinical trial to evaluate the relative effectiveness of spinal manipulation versus passive mobilization in the treatment of mechanical lower back pain. A sample population of thirty subjects were divided into two groups of fifteen each. Each group received the appropriate spinal manipulation or mobilization. The author concluded that both treatment groups responded equally well to the respective treatment protocols given, but due to the low power of the study, the chance of a Type II error was high, indicating that even if significant changes were present, they would not have been detected due to the small sample size.

Pillay (2001) conducted a randomised, controlled clinical trial to investigate the effectiveness of spinal manipulation compared to passive oscillatory mobilization in the management of chronic mechanical thoracic spine pain. The study consisted of sixty patients who were randomly allocated into two groups of thirty each, one group receiving spinal manipulation while the other group received Maitland's passive oscillatory mobilization. Both groups of patients received five treatments over a two-week period. The author concluded that both spinal manipulation (p value not stated) and passive oscillatory mobilization (p value not stated) are effective interventions in the treatment of chronic mechanical thoracic spine pain.

In a study similar to that of Pillay (2001), Dimopoulos (2002) randomly divided forty patients with chronic thoracic spine pain into two groups of twenty each. The results of the study indicated that both spinal manipulation (p value not stated) and passive oscillatory mobilization (p value not stated) are effective manual interventions for the reduction of quality of patients' pain response, pain intensity and range of motion measurements. However, he added that further studies were needed to determine the more effective of the two treatments.

These studies highlight the possible beneficial and mechanical effects of spinal joint mobilization. However, in spite of an exhaustive literature survey of journals, books and data bases e.g. Medline by the researcher, no studies (except for the study by Hightower et al. [1999] which we discuss later) on rib mobilization could be found. The theoretical basis for using rib cage mobilization is explained later in this chapter. Although these studies have nothing to do with the rib, they do highlight physiological and biomechanical effects which we assume to be similar when mobilizing the rib cage.

2.4 RESPIRATION AND VENTILATION:

Respiration in man may be defined as the process concerned with gaseous exchange between man and the environment, starting with the inhalation of oxygen and ending with the exhalation of carbon dioxide (Moxham and Costello 1994: 444-445). The respiratory system, which ensures the functioning of the above process, is comprised of the lungs, the central nervous system, the chest wall and the pulmonary circulation. Respiration is unique, in that, of all the vital functions, it alone is regulated not only by autonomic centres located in the brainstem but also by voluntary signals initiated in the cortex (American Thoracic Society 1999).

The term ventilation refers to the mechanical process of moving air into and out of the lungs (McArdle et al. 2000: 218-219), a process which is achieved by the diaphragm in association with the respiratory muscles which act as a pump on the chest wall, and is under the control of the central nervous system (Weinberger and Drazen 1994: 1152-1153).

The respiratory centre in the medulla oblongata, consisting of dorsal and ventral groups of neurons, controls spontaneous respiration. Efferent fibres from the respiratory centre pass in the ventral and lateral parts of the spinal cord to the motor neurons that control the respiratory muscles, while the vagus nerve supplies the accessory muscles involved in respiration.

Descending pathways to the inspiratory muscles inhibit the expiratory muscles via inhibitory interneurons in the brain stem thereby preventing the muscles from contracting and conflicting with the inspiratory muscles. The converse occurs when the expiratory muscles become active. Also, an indication that higher centres of the brain have an influence on the medullary centres controlling respiration can be demonstrated through the fact that emotional factors as well as pain have an influence on inspiration (Rang and Dale 1991: 399-400).

McArdle et al. (2000: 218-220) are of the opinion that any change in the volume of the thoracic cavity causes a corresponding change in lung volume. Thus, the lungs depend on accessory means for altering their volume because they contain no muscles and this volume is altered during inspiration and expiration by the action of voluntary muscles. According to Solomon, Schmidt and Andragna (1990: 832-842), each lung is surrounded and enclosed by pleurae, the inner layer called the visceral pleura which covers the surface of the lung, and the parietal pleura which is attached to the chest wall. This view is shared by Moore and Agur (1996: 45-52) who state that the parietal pleura is adherent to the chest wall, mediastinum and diaphragm.

Davies, Blakeley and Kidd (2001: 651-653) are of the opinion that the respiratory muscles, the chest wall and the diaphragm operate on the lungs to cause inspiration as well as expiration. They also credit the respiratory muscles with acting to inflate and deflate the lungs through the generation of a pressure difference, which causes movement of air through the airways. Thus, movement of the respiratory muscles and chest wall, as a whole, result in a corresponding movement within the lungs.

Edmunds (2003) cites Gatterman (1990: 179-180) and Solomon et al. (1990: 839-841) who state that the respiratory muscles may be broken down into two groups according to the role they play in respiration, namely inspiratory and expiratory muscles, with further division into primary and accessory muscles. The primary muscles of inspiration include the diaphragm and external intercostal muscles. The accessory muscles include the sternocleidomastoid, scalenius anterior, scalenius medius, scalenius posterior, serratus anterior, serratus posterior, latissimus dorsi, pectoralis major, pectoralis minor and the superior fibres of the iliocostalis muscles. The primary muscles of expiration include the internal intercostal muscles and the diaphragm, while the accessory muscles include the external abdominal oblique, internal abdominal oblique, transverse abdominal, latissimus dorsi, serratus posterior inferior and the quadratus lumborum muscles. Powers (1997: 181-183) is of the opinion that during quiet normal breathing, the diaphragm performs most of the work of inspiration, but during exercise, accessory muscles are called into play.

Expiration, the process of air movement out of the lungs, is predominantly a passive process during rest and light exercise. During ventilation in heavy exercise, the internal intercostal and abdominal muscles act powerfully on the ribs and abdominal cavity to facilitate the reduction of thoracic dimensions. This suggests that the muscles of the ribs are capable of more rapid action than the diaphragm and the abdominal muscles (McArdle et al. 2000: 218-222)

2.5 MECHANORECEPTORS:

Muscle spindles are responsible for the observation that rapid stretching of skeletal muscles results in a reflex contraction. The function of the muscle spindle is to assist in the regulation of movement and to maintain posture. This is accomplished by the muscle spindle’s ability to respond to changes in length of skeletal muscle fibres. The Golgi tendon organs (GTOs) continuously monitor tension produced by muscle contraction (Powers et al. 1997: 145-147). This view is shared by Duron (1981: 473-540) who states that GTOs sense changes in the force of contraction exerted by the muscles of respiration and are involved in monitoring the force of muscle contraction during breathing at rest or with a respiratory load.

In their in vivo studies of cat intercostal muscles, Holt et al. (2002) showed that there are three populations of intercostal muscle mechanoreceptors:

primary muscle spindles, secondary muscle spindles and GTOs. It was found that both primary and secondary degree muscle spindles were evenly distributed within the intercostal muscle space, while the GTOs were localized along the rib borders. The researcher assumes that similar mechanoreceptors and their distribution may be found in the intercostal muscles of humans; however, it appears that there are no human studies that prove this.

According to Mitchell et al. (1981: 541-620) mechanoreceptors are sensors that respond to changes in length, tension and movement. The primary mechanoreceptors in the chest are the muscle spindle endings and tendon organs of the respiratory muscles and the joint proprioceptor. Muscle spindles are primarily influenced by changes in length and are responsible for reflex contraction of the skeletal muscles in response to stretching. Afferent information from these receptors in the chest wall is carried in the anterior columns of the spinal reticular pathway and terminates in the region of the respiratory centres in the medulla. Muscle receptor afferents play a role in the level and timing of respiratory activity (Duron 1981: 473-540).

The respiratory muscles, of which the intercostal muscles form an integral part, are innervated by a variety of sensory receptors including muscle spindles. Afferent activity from them is involved in spinal and supraspinal reflexes (Bolsher et al. 1998). According to Powers et al. (1997: 144-146), in order for the nervous system to properly control skeletal muscle movements, it must receive continuous sensory feedback from the contractile muscle. This sensory feedback includes (1) information concerning the tension developed by a muscle and (2) an account of muscle length (Powers et al. 1997: 144-146).

Younes (1995: 867-922) stated that feedback of afferent information from the lung and chest wall mechanoreceptors provides respiratory motor and pre-motor neurons with important information regarding the status of the ventilatory pump as well as changes in length and force of contraction of the respiratory muscles. These signals allow adjustments to be made in the level and pattern of brainstem respiratory motor activity to compensate for changes in respiratory muscle function.

Projections to the brain of afferent signals from mechanoreceptors in the joints, tendons and muscles of the chest all appear to play a role in shaping respiratory sensations (Gandevia and Macefield 1989). Specifically afferents from the intercostal muscles have been shown to project to the cerebral cortex and contribute to proprioception and kinaesthesia (Homma et al. 1988: 161-166). Joint proprioceptors sense the degree of chest wall movement and may also influence the level and timing of respiratory activity (Duron 1981: 473-540). These mechanoreceptors may also be important in the sensation of dyspnea (Manning and Schwartzstein 1995: 547-553).

The effects of movement on the chest wall and its components (the ribs, respiratory muscles and joints) by the application of rib mobilizations, may lead to a response by the mechanoreceptors (Duron 1981:473-540). These mechanoreceptors as stated previously, sense changes in length, tension, force of contraction, and degree of chest wall movement. As earlier stated by Duron (1981: 473-540), afferent information from these receptors are carried via reticular pathways to the respiratory centres in the medulla or they may be projected to the cerebral cortex where it may be perceived that ventilation is being compromised (Homma et al. 1988:161-166). Mechanoreceptors may respond by causing adjustments to chest wall movement or by bringing about a reflex contraction as alluded to by Powers et al. (1997: 145-147).

2.6 INVESTIGATIVE STUDIES:

As mentioned above, Hightower et al. (1999) tested the effects of respiratory muscle stretching and rib cage mobilization on vital capacity and chest wall expansion in fourteen elderly adults (aged fifty eight to eighty three). The programme was designed to counteract the effects of poor posture and chest wall restrictions through manual stretching, soft tissue mobilization to the rib cage, and home exercises. A secondary purpose was to examine the impact of home exercises alone versus therapeutic visits in addition to home exercises to improve thoracic expansion and vital capacity.

Seven participants, who received no treatment interventions, formed the control group. They were utilized to examine day-to-day variation in chest wall expansion and vital capacity measurements. Four participants formed a home exercise group, also receiving no treatment intervention from the researchers. The three experimental subjects received treatment which included manual stretching of the pectoralis, intercostal and quadratus lumborum musculature, as well as soft tissue rib cage mobilization. These three subjects were treated twice per week, while the other three days entailed them performing the home exercise programme.

The results indicated that the experimental group showed an improvement in xiphoid and axillary chest expansion measurements, which although clinically relevant were not statistically significant as the sample size was too small. Other shortcomings of the study included: the presence of too many variables, a) in terms of the variety of interventions employed; b) the number of muscles treated; c) combining an intervention with a home exercise programme in the experimental group, leaving one unsure as to which intervention caused the proposed effect; the age of the subjects, who although healthy must have had varying degrees of degeneration e.g. joint disease or according to Hightower et al. (1999) decreased chest wall elasticity due to increased collagen formation. There also appeared to be no objective assessment of patient adherence to the home exercise programme to observe how well patients could perform the exercises either via a patient diary or by patients coming in to the clinic to have their exercise performance rated.

A study by Cox et al. (2002) aimed to measure the effects, if any, of standard high-velocity, low-amplitude rib adjustments on vital lung capacity as measured by chest expansion during forced inspiration and on tissue oxygenation. The study consisted of sixty subjects, of which thirty made up the treatment group, while the other thirty formed the control group who received no intervention. Both groups first had their chest expansion measurements taken with a standard soft tape measure. Tissue oxygenation was measured using The Healthdyne Pulse Oximeter 950. The treatment group then received an adjustment to the involved rib, while the control group received no intervention. Chest expansion and tissue oxygenation was then again measured for both the control and treatment groups. It was concluded that the adjustment increased chest expansion ($p < .001$) and blood tissue oxygenation ($p < .001$), and therefore improves lung function as well. Although this study showed statistically significant increase in both outcome parameters due to rib adjustment, the authors still questioned the clinical significance of the increase in tissue oxygenation. However, in light of the above findings, it is reasonable to assume that with increased oxygen available to the tissues, the metabolic activity of the cells would improve.

A study by Caro et al. (1959) tested the effects of restricting chest cage expansion on pulmonary function in man. Twenty-five normal subjects ranging in age from nineteen to forty were studied. Their thoracic cages were strapped in full expiration. The vital capacity was measured using a spirometer. The results of this study showed that restricting chest wall expansion in normal man reduced the total lung capacity and its subdivisions. Following the release of chest restriction, the mechanical changes in the lungs were reversed via a hysteresis-like pathway.

Gonzalez et al. (1999) makes mention of the fact that chest wall restriction, whether it be caused by disease or mechanical constraints, can cause decrements in pulmonary function and exercise capacity. Thus, any abnormality e.g. hypertonicity affecting the muscles of respiration, especially the intercostal muscles, or rib biomechanics will have an effect on the optimal functioning of the lungs and the respiratory system as a whole. Gonzalez et al. (1999) also stated that there is a significant increase in oxygen cost associated with external chest wall restriction, which is directly related to the level of chest wall restriction.

Bourdillon et al. (1992: 221-223) state that there are several dysfunctions to which ribs are subjected. The dysfunctions consist of restrictions in either inhalation or exhalation and are commonly known as 'respiratory rib dysfunctions'. They are associated with increased tone of the intercostal muscles above and below the affected area.

Sibuya et al. (1994) found that vibration of inspiratory muscles located in the upper rib cage in phase with inspiration produces a sensation of chest expansion and reduces the intensity of dyspnea in patients with chronic lung disease, both at rest and during exercise. To a certain extent this is supported by Homma et al. (1984: 8-11) who earlier observed that vibration of the chest wall activated muscle spindles. The mechanism by which this occurs is unclear. The effect is proposed to be from direct influence of the afferents from the intercostal muscle spindles on higher brain centres, reflex respiratory output, or a decrease in the sense of effort. They also showed that the application of vibration to the intercostal muscles reduced dyspnea in normal control subjects made breathless with an inspiratory resistive load.

2.7 CONCLUSION:

It is brought to the reader's attention that the current body of literature on this topic is quite scant, especially with regard to investigative and clinical trials. The few studies that have been investigated show inherent flaws in design and methodology. Therefore it is hoped that the outcome of this study will contribute significantly to the current literature.

CHAPTER THREE

MATERIALS AND METHODS

3.1 INTRODUCTION:

This study was designed as a comparative clinical trial, involving three groups of 20 participants each. The objective was to compare three different approaches (i.e. rib mobilization, sham laser and a control group) to assess for inter- and intra- group improvement or change.

3.2 THE SUBJECTS:

The participants were made aware of the study by advertisements (Appendix I) that were placed around The Durban Institute of Technology and at various venues e.g. at sport clubs, religious organizations and gymnasiums, etc. Sixty participants were selected from those who responded. Only male participants were allowed into the study as Bellemare et al. (2003) state that the volume of an adult female's lungs is typically 10-12 % smaller than that of males who are of similar height. There was no bias given to race, religion or socio-economic standing. To the best of the researcher's knowledge, there have been no clinical studies in South Africa comparing normal lung volumes between White, Black, Coloured or Indian groups.

Preliminary questions such as:

a) How old are you?
b) Do you suffer from chest pain; bronchitis; asthma?
c) Are you a smoker?

were asked by the researcher via a telephonic or personal interview to establish if the prospective participant was eligible for inclusion in the study. If the patient was above the age of 45 or below the age of 18 or answered "yes" to questions b and/or c, or if the prospective participant was a female, such a subject was deemed ineligible to participate in this study

If the participant was deemed likely by the researcher to meet the criteria necessary for acceptance into the study, he then underwent a case history (Appendix A), physical examination (Appendix B) and a thoracic spine regional examination (Appendix C). This took place to assess for any conditions such as asthma, influenza, rib fractures, etc. that could have excluded the participant from the study.

Participants who were accepted into the study received a letter of information (Appendix D) regarding the nature of the study, and were asked to complete a letter of informed consent (Appendix E). The nature of the study was explained verbally to each participant who was told that they had a one-in-three chance of falling into any one of the three groups.

3.3 INCLUSION AND EXCLUSION CRITERIA OF THE PARTICIPANTS:

3.3.1 Inclusion Criteria:

- Participants had to be between the ages of 18 to 45 years. Participants older than 45 years were not included because Brandt (2002) found that little radiographic evidence of osteoarthritis existed in people below the age of 45 years. Any prospective participant under the age of 18 would have required parental consent to participate in this study and for the purpose of this study, an adult male was considered as one being over the age of 18.
- Only healthy male participants were considered, so as to keep the sample homogeneous and also the volume of a female’s lungs is typically 10-12% smaller than that of males who have similar height and age (Bellemare et al. 2003).
- Participants were only accepted into the study if they gave their informed consent in writing (Appendix E).

3.3.2 <u>Exclusion Criteria</u>:

- Participants were excluded if they were diagnosed with any respiratory disease of the upper or lower respiratory tracts e.g. emphysema, asthma, chronic bronchitis, etc. which could have altered the chest wall expansion or optimal lung functioning.
- Participants were excluded if they had a previous history of rib fractures, dislocations, sprains of costochondral, costosternal and interchondral joints.
- Participants were excluded if they were diagnosed with any cardiac disease e.g. a previous history of myocardial infarction, angina pectoris, etc.
- Smokers were excluded from the study.
- Females have increased and varied amounts of breast tissue that may affect measurements of chest wall expansion.
- Third to sixth year Chiropractic students and interns at the Durban Institute of Technology were excluded as they are not naïve to the effects of laser therapy or rib mobilization. The use of therapeutic laser and mobilization techniques are taught as part of their course curriculum from the third year of study.
- Participants who suffered from any of the following contra-indications to manipulation or mobilization (Giles and Singer 2000):
    - Primary and secondary neoplastic lesions of the spine and/or ribs
    - Obvious advanced spinal deformity e.g. kyphoscoliosis
    - Healing fracture or dislocation
    - Infection e.g. tuberculosis
    - Non-neoplastic bone diseases e.g. osteoporosis
    - Inflammation e.g. acute rheumatoid arthritis or ankylosing spondylitis
    - Primary and secondary neoplastic lesions of the soft tissue structures of the chest

- Gross segmental instability

These were primarily excluded on the basis of clinical history and examination findings.

3.4 <u>THE SAMPLE GROUP</u>:

A sample of sixty participants was randomly divided into three groups of twenty participants each according to a randomization process similar to the one done by Azizi (2001). Twenty labels representing the rib mobilization group (Group a - indicated by the word 'Orange'), twenty labels representing the control group (Group b - indicated by the word 'Red') and twenty labels representing the sham laser group (Group c – indicated by the word 'Yellow') were folded so that they were obscured and then put in an envelope. Each participant was asked to draw out a label or colour to determine which group they would be assigned to. Only the researcher was aware what each colour stood for.

3.5 <u>INTERVENTIONS</u>:

Once the participants were assigned to one of the three groups a, b or c they were managed as follows:

Participants in all three groups had their chest wall expansion and lung function measurements taken and recorded (see below for details). The researcher first demonstrated the proper spirometric technique to each participant. Thereafter each participant was allowed to practice with the instrument until the researcher was satisfied that the participant understood the instructions (Appendix F) and was capable of performing the proper spirometric technique. Group a received rib mobilizations, Group b received no treatment, while Group c received sham laser.

The participants in Group a were required to sit in a comfortable position with their torso exposed. They were then briefly educated on the mobilization technique and told what to expect in terms of sensation during the procedure e.g. the possibility of mild, transient discomfort during the mobilization. These participants then received rib mobilizations for ten minutes according to the technique described by Nook (1997). According to Maitland et al. (2001: 3-4) passive oscillatory mobilizations may be performed slowly (one in 2 seconds), smooth or staccato, with small or large amplitude, and applied in any part of the total range of movement. Maitland et al. (2001: 170-171) also grouped mobilization procedures into four different grades where Grade 1 is a small-amplitude movement near the starting position of the range of motion, Grade 2 is a large-amplitude movement that carries well into the range of motion and can occupy any part of this range that is free of any stiffness or muscle spasm, Grade 3 is also a large-amplitude movement; but one that does not move into stiffness or muscle spasm, and Grade 4 which is a small-amplitude movement stretching into stiffness or muscle spasm.

After discussion with various chiropractic clinicians, it was decided that rib mobilization of Grades 2 to 4 would be employed and that ten minutes would be an adequate time interval for rib mobilization. Immediately after the rib mobilizations i.e. within one minute, chest wall expansion and lung function measurements were re-taken and re-recorded.

The participants in Group b were required to sit in a comfortable position with their torso exposed for ten minutes, but they received no treatment intervention. They were given various magazines to read during this time. Once the ten minutes had elapsed, chest wall and lung function measurements were re-taken and re-recorded.

The participants in Group c were required to sit in a comfortable position with their torso exposed. The researcher demonstrated on the participant's hand the colour and nature of the laser beam i.e. it was red in colour and caused no alteration to his sense of touch and temperature. The laser unit was set to zero, and the time was set to ten minutes. During this 'intervention', the participant was told to look straight ahead so as to avoid any direct eye contact with the laser beam i.e. not to look at the laser beam, as this would adversely affect his eyesight. The researcher himself who wore protective eyewear during this intervention reinforced this. However, because the energy settings were set to zero, there was no laser beam emitted from the laser unit. At the end of ten minutes, the laser unit beeped to signal the end of the ‘intervention’. Immediately after the sham laser intervention i.e. within one minute, chest wall expansion and lung function measurements were re-taken and re-recorded.

Participants who received the rib mobilization and sham laser application may have tried to impress the researcher during the post-laser or post-mobilization chest wall expansion and lung function measurements – the Hawthorne effect (The Burton Report 2004). In order to minimize this effect, it was necessary for a control group (who received no intervention) to be included in this study. The reason the sham laser application was included was because the researcher wanted to investigate whether it was the “touch effect” of the rib mobilizations or whether participants’ perception that they were getting some “treatment” or intervention which could have influenced the outcome of the study.

3.6 MEASUREMENTS:

An objective assessment of changes in the participant during the intervention was required for this study. To this end, two instruments i.e., a soft tape measure and a spirometer were used.

3.6.1 Chest wall expansion measurements:

Chest wall expansion measurements were taken circumferentially at the level of the anterior flexure of the axilla, the xiphoid process and halfway between the xiphoid process and umbilicus utilising a soft tape measure in keeping with measurement protocols by Hightower et al. (1999). Corresponding posterior landmarks were found and marked off with a skin pencil. Thus, posteriorly the anterior flexure of the axilla corresponded to the fourth thoracic vertebra; the xiphoid process the eighth thoracic vertebra, while halfway between the xiphoid process and umbilicus corresponded to the twelfth thoracic vertebra (Korporaal 2003). This was done on all participants

3.6.2 <u>Spirometry</u>:

According to Pierce and Johns (2003), much can be learned about the mechanical properties of the lungs from measurements of forced expiration and inspiration. Among the indications for spirometry, The American Association for Respiratory Care (1996) includes the need to assess the change in lung function following the administration of a therapy as one of the indications for the use of spirometry. For this study, lung function was determined using The Micro Medical Pocket Spirometer 9000 Series to measure lung volumes, through the forced expiration of air out of the participant's lungs.

The standard indices used were the Forced Expiratory Volume in one second (FEV1), Forced Vital Capacity (FVC) and the ratio of FEV1/FVC as a percentage. Pierce and Johns (2003) describe these indices as follows: FEV1 is the volume expired in the first second of maximal expiration after a maximal inspiration, and is a useful measure of how quickly full lungs can be emptied. FVC is the maximum volume of air that can be exhaled or inspired during a forced manoeuvre. FEV1/FVC% is expressed as a percentage of the FVC and gives a clinically useful index of airflow limitation.

Three such readings were taken with at least two readings of FEV1 within 100mls or five percent of each other (Clement Clarke International, 2000). According to The College of Physicians and Surgeons of Alberta (2002), the patient has to be actively coached to obtain accurate results. This took place via verbal instructions and encouragement, which were the same for the all participants.

3.6.2.1 <u>Predicted Normal Values:</u>

Gender: For a given height and age, males have a larger FEV1 and FVC, but a slightly lower FEV1/FVC% than females.

Height: All indices other than FEV1/FVC% increase with standing height.

Age: FEV1 and FVC increase, while FEV1/FVC decreases until about 25 years in males. After this, all indices gradually fall.

To confirm the acceptability of lung function tests, the measurement and evaluation techniques include the question of controls. According to the American Thoracic Society (1999), using subjects as their own control gives better sensitivity than comparison with the normal population. It is for this reason each participant was used as his own control during statistical analysis.

3.6.2.2 <u>Advantages of Spirometry</u>:

Among the advantages of using a spirometer, Brewis (1991) listed the following:

- A considerable amount of information is readily available at once, such as FVC, FEV1, and others.
- The ease with which the adequacy of forced expiration may be checked. The FEV1 is more reproducible than the Peak Expiratory Flow Rate
- Most micro-spirometers today are lightweight, durable and easy to use.

3.7 STATISTICAL ANALYSIS:

The SPSS statistical package version 12.0.1 (as supplied by SPSS Inc. Marketing Department, 444 North Michigan Avenue Chicago, Illinois, 60611) was used to analyse the data. Variables were checked for departure from normality using the skewness statistic and standard error. As a rule, if the skewness statistic was more than twice the standard error, the variable was considered to be significantly skewed. Skewed data were described using medians and inter quartile ranges, and analysed non-parametrically using the Kruskal-Wallis tests. Normally distributed data were described using means and standard deviations, and were analysed parametrically using ANOVA and paired t-tests.

An alpha level of 0.05 was used to assess significance of statistical tests. Two-tailed tests were used in all cases.

3.7.1 Hypothesis Testing:

3.7.1.1 Intra-group Comparison:

The Null Hypothesis (H_o) stated that there was no significant difference within each group before and after the respective interventions.

The Alternative Hypothesis (H_1) stated that there was a significant difference within each group before and after the respective interventions.

α was set at 0.05 level of significance.

3.7.1.2 Inter-group Comparison:

The Null Hypothesis (H_o) stated that there was no significant difference between each group before and after the respective interventions.

The Alternative Hypothesis (H_1) stated that there was a significant difference between each group before and after the respective interventions.

α was set at 0.05 level of significance.

CHAPTER FOUR

RESULTS

4.1 INTRODUCTION:

This chapter represents the data collected during the study. It begins with a comparison of the demographic data between the three groups. The results attained from statistical analysis of the raw data are then reported in tabular form with relevant interpretations in narrative texts. Visual representation of age and height distribution is in the form of boxplots while mean value changes of the three groups are then represented in the form of colour-coded graphs.

SPSS version 12.0.1 (SPSS Inc. Chicago, Ill) was used to analyse the data. Variables were checked for departure from normality using the skewness statistic and standard error. As a rule, if the skewness statistic was more than twice the standard error, the variable was considered to be significantly skewed. Skewed data were described using medians and inter quartile ranges, and analysed non-parametrically using the Kruskal-Wallis tests. Normally distributed data were described using means and standard deviations, and were analysed parametrically using ANOVA and paired t-tests.

An alpha level of 0.05 was used to assess significance of statistical tests. Two-tailed tests were used in all cases. There were no missing data.

Key for abbreviations:

p – Probability

IQR - inter quartile range

m - metres

SD - standard deviation

SE - standard error

T1 - Time 1 (measurement values before intervention)

T2 - Time 2 (measurement values after intervention)

F - F statistic

4.2 DEMOGRAPHIC DATA:

Sixty males were included in the study and randomized into three groups: Group a which received the intervention, Group b which received no intervention and Group c which received a sham intervention. There were twenty subjects per group.

Age ranged from 18 to 40. Median age of all participants was 24.5 years (IQR 21 to 30.75 years). There was a borderline non significant difference in median age between the three groups (Kruskal-Wallis $p = 0.055$). Figure 1 shows the boxplots of age by group. It can be seen that the median age of Group a was slightly lower than those of the other groups; however there was overlap between the IQRs of the three groups.

Height ranged from 1.6m to 1.97m, with a mean of 1.75m and a SD of 0.08m. There was no significant difference between the mean heights of the three groups (ANOVA $p = 0.456$). Figure 2 shows the boxplots of height by group. The distribution of height was very similar in all three groups.

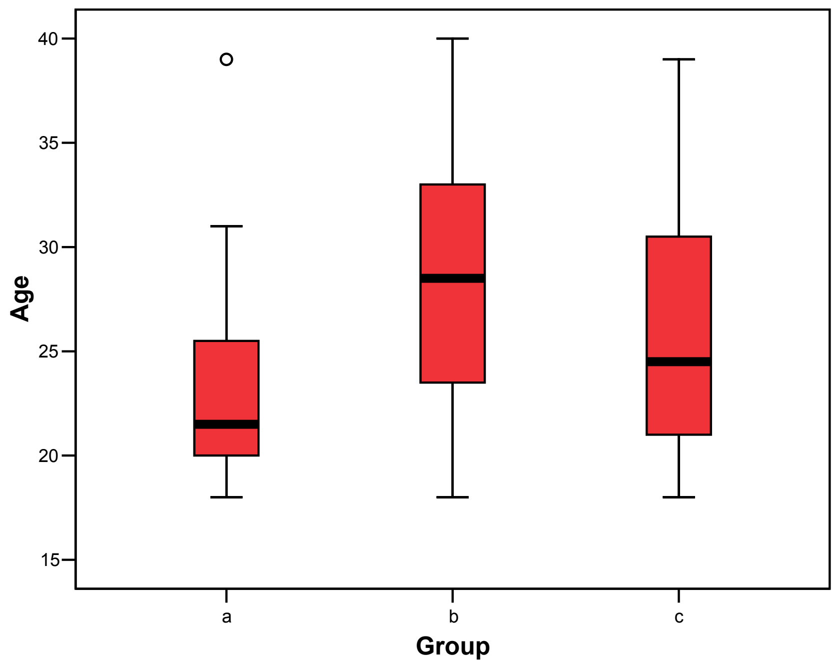

Figure 1: Boxplots of age by group

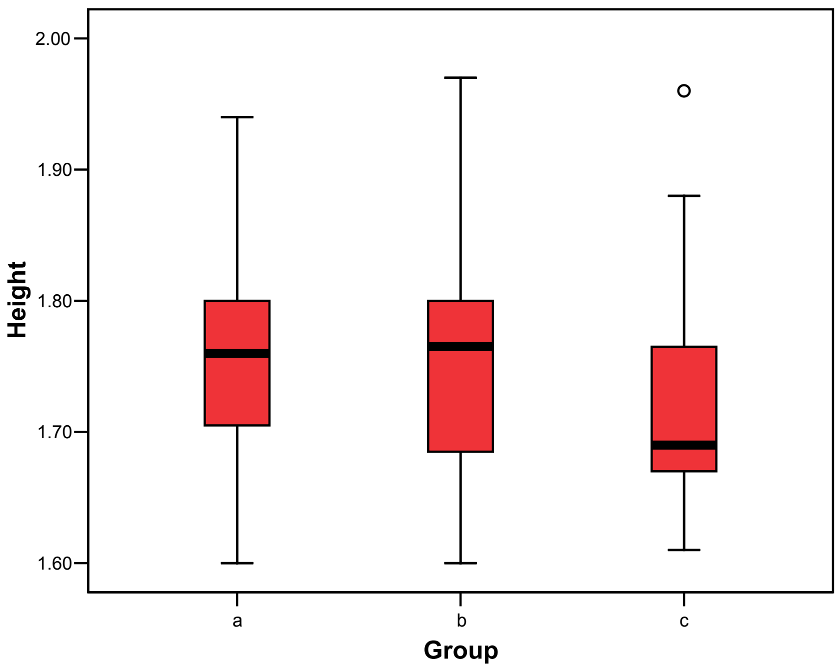

Figure 2: Boxplots of height by group

4.3 COMPARISON OF BASELINE MEASUREMENTS BETWEEN GROUPS:

Six outcome measurements were recorded before (T1) and after (T2) the intervention (or no intervention). These were three lung function variables: FVC, FEV1, FEV1/FVC, and three chest wall expansion measurements: axilla, xiphoid and halfway between xiphoid and umbilicus. Subjects were randomized into the 3 treatment groups, thus it was expected that no baseline differences existed between the 3 groups. This assumption was checked using one-way ANOVA since all T1 measurements were approximately normally distributed. Table 1 shows that there were no significant differences in any of the baseline variables between the three groups.

Table 1: One-way ANOVA analysis of mean baseline measurements between the three groups

T1 Measurement	F	p
FVC	1.367	0.263
FEV1	0.650	0.526
FEV1/FVC	2.129	0.128
Axilla	2.247	0.115
Xiphoid	1.745	0.184
Halfway	1.774	0.179

4.4 INTRA-GROUP COMPARISONS:

Paired t-tests were used within each group to assess if there was a significant change between the T1 and T2 measurement for each outcome measure.

Group a is shown in Table 2. Mean differences and t values were negative since the statistic was computed using T1-T2, indicating that T1 values were lower than T2 values (an increase from T1 to T2). For all outcomes there was a significant change between T1 and T2 in Group a.

Table 2: Group a paired t-tests comparing mean values at T1 and T2

	Mean difference T1 – T2	**t**	**df**	**p**
FVC	-0.13250	-4.770	19	<0.001*
FEV1	-0.17450	-6.960	19	<0.001*
FEV1/FVC	-1.4000	-3.167	19	0.005*
Axilla	-0.410	-2.738	19	0.013*
Xiphoid	-0.3500	-4.377	19	<0.001*
Halfway	-0.7350	-3.318	19	0.004*

*statistically significant at the 0.05 level.

Group b paired comparisons are shown below in Table 3. There were no significant differences for any of the outcome variables in Group b. Thus there was no mean change in values between T1 and T2 in this group.

Table 3: Group b paired t-tests comparing mean values at T1 and T2

	Mean difference T1 – T2	**t**	**df**	**p**
FVC	-0.1000	-1.636	19	0.118
FEV1	-0.004	-0.550	19	0.589
FEV1/FVC	0.1900	0.880	19	0.390
Axilla	0.005	0.137	19	0.893
Xiphoid	0.020	1.165	19	0.258
Halfway	0.0250	0.754	19	0.460

Paired comparisons for Group c are shown in Table 4. None of the mean differences are statistically significant. Thus there was no significant change between T1 and T2 for any measurements in Group c.

Table 4: Group c paired t-tests comparing mean values at T1 and T2

	Mean difference T1 – T2	**t**	**df**	**p**
FVC	-0.01650	-0.915	19	0.372
FEV1	0.00150	0.136	19	0.893
FEV1/FVC	0.2200	0.599	19	0.556
Axilla	0.050	0.872	19	0.394
Xiphoid	-0.1050	-1.330	19	0.199
Halfway	-0.0350	-0.492	19	0.629

The mean values at T1 and T2 are represented graphically below for each outcome by group.

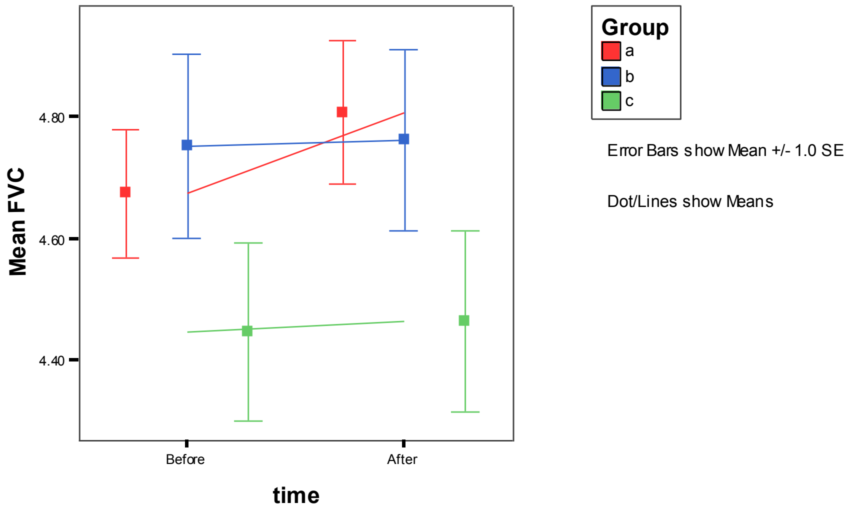

Figure 3: Mean (+- 1 SE) FVC before and after by group

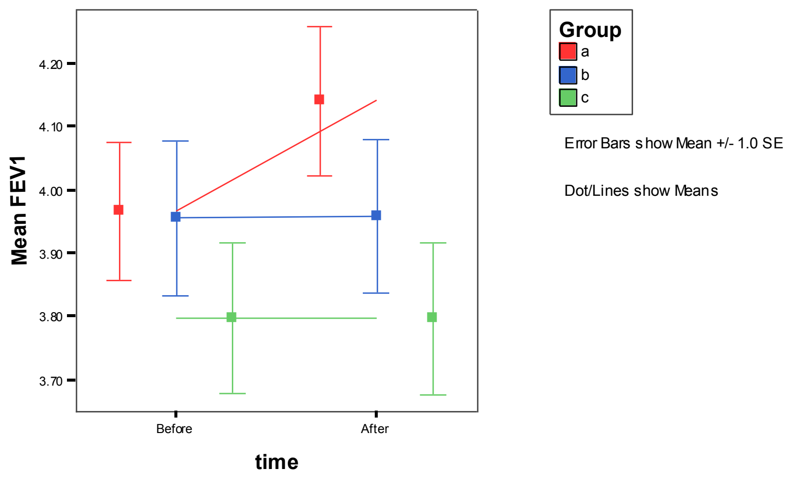

Figure 4: Mean (+- 1 SE) FEV1 before and after by group

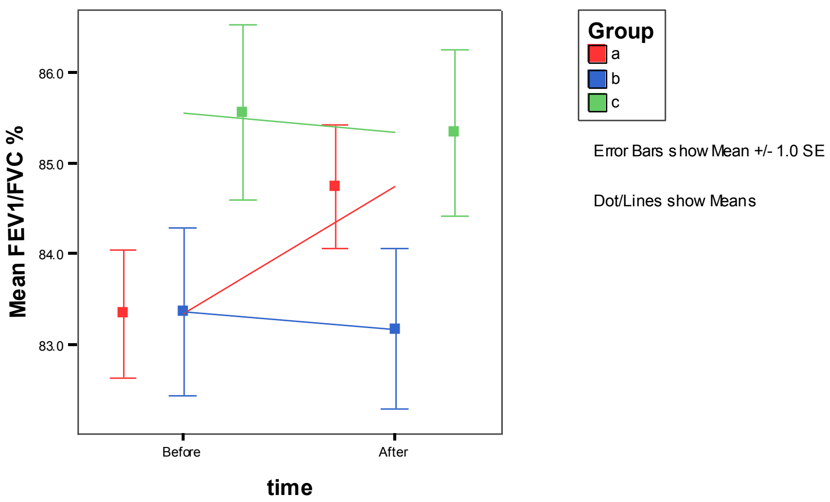

Figure 5: Mean (+- 1 SE) FEV1/FVC before and after by group

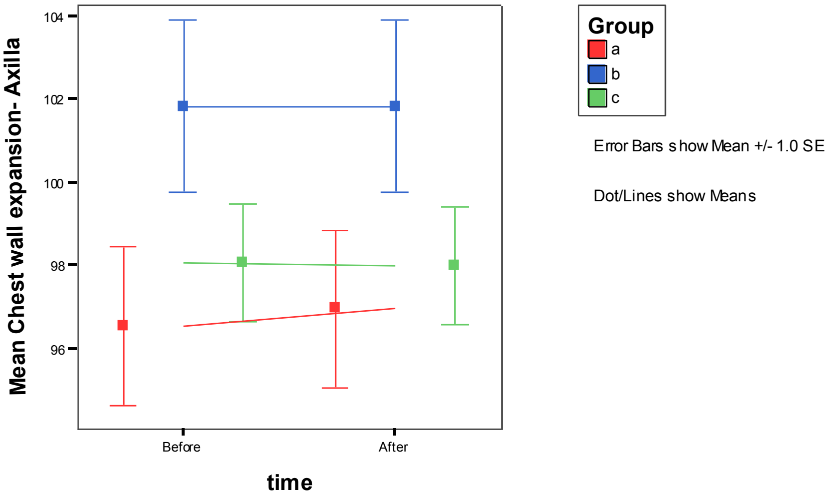

Figure 6: Mean (+- 1 SE) Axilla measurement before and after by group

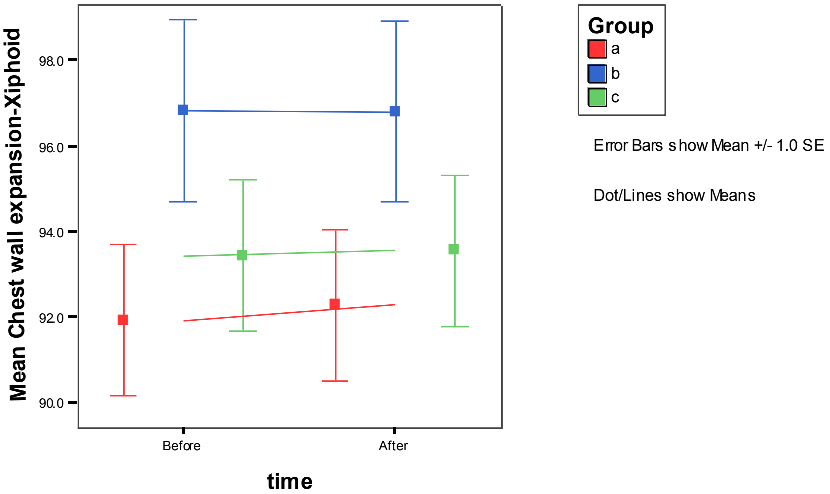

Figure 7: Mean (+- 1 SE) Xiphoid measurement before and after by group

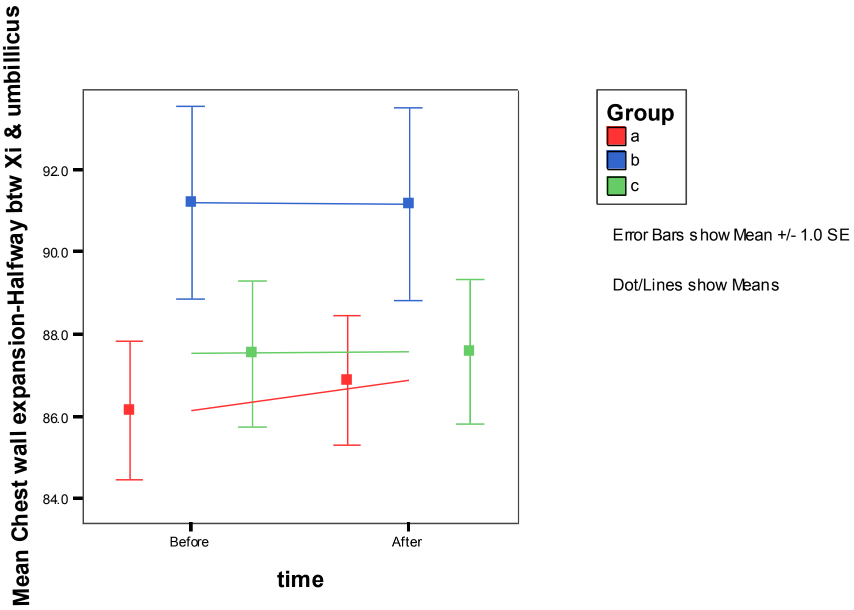

Figure 8: Mean (+- 1 SE) Halfway measurement before and after by group

4.5 INTER-GROUP COMPARISONS:

Percentage change was used for inter-group comparisons. The percentage change for the three lung function variables were normally distributed, thus ANOVA with post hoc Bonferroni tests was used. The percentage change of the three chest measurements were non-parametrically distributed, thus Kruskal-Wallis tests were used with Dunn's post hoc tests.

Table 5: ANOVA table for comparison of mean percentage change in lung function variables between the three groups

		Sum of Squares	df	Mean Square	F	p
FVC Percentage	Between Groups	74.060	2	37.030	10.811	<0.001*

change	Within Groups	195.238	57	3.425		
	Total	269.298	59			
FEV1 Percentage change	Between Groups	220.477	2	110.238	31.694	<0.001*
	Within Groups	198.259	57	3.478		
	Total	418.736	59			
FEV1/FVC Percentage change	Between Groups	46.814	2	23.407	6.774	0.002*
	Within Groups	196.953	57	3.455		
	Total	243.767	59			

* statistically significant at the 0.05 level.

Table 5 shows that there was a significant difference in percentage change between the three groups for FVC, FEV1 and FEV1/FVC.

Table 6: Bonferroni post hoc tests for the difference in mean percentage change between the three groups

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	p	95% Confidence Interval	
						Lower Bound	Upper Bound
FVC Percentage change	a	b	2.40347%(*)	.58525%	<0.001	.9598%	3.8471%
		c	2.30719%(*)	.58525%	0.001	.8636%	3.7508%
	b	a	-2.40347%(*)	.58525%	<0.001	-3.8471%	-.9598%
		c	-.09627%	.58525%	1.000	-1.5399%	1.3474%
	c	a	-2.30719%(*)	.58525%	0.001	-3.7508%	-.8636%
		b	.09627%	.58525%	1.000	-1.3474%	1.5399%
FEV1 Percentage change	a	b	3.98845%(*)	.58977%	<0.001	2.5337%	5.4432%
		c	4.14014%(*)	.58977%	<0.001	2.6854%	5.5949%
	b	a	-3.98845%(*)	.58977%	<0.001	-5.4432%	-2.5337%
		c	.15168%	.58977%	1.000	-1.3031%	1.6065%
	c	a	-4.14014%(*)	.58977%	<0.001	-5.5949%	-2.6854%

		b	-.15168%	.58977%	1.000	-1.6065%	1.3031%
FEV1/FVC Percentage change	a	b	1.85500%(*)	.58782%	0.008	.4050%	3.3050%
		c	1.89202%(*)	.58782%	0.006	.4421%	3.3420%
	b	a	-1.85500%(*)	.58782%	0.008	-3.3050%	-.4050%
		c	.03702%	.58782%	1.000	-1.4129%	1.4870%
	c	a	-1.89202%(*)	.58782%	0.006	-3.3420%	-.4421%
		b	-.03702%	.58782%	1.000	-1.4870%	1.4129%

* The mean difference is significant at the 0.05 level.

The multiple pairwise post hoc comparisons with Bonferroni correction are shown in Table 6. For FVC, FEV1 and FEV1/FVC the significant difference was between groups a and b, and a and c, while groups b and c were not significantly different from each other.

Table 7: Kruskal-Wallis tests for median percent change in chest measurement variables between the three groups

	Group	n	Mean Rank	p
Axilla Percentage change	a	20	42.98	<0.001*
	b	20	23.28	
	c	20	25.25	
	Total	60		
Xiphoid Percentage change	a	20	43.20	<0.001*
	b	20	21.35	
	c	20	26.95	
	Total	60		
Halfway Percentage change	a	20	42.45	<0.001*
	b	20	23.15	
	c	20	25.90	
	Total	60		

Table 7 above shows that there was a highly significant difference between the median percentage changes of the three groups for the axilla, xiphoid and halfway measurements. The mean ranks show that Group a has a higher value percent change for all three measurements.

Table 8: Dunn Post Hoc tests for differences in percentage change of the chest measurements between the three groups.

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	p	95% Confidence Interval	
						Lower Bound	Upper Bound
Axilla Percentage change	a	b	.43384%(*)	.15287%	0.028	.0394%	.8283%
		c	.47707%(*)	.16028%	0.019	.0685%	.8857%
	b	a	-.43384%(*)	.15287%	0.028	-.8283%	-.0394%
		c	.04322%	.07116%	0.904	-.1358%	.2223%
	c	a	-.47707%(*)	.16028%	0.019	-.8857%	-.0685%
		b	-.04322%	.07116%	0.904	-.2223%	.1358%
Xiphoid Percentage change	a	b	.40882%(*)	.09150%	0.001	.1720%	.6457%
		c	.27205%	.12415%	0.099	-.0375%	.5816%
	b	a	-.40882%(*)	.09150%	0.001	-.6457%	-.1720%
		c	-.13677%	.08768%	0.341	-.3636%	.0901%

	c	a	-.27205%	.12415%	0.099	-.5816%	.0375%
		b	.13677%	.08768%	0.341	-.0901%	.3636%
Halfway Percentage change	a	b	.91531%(*)	.27560%	0.010	.1990%	1.6316%
		c	.84608%(*)	.28845%	0.022	.1065%	1.5857%
	b	a	-.91531%(*)	.27560%	0.010	-1.6316%	-.1990%
		c	-.06922%	.09739%	0.856	-.3183%	.1799%
	c	a	-.84608%(*)	.28845%	0.022	-1.5857%	-.1065%
		b	.06922%	.09739%	0.856	-.1799%	.3183%

* The mean difference is significant at the .05 level.

The post hoc tests (Table 8) show that for the percent change in axilla measurements, groups a and b (p = 0.028) and groups a and c (p = 0.019) were significantly different from each other, while groups b and c (p = 0.904) were not different from each other. This was also the case for the halfway measurement. However, for the xiphoid measurement, only groups a and b were significantly different (p = 0.001). Group a was not significantly different to Group c (p = 0.099), and groups b and c were also not different (p = 0.341).

Thus for all lung function measurements Group a was significantly better than Group b and Group c. There was no difference between Groups b and c. Group a was the only group to show an increase (statistically significant) between the two time points. For axilla and halfway chest measurements, Group a was significantly better than Group b and Group c. There was no difference between Groups b and c. However for xiphoid chest measurements, Group a was significantly better than Group b but not significantly better than Group c. There were no significant differences between groups a and b and groups b and c. Thus the sham intervention may have had a slight effect on xiphoid chest measurements.

CHAPTER FIVE

DISCUSSION OF THE RESULTS

5.1 INTRODUCTION:

This chapter deals with the discussion of demographic data and the results after statistical analysis of the data, with regards to intra-group and inter-group comparison, as presented in Chapter 4.

5.2 THE DEMOGRAPHIC DATA:

The demographic data collected and analysed in this study is located in Figures 1 and 2.

From a review of the demographic data, it can be seen that the three groups were similar in terms of height distributions with a mean of 1.75 m and a SD of 0.08 m.

The age distribution of the participants ranged from 18 to 40 years, with a median age of 24.5 years. Though the median age of Group a was slightly lower than groups b and c, there was overlap between the inter quartile ranges of the three groups.

There was no particular reason why the median age of Group a was lower than the other two groups, as each participant was randomly assigned to his respective group. One reason why half the participants were 24 years or younger could be due to the fact that this study was conducted at the Durban Institute of Technology, which is easily accessible to young adults.

5.3 INTRA-GROUP COMPARISON:

The statistical data comparing each of the three groups individually is located in Tables 2 to 4.

Statistical analysis showed that for all outcomes there was a significant change for all measurements before and after rib mobilizations were performed in Group a (Table 2).

In terms of chest wall expansion, these significant changes could have resulted from either a response from the chest wall mechanoreceptors, or be due to a stretching mechanism of the intercostal muscles and the costovertebral synovial joint capsules and associated ligaments of the costo-central and costo-transverse joints due to the movements that occurred as a result of mobilizations to the rib cage.

As discussed earlier in Chapter 2, mechanoreceptors are sensors that respond to changes in length, tension movement of muscles, joints and tendons (Mitchell et al. 1981: 541-624). This was supported by Powers et al. (1997: 145-147) who state that mechanoreceptors consist of muscle spindles which respond to changes in muscle length by bringing about a reflex contraction within muscles and GTOs which continuously monitor tension produced by muscle contraction. The assumption was made that the distribution of the chest wall mechanoreceptors (muscle spindles and GTOs) in humans is similar to that found by Holt et al. (2002) in cats. Holt et al. (2002) further explained in their study that the muscle spindles were distributed evenly in the intercostal muscles while the GTOs were located along the rib borders of a cat. Therefore, just by contacting these areas may have elicited a response from these mechanoreceptors. These muscle spindles could also have been activated by vibration of the chest wall (Homma et al. 1984: 4-11).

According to Younes (1995: 867-922) chest wall mechanoreceptors provide respiratory motor and pre-motor neurons with important information regarding the length and force of contraction of the respiratory muscles. These signals allow changes to be made in the level of the brainstem, which lead to a compensation for changes in respiratory muscle function.

Thus, by performing rib mobilizations, stimulation of mechanoreceptors in the chest wall region is likely which could have led to a neural response which produced a reflex contraction within the intercostal muscles eventually leading to an increase in the participant's inspiration and hence, expiration.

These increases in chest wall expansion increased after rib cage mobilization despite the varying degrees of stiffness each rib possesses as one moves from the second to tenth ribs.

If we accept that the rib mobilizations caused an increase in chest wall expansion (as evidenced by the results in Table 2), there had to be a corresponding change in lung function as well (Table 2) if we take into account that the lungs can be expanded and contracted by the elevation of the ribs (Guyton and Hall 2000: 311-312). This is supported by McArdle et al. (2000: 218-220) who state that the lung volume is affected by the action of the respiratory muscles. It is important to take into account the fact that for both groups b and c there was no significant change between measurements of chest wall expansion and lung function before and after the control or sham laser intervention. This observation lends more support to the changes seen after rib mobilizations in which both measurements for chest wall expansion, as well as lung function, increased.

Thus, for Group a, the Null Hypothesis (H_o) is rejected, as there was a significant difference within this group with respect to changes in the measurement protocols before and after the rib mobilizations. In spite of the possibility of the Hawthorne Effect, there were still no significant changes within the group for the measurement protocols before and after the ten-minute rest (control) and sham laser 'intervention'. Thus, for Groups b and c we accept the Null Hypothesis.

5.4 INTER-GROUP COMPARISON:

The statistical data for the inter-group comparisons are located in Tables 5 to 8.

The percentage change of the three chest measurements were non-parametrically distributed, thus Kruskal-Wallis tests were used with Dunn's post hoc tests.

In terms of chest wall expansion, there was a significant difference between the median percent of the three groups (Table 7) for the axilla, xiphoid, and halfway between the xiphoid and umbilicus measurements. The mean ranks show that Group a had the highest value percent change for all three measurements. This is not surprising when we consider the results for the intra-group comparisons.

The post hoc tests (Table 8) show that for percent change in axilla measurements, Group a and b as well as Groups a and c were significantly different from each other, while Groups b and c were not different from each other. This was the case for the measurement halfway between the xiphoid and umbilicus.

Here we can see that rib mobilizations, through either a neural response (via the mechanoreceptors and their effects) or a mechanical response (as suggested for the intra-group comparison) caused an increase in chest wall expansion at the level of the axilla and halfway between the xiphoid and umbilicus. This result is consistent with earlier findings (intra-group analysis).

For the xiphoid measurement, only Groups a and b were significantly different from one another. Group a was not significantly different to Group c, and Groups b and c were not significantly different from one another either.

Thus, the sham laser may have had a slight effect on xiphoid chest measurement. This is however, not consistent with the rest of the results, and the explanation for this perceived anomaly is unknown to the researcher.

In terms of lung function measurements there was a significant difference between the three groups for FVC, FEV1 and FEV1/FVC% (Table 5).

Table 6 shows that for FVC, FEV1 and FEV1/FVC the significant difference was between Groups a and b, and Groups a and c, while Groups b and c were not significantly different from each other. These results are consistent with those found when analysis was performed for the intra-group comparison. Although there were no significant differences between Groups a and c in terms of chest wall expansion at the xiphoid, this did not seem to affect the improvements in lung function which were only significant in Group a.

The Null Hypothesis (H_o) is rejected, because for all lung function measurements, Group a was significantly better than Group b and c. In terms of chest wall expansion the Null Hypothesis can only be rejected when comparing the difference in results at the axilla and at the point halfway between the xiphoid and umbilicus. However, for the xiphoid measurement the Null Hypothesis can be accepted, as there was no significant difference between Groups a and c as well as b and c. Thus, only Groups a and b were significantly different.

5.5 COMPARISON WITH PREVIOUS STUDIES:

To the best of the researcher's knowledge, only a study by Hightower et al. (1999) investigated the concept of rib mobilization (and respiratory muscle stretching) and its effect on chest wall expansion and vital capacity. Although the results indicate an improvement in xiphoid and axillary chest wall expansion measurements, it was not statistically significant.

The study by Hightower et al. (1999) contained various design flaws e.g. a small population size (14 subjects), as well as a small sample size, which was made up of only 7 control subjects (4 subjects in a home exercise group who received no treatment and 3 experimental subjects who received treatment as well as having to perform home exercises). There were also too many variables in terms of the treatment interventions employed e.g. too many different muscles treated at the same time, and incorporating a home exercise programme in the experimental group, leaving one unsure as to which intervention led to the proposed effect. Our study consisted of a population size of 60 participants, with a sample group of 20 participants in each group. Also, our 3 groups were distinct from one another in that no one group employed a similar intervention to the other or a combination of the same interventions.

5.6 CONCLUSION:

From the above data it can be concluded that rib mobilization is effective in increasing chest wall expansion during a short-term period and lung function as compared to a control and sham intervention group. The findings of this study also demonstrate that in the clinical setting, rib mobilizations could be used as part of a treatment protocol to improve the lung function and chest expansion of people suffering from illnesses such as chronic obstructive pulmonary disease e.g. asthma.

CHAPTER SIX

RECOMMENDATIONS AND CONCLUSIONS

RECOMMENDATIONS:

The following factors should be considered for future studies of this nature.

6.1 HOMOGENEITY:

According to Mohseni-Bandpei et al. (1998: 185-194), in any randomised clinical trial, the goal is that the study should be similar in terms of relevant patient characteristics i.e. age, gender, etc. They also emphasized that the similarity of relevant baseline characteristics was one of the criteria they used to assess the methodological quality of the randomised controlled trials that they reviewed. This was dealt with earlier in Chapter Four (under the heading: Comparison of baseline measurements between groups).

The demographic results from Figures 1 and 2 showed that the three groups were similar in terms of age and height distribution. Although we selected an age range of between 18 and 45 (which was advocated by Brandt 2002), we could have allowed for a narrower age range (i.e. 18 – 25 years of age or 26 – 32 years of age). This is because FEV1 and FVC measurements increase, while FEV1/FVC decreases until twenty-five years of age. Thereafter all indices decline. The study sample could have also been stratified according to ethnicity. According to Pierce and Johns (2003), Caucasians have the largest FEV1 and FVC of the various ethnic groups. However, this claim can only be strengthened or weakened if the study is done on the various ethnic groups in South Africa. In spite of an exhaustive literature search the researcher found no studies investigating the differences in lung function amongst the various ethnic groups of South Africa.

6.2 **STUDY SIZE**:

The study utilized a sample of twenty patients in each of the three groups. Mohseni-Bandpei et al. (1998: 185-194) state in their review of randomised controlled trials that one of the most important flaws seen in trials reviewed included the sample size of the study population. Although the sample size of this study was statistically acceptable, an even larger sample size would definitely decrease the likelihood of a Type II error occurring. It was however, not possible in the context of this study, to use a larger study population, due to budgetary as well as time constraints.

6.3 **BLINDING**:

It is essential to eliminate observer, therapist, investigator and participant bias so that the possibility of bias occurring in any trial is reduced (Haldeman 1992: 48-50). In a study of this nature, it is not possible for the participant to be blinded to the intervention, as the respective interventions differ markedly from each other. The possibility of researcher bias exists, as the author was the sole conductor of this study. The inclusion of an independent observer to obtain and record the measurements before and after the respective interventions would certainly reduce the possibility of observer and measurement bias.

6.4 **ACCURACY OF MEASUREMENTS**:

Significance may not be revealed by statistical analysis of the data, if outcome measures are not valid, precise and sensitive for measuring small but clinically relevant changes (Koes et al. 1995: 228-235). The spirometer and tape measure are considered reliable tools for assessing changes within the participants' lung function and chest wall expansion. However, the possibility does exist that minute clinical changes or variations of the rib cage during the various interventions, may have been inaccurately measured or unaccounted for.

The spirometer employed in this study was The Medical Pocket Spirometer 9000 series. Future studies should include the use of a more advanced spirometer because, though the spirometer did include a visual display that the participant could view to see his progress in terms of expiratory flow, it did not include a printout with graphic representation of the results. Once again, budgetary constraints did not allow for this.

Although the participant was briefed about proper technique and what to expect after the spirometry, as well as being actively coached and encouraged by the researcher throughout the procedure, it was difficult for some patients to execute the manoeuvres in the beginning. As participants practised their techniques, the subsequent readings were recorded within a much narrower range.

In terms of chest expansion, great care was taken when readings were measured and recorded. Landmarks were identified and then marked with a skin pencil so that every effort was made to locate the exact same spot when subsequent measurements were taken. However, it was required by the participant to inspire fully and then hold his breath when chest wall measurements were taken, but there was no way to control how much air each participant inspired, as some of them could have held their breath before full inspiration. This could have led to a decrease in the chest expansion measurement. Participants must therefore be told to fully expire and then inspire to their full capability. They should (and must) be able to hold their breath for the duration it takes the researcher to measure the chest wall expansion at the three sites.

6.5 FOLLOW-UP STUDIES:

It is suggested that a follow-up study be conducted e.g. to investigate if similar and significant changes exist 24 hours after rib mobilizations are performed. If there are still significant results thereafter, and then perhaps a study with a longer follow-up period could be designed.

It is further suggested that a follow-up study be conducted in patients suffering with lung pathologies e.g. asthma, to determine the efficacy of rib cage mobilization.

Mohseni-Bandpei et al. (1998) state that more effort should be made to establish long-term follow-up, as lasting improvement will be the most convincing estimate of cost-effectiveness.

6.6 EXPERIENCE:

A more experienced manual therapist, with at least 5 years clinical experience, should repeat this study. Limited experience of any undergraduate researcher may bias the results of a study.

6.7 ADVANTAGES AND DISADVANTAGES:

6.7.1 Advantages:

The results of the study appear to warrant that rib mobilization at least be incorporated as part of the physical therapy of patients suffering with chronic obstructive pulmonary disease e.g. asthma. The procedure itself is easy to learn. Thus, it can be incorporated as part of a home treatment programme. It is also very cost-effective, with no need for any tools or instruments. No participant in this study reported any adverse effects in terms of pain and discomfort, therefore it is unlikely that this procedure would cause undue discomfort to a symptomatic patient.

6.7.2 Disadvantages:

The time interval for rib mobilizations may need to be increased to 15 to 20 minutes when designing future long-term studies. This can, however, be physically exhausting for the therapist.

Rib mobilization may not be feasible and effective in the following cases:

- An acutely ill patient.
- Obese patients, because the therapist may find it difficult to gain contact onto the ribs and intercostal muscles, especially if the therapist is small.

It will be difficult (but not impossible) to mobilize the anterior chest in females due to the presence of breast tissue.

6.8 CONCLUSION:

The findings of this study appear to lend support to the claim that rib mobilization is effective in increasing chest wall expansion and lung function as compared to control and sham intervention groups.

The effect could be attributed to either a neural cause (stimulation of mechanoreceptors) or a mechanical cause (either by vibration, stretch mechanism i.e. lengthening of actin and myosin filaments and/or costovertebral mobilization).

However, in spite of these results, and due to the paucity of the literature surrounding this topic, it is recommended that further studies be conducted in this field. The recommendations outlined in this chapter may help the reader in planning future or follow-up studies.

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