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THE EFFECT OF TWO PASSIVE HEAD DOWN DIAPHRAGM STRETCHING MANOEUVRES ON DIAPHRAGM LENGTH IN HEALTHY ADULT INDIVIDUALS.

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Johannesburg, 2013

DECLARATION

I, Jacqueline Schewitz declare that this research report is my own work. It is being submitted for partial fulfillment for the degree of Masters of Science in Physiotherapy in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University

 (Signature)

13th day of September 2013

DEDICATION

To my husband, sons and entire family who have helped me and supported me through this endeavor.

To my supervisors, Ronel Roos and Heleen van Aswegen. For their time, effort and generosity with their knowledge and expertise.

ABSTRACT

Objectives:

The diaphragm is the primary muscle of inspiration and provides life sustaining oxygen to the body (Voyvoda et al, 2011). It is active during relaxed and effort induced ventilation. Diaphragm contraction results in pressure changes within the thorax thereby assisting in airflow into the lungs and increasing lung volumes. During this inhalation process the diaphragm moves from a dome-shaped relaxed position into a flattened shortened position. Often during the increased work of breathing in patients suffering from chronic obstructive pulmonary disease (COPD), the diaphragm does not sit in its anatomical resting position; it shortens and weakens (Watson et al, 2001). Stretching of skeletal muscles is a physiotherapy treatment modality commonly used in clinical practice. The aim of this treatment modality is to increase the length of a shortened muscle thereby improving the range of motion of said muscle and improving the specific joint motion (Wepler and Magnusson, 2011). Head down tilt positions are commonly used in cardiopulmonary physiotherapy to utilise gravity to facilitate sputum drainage from different lung segments (Pryor & Prasad, 2008; Selsby & Jones, 1990). A head down tilt position could potentially have an influence on diaphragm length if applied for a sustained period of time due to likely abdominal content displacement from a caudal to cranial position resulting in a stretch on the diaphragm.

The objective was to determine if diaphragm length could be influenced by providing a stretch using the abdominal contents. Moreover, to see if this hypothesized change in length would influence the diaphragm's function.

Method:

A quasi-experimental study was conducted from January to April 2012 with undergraduate physiotherapy students as study participants. Seventy five study participants were assessed

for baseline outcome measures at rest. They then underwent four body position changes after which each measurement was re-recorded. These body position changes were:

- lying in a head down tilt position at 15 degrees for 30 seconds
- lying in a head down tilt position at 15 degrees for two minutes
- lying in a head down tilt position at 30 degrees for 30 seconds
- lying in a head down tilt position at 30 degrees for two minutes

Ultrasound was used to measure the diaphragm length. Its function was recorded in terms of the expiratory flow generated and the thoracic expansion measured. Dyspnoea was recorded for a subjective view of tolerance of the position and vital signs were monitored throughout for the volunteers' safety. ANOVA, Kruskal Wallis, Bartlett's test and the student's t test were used for statistical analysis.

Results:

All 75 participants completed the entire study and none were withdrawn as a result of negative side effects. The results showed that the diaphragm could be stretched by using the abdominal contents in a head down tilt position ($p=0.00$). The mean and standard deviation for the greatest change from rest was 38.78mm (±11.51) on the left and 39.38mm (±11.92) on the right. There were no detrimental effects to the participants' cardiovascular or pulmonary stability. Thoracic expansion and peak flow showed an insignificant change throughout the changes in position. Thoracic expansion had a mean change of 2.48cm (±0.86) with a p value of 0.54. Peak expiratory flow rate had a change of 428.94L/min (±95.01) with a p value of 0.98. These values were less than the normal expected values for the participants.

Conclusion:

A change in diaphragm length is possible by applying a stretch to the muscle. A stretch can be applied by placing the participant in a head down tilt position which allows the abdominal contents to push on the underside of the diaphragm in a cranial direction. No adverse effects occurred in healthy adult individuals during the different head-down tilt positions. Respiratory function did not show a significant improvement due to the change in diaphragm length as measured by peak expiratory flow rate and thoracic expansion.

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CONTENTS

Declaration ii

Dedication iii

Abstract iv

Acknowledgements vii

Contents ..... **Error! Bookmark not defined.**

List of Figures xi

List of Tables xii

List of Abbreviations xiv

Chapter 1 1

1 Introduction 1

1.1 Background 1

1.2 Problem statement 2

1.3 Significance of the research 2

1.4 Research Aim 3

1.5 Research objectives 3

CHAPTER 2 4

2. LITERATURE REVIEW 4

2.1 Introduction 4

2.2 The role of cardiopulmonary physiotherapy 4

2.3 The influence of a head down tilt position 5

2.4 The influence of stretch on muscle length 9

2.5 The Diaphragm 14

2.6 Factors that influence diaphragm structure and function 17

2.7 Conclusion 22

CHAPTER 3 23

3. METHODOLOGY 23

3.1 Study Design 23

3.2 Subjects 24

3.3 Instrumentation and Outcome measures 26

3.4 Ethical considerations 33

3.5 Procedure 34

3.6 Data analysis 44

Chapter 4 46

4. Results 46

4.1 Introduction 46

4.2 Demographics 47

4.3 Baseline values at rest (position one) 49

4.4 Variables after head-down tilt position two (15 degrees for 30 seconds) 51

4.5 Variables after head-down tilt position three (15 degrees for two minutes) 53

4.6 Variables after head-down tilt position four (30 degrees for 30 seconds) 55

4.7 Variables measured after head-down tilt position five (30 degrees for two minutes) 56

4.8 Variables compared across all the changes in position 58

Chapter 5 65

5. Discussion 65

5.1 Introduction 65

5.2 Demographics 65

5.3 The influence of a head-down tilt on diaphragm length 67

5.4 The influence of a head-down tilt on peak expiratory flow rate 69

5.5 The influence of a head-down tilt on thoracic expansion 70

5.6 The influence of a head-down tilt position on heart rate, oxygen saturation, blood pressure and dyspnoea 71

5.7 Conclusion of the study 72

5.8 Limitations of the study 73

5.9 Recommendations for future research 73

6. References: 75

Appendix 1 89

Appendix 2 90

Appendix 3 91

Appendix 4 92

Appendix 5a 93

Appendix 5b 94

Appendix 6 95

Appendix 7 96

Appendix 8 97

Appendix 9 99

Appendix 10 100

LIST OF FIGURES

Figure **Page**

4.1 The distribution of percentage of students' per undergraduate year of study in the current study 48

4.2 Comparison of diaphragm length in different head-down tilt positions 59

4.3 Comparisons of systolic and diastolic blood pressure in different positions 60

4.4 Sensation of breathlessness assessed with the Modified Borg Dyspnoea Scale in different head-down tilt positions 61

4.5 Oxygen saturation and heart rate in different head-down tilt positions 62

4.6 Changes in thoracic expansion in different head-down tilt positions 63

4.7 Peak expiratory flow rate measurements in different head-down tilt positions compared to the predicted peak expiratory flow rate 64

LIST OF TABLES

Table **Page**

3.1 Numbers assigned to the different head down tilt positions and angles 23
3.2 Baseline intrarator reliability values of study participants 38
3.3 Intrarator reliability of study participants after 15 degree head down tilt for 30 seconds. 39
3.4 Intrarator reliability of study participants after 15 degree head down tilt for two minutes 40
3.5 Intrarator reliability of study participants after 30 degree head down tilt for 30 seconds. 41
3.6 Intrarator reliability of study participants after 30 degree head down tilt for two minutes 42
3.7 Numbers assigned to the different head down tilt positions and angles 44
4.1 Normal Values for variables measured 47
4.2 The average age, height, weight and BMI of participants 49
4.3 The average heart rate, oxygen saturation, blood pressure and breathlessness at rest 50
4.4 The average peak flow, right and left hemi-diaphragm length and thoracic expansion for study participants at rest 51
4.5 The average heart rate, oxygen saturation, blood pressure and Breathlessness scores after 15 degrees head down tilt position for 30 seconds 52
4.6 The average peak flow, right and left hemi-diaphragm length and thoracic expansion after 15 degrees head down for 30 seconds 53
4.7 The average heart rate, oxygen saturation, blood pressure and Breathlessness scores after 15 degrees head down tilt for two minutes 54
4.8 The average peak flow, right and left hemi-diaphragm length

and thoracic expansion after 15 degrees head down tilt for two minutes 54
4.9 The average heart rate, oxygen saturation, blood pressure and Breathlessness scores after 30 degrees head down tilt for 30 seconds 55
4.10 The average peak flow, right and left hemi-diaphragm length and thoracic expansion after 30 degrees head down tilt for 30 seconds 56
4.11 The average heart rate, oxygen saturation, blood pressure and Breathlessness scores after 30 degrees head down tilt for two minutes 57
4.12 The average peak flow, right and left hemi-diaphragm length and thoracic expansion after 30 degrees head down tilt for two minutes 57

LIST OF ABBREVIATIONS

Chronic Obstructive Pulmonary Disease- COPD

Intensive Care Unit- ICU

Active Cycle of Breathing Technique- ACBT

Manual Hyperinflation- MHI

Peak Expiratory Flow Rate- PEFR

Functional Residual Capacity- FRC

Residual Volume- RV

Body Mass Index- BMI

CHAPTER 1

1 INTRODUCTION

1.1 BACKGROUND

Cardiopulmonary physiotherapists are involved in improving the cardiorespiratory function of their patients and thereby influencing their functional capabilities (WCPT, 2011).Cardiopulmonary therapists aim to improve the lungs ability to ventilate air in a variety of conditions as well as in athletes and sedentary individuals (Griffiths & McConnell, 2007). Respiratory therapy has been shown to increase time to exercise exhaustion, maximum voluntary ventilation and to reduce ventilatory fatigue (Enright et al, 2006).

The diaphragm is the primary muscle of inspiration and provides life sustaining oxygen to the body (Voyvoda et al, 2011). It is active during relaxed and effort induced ventilation. Diaphragm contraction results in pressure changes within the thorax thereby assisting in airflow into the lungs and increasing lung volumes. During this inhalation process the diaphragm moves from a dome-shaped relaxed position into a flattened shortened position. Expiration at rest is mainly passive caused by relaxation of the diaphragm. It then returns to its anatomical resting position which is dome-shaped (Ruppel, 2009). This muscle relaxation results in thoracic recoil thereby compressing the lungs and reducing lung volumes as air is expelled out of the lungs. When the work of breathing increases, this exhalation process requires extra effort by the body and is more demanding on the respiratory system. Often during the increased work of breathing in patients suffering from chronic obstructive pulmonary disease (COPD), the diaphragm does not sit in its anatomical resting position; it shortens and weakens (Watson et al, 2001). This shortened diaphragm allows the volume of the lungs to be increased resulting in a state of hyperinflation. During a state of hyperinflation the accessory muscles of respiration are often used to assist in inspiration as minimal diaphragm displacement can occur (Kang et al, 2011).

Stretching of skeletal muscles is a physiotherapy treatment modality commonly used in clinical practice. The aim of this treatment modality is to increase the length of a shortened

muscle thereby improving the range of motion of said muscle and improving the specific joint motion (Wepler and Magnusson, 2011). This principle could also be applied to the diaphragm. A quick stretch influences both inspiratory and expiratory muscles thereby affecting respiratory system function (Puckree, Cerney & Bishop, 2002). The diaphragm while being the primary muscle of respiration is still a skeletal muscle and therefore should be stretchable like all other skeletal muscles. Head down tilt positions are commonly used in cardiopulmonary physiotherapy to utilise gravity to facilitate sputum drainage from different lung segments (Pryor & Prasad, 2008; Selsby & Jones, 1990). A head down tilt position could potentially have an influence on diaphragm length if applied for a sustained period of time due to likely abdominal content displacement from a caudal to cranial position resulting in a stretch on the diaphragm.

Currently, it is not known if a head down tilt position would have a stretching effect on the diaphragm. The current study set out to investigate this possibility.

1.2 PROBLEM STATEMENT

Currently there is no published information available concerning the effect of head down tilting as a means of stretching the diaphragm and evaluating the effect of such a stretch on diaphragmatic function. The appropriate angle for head down tilting and time required to achieve an effective stretch of the diaphragm is also not available. This study hoped to answer these specific questions.

1.3 SIGNIFICANCE OF THE RESEARCH

Physiotherapists aim to maintain function and movement and prevent dysfunction in the rehabilitation of their patients. Cardiopulmonary physiotherapists aim to optimise the functioning of the respiratory muscles of patients with acute or chronic respiratory diseases**.** The diaphragm is the main muscle of inspiration and cardiopulmonary physiotherapists use breathing techniques that optimises its function. However respiratory muscle weakness and shortening due to a decrease in exercise tolerance and a loss of movement lead to a shortened diaphragm position (Watson et al, 2001). This study aimed to ascertain if stretching the diaphragm had an effect on its position and hence its function.

By testing healthy individuals and determining the most appropriate angle for head down tilting and time required for tilting in order to facilitate stretching of the diaphragm, the information collected with this study will serve as a basis for further research. This research will therefore establish if the head down tilt position has an effect on the diaphragm as well as the optimum time and position. Future research could then be conducted to investigate the effects of diaphragm stretching on patients with shortened diaphragms such as those who suffer from COPD.

1.4 RESEARCH AIM

To determine the effect of passive head-down tilt stretch positions on diaphragm length in healthy adult individuals.

1.5 RESEARCH OBJECTIVES

- To determine which stretch position and time period is most beneficial in improving diaphragm length.
- To determine if there is an effect on diaphragm displacement before and after a head down tilt intervention.
- To determine if there is an effect on thoracic expansion before and after a head down tilt intervention.
- To determine if there is an effect on peak expiratory flow rates before and after a head down tilt intervention.
- To assess blood pressure, oxygen saturation and heart rate changes before and after a head down tilt intervention.
- To assess subjects' level of perceived breathlessness before and after a head down tilt intervention.

The following chapter will consist of a review of the literature pertaining to the role of cardiopulmonary physiotherapy; the influence of a head down tilt position; the influence of stretch on muscle length; and relevant information pertaining to the diaphragm muscle.

CHAPTER 2

2. LITERATURE REVIEW

2.1 INTRODUCTION

This literature review was conducted in order to ascertain the evidence that is available on stretching muscles especially muscle's of respiration as well as the effect of a head-down tilt position.

The search engines used in order to conduct this review were the Cochrane collection, Pubmed, Pedro database, Science Direct as well as Google Scholar. Keywords that were used were: diaphragm, length, stretch, head-down tilt, postural drainage, positioning, peak expiratory flow, thoracic expansion, diagnostic ultrasound and weakness.

2.2 THE ROLE OF CARDIOPULMONARY PHYSIOTHERAPY

Physiotherapists aim to restore movement and prevent dysfunction when treating patients with disabilities (WCPT, 2011). Cardiopulmonary physiotherapists share the same goal within a cardiopulmonary framework. Cardiopulmonary physiotherapists therefore aim to optimise a patient's function whether it be relieving acute post surgical breathlessness or managing a long term chronic respiratory complication. In a cardiopulmonary framework they generally aim to maximise the patient's functional activities, improve lung capacity and volume if it is decreased, mobilise and clear secretions and prevent secondary complications from developing (Hanekom, Louw et al, 2012). Moreover, in chronic disease, cardiopulmonary physiotherapists are actively involved in managing a person's lifestyle so that they can best function within their specific disease limitations. They do this by having an understanding of the respiratory physiology and anatomy, specifically the primary muscle of inspiration, the diaphragm.

The treatment techniques that are used to attain cardiopulmonary physiotherapy objectives are in line with the rest of the physiotherapy field. An example of such an aim is to strengthen

weak muscles and stretch or elongate shortened structures. This is to try and position the body in an anatomically correct position and thereby allowing the muscles to work at their optimum length which in turn leads to optimum power and control (Weppler & Magnusson, 2010).

One of the primary goals of cardiopulmonary physiotherapy is to clear pulmonary secretions. A postural drainage technique is a gravity-assisted position often used by physiotherapists where the patient lies in a position that is anatomically suited to drain secretions from a specific segment of the lung (Ross, Dean & Abboud, 1992). These positions are often performed by positioning a patient in a head-down tilt position. The application of a general head-down tilt position could use the person's own abdominal contents to push the diaphragm in a cephalad direction thereby stretching the muscle. This could potentially be beneficial for patients with shortened diaphragms such as people suffering with COPD or patients who are on long term mechanical ventilation where the diaphragm weakens and possibly shortens (Kang et al, 2011; Callahan & Supinski, 2010).

Previous research has shown that we can measure the diaphragm's length, but it has not been shown if we can stretch the diaphragm or if by changing the length its function could be manipulated.

2.3 THE INFLUENCE OF A HEAD DOWN TILT POSITION

Body positioning is a first line treatment modality for patients with cardiopulmonary dysfunction (Jones & Dean, 2004). Changes in body position are used to improve oxygenation in different areas of the lungs as well as aid in secretion clearance. The body's organs and systems function differently in different positions due to the influence of gravity on certain structures. Heart rate, blood pressure and oxygen consumption are significantly higher in a sitting position as compared to a lying position (Jones & Dean, 2004). Thus body position can have an adverse or beneficial effect on the physiological status of a patient as it influences optimal blood flow and oxygen transport (Dean, 1997). Positioning is therefore used in intensive care units (ICU) to manage the cardiovascular and pulmonary systems of these patients by influencing gravity as well as affecting the neuromuscular and musculoskeletal systems of such patients.

Conversely, the adverse effects of not positioning and not moving are deleterious for the health of a patient. Oxygen transport can be severely restricted in certain positions especially for the elderly. Problems such as neuropathies, myopathies and skin breakdown are common problems associated with poor positioning (Jones & Dean, 2004). Any position that is maintained for an extended period will compromise oxygen transport via the hydrostatic, gravitational and compression forces that act on the heart, blood volume, lungs, chest wall and lymphatic system (Frowenfelter & Dean, 1996).

Physiotherapists use changes in body position to achieve certain aims. These aims include: ventilation and perfusion matching in a high sitting or standing position; and to clear secretions in a postural drainage position that is specific to the lung segment that has secretions by assuming a head-down tilt position (Berney et al 2004; Cecins 1999; Stiller 1996). The head-down tilt position has been defined as a 30 degree head-down tilt in a supine position either with a tip of the bed or with a tilt table (Naylor, 2006; Jones & Dean, 2004). The head-down tilt position can also be used for patients with severe hypotension by assisting with venous return and improving blood pressure (Jones & Dean, 2004). All techniques are not suitable to all patients and each treatment technique should be chosen with the patient's problem in mind as well as an understanding of the relevant co-morbidities and complicating factors.

The head-down tilt position causes cardiovascular and pulmonary changes. In healthy people it is said to cause an increase in central blood volume, ventricular preload, myocardial oxygen consumption, cardiac output and stroke volume respectively (Naylor, 2006; Norsk, 1993; Nixon, 1992). The extent of the changes that occur is proportional to the time spent in the head-down tilt position as well as the degree of tilt exerted. Ten minutes in a head-down tilt position has proven to cause an unfavourable shift in myocardial oxygen supply demand ratio (Naylor, 2005). This would imply that caution should be used in patients that have a cardiac complication when positioning them in a head-down tilt position as they do not have the cardiac reserve of healthy individuals. However, Naylor (2006) compared modified postural drainage (a horizontal supine position) to a head-down tilt position and found that both positions were well tolerated by patients with severe left ventricular systolic dysfunction (mean ejection fraction of 23 percent) who were stable and free of acute respiratory illness. It

is therefore necessary to monitor vital signs in individuals when tilting them in a head-down tilt position to evaluate if any adverse events occur during tilting.

There are numerous applications of the head-down tilt position in clinical practice and it is often used as adjunct to other physiotherapy modalities such as the active cycle of breathing technique (ACBT) and/ or manual hyperinflation (MHI).

The ACBT is a well proven method for sputum clearance (Lewis, Williams & Olds, 2012). This breathing technique is said to be less effective when used in isolation as compared to when using it in conjunction with a head-down tilt (Cecins et al, 1999). However, in a study conducted by Cecins et al (1999), subjects with bronchiectasis, preferred doing ACBT in a horizontal position and were also less breathless (2.3 vs. 3.3) on the visual analogue scale (Cecins et al, 1999). This may be due to the fact that these patients need to carry out this treatment daily and adherence was found to be better in a horizontal position. Due to the possibility of eliciting shortness of breath in individuals when they are tilted head-down it is therefore advisable to monitor shortness of breath to ensure subjective tolerance of said position. The efficacy of gravity-assisted drainage has been well described in spontaneously breathing people with chronic sputum-production (Sutton et al, 1992; Selsby & Jones, 1990) and is often used by cardiopulmonary physiotherapists. Its use however is not restricted to only the spontaneously breathing population.

A head-down tilt position with the addition of MHI in a ventilated patient aids secretion removal. The head-down tilt allows gravity to assist in secretion flow as well as access areas of the lungs that are more difficult to clear in a conventional supine position (Berney, Denehey & Pretto, 2004). Manual hyperinflation has been postulated to clear secretions by the generation of annular two phase gas liquid flow (Maxwell & Ellis, 2002). The addition of a head-down tilt to MHI increases sputum production by 25 percent and expiratory flow by eight percent (Berney et al, 2004). In addition, the head-down tilt position can also improve pulmonary mechanics in specific population groups such as people suffering from cystic fibrosis or who have a spinal cord injury.

Gravity affects the positioning of the abdominal contents and how it interacts with the diaphragm. For patients with a neurological impairment, abdominal positioning is an important

factor in respiratory function. The diaphragm rests at a higher position in such patients, approximately the level of the fifth rib due to the abdominal contents forcing the intestines higher. The diaphragm mainly moves superiorly and laterally putting it at a mechanical disadvantage (Cameron et al, 1955; Slack & Shucart, 1994; Frowenfelter & Dean, 1996; Winslow & Rozovsky, 2003). An abdominal binder increases the apposition of the diaphragm relative to the caudal circumference of the rib cage (Olive et al, 2002). This reconfiguration increases tidal volume and improves efficiency of the ventilatory mechanics by influencing rib cage motion over the inspiratory capacity in patients with tetraplegia (Olive et al 2002). Placing a patient with a spinal cord injury in a head-down tilt position has the same physiological consequences as using an abdominal binder. Moreover findings suggest that an increased cardiac output caused by the head-down position, increases blood flow to the diaphragm and therefore enhances the ability to perform spontaneous breathing trials in spinal cord patients who are ventilated. An increased cardiac output may last as long as 120 minutes in some patients (Gutierrez, 2010). Individuals besides those with spinal cord injuries also benefit from the head-down tilt position.

Patients with cystic fibrosis use the head-down tilt position to remove secretions. This position has been shown to be more effective than supine or prone positioning to remove excess secretions (Button et al, 2003). Secretions are a viscous fluid and by putting the lungs in a dependant position, the sputum can flow towards the central region allowing a cough or huff to expectorate it. However there is a higher incidence of gastro-oesophageal reflux associated with a head-down tilt in patients with cystic fibrosis (Button et al, 2003). Other population groups, such as those with COPD may also benefit from the head-down tilt position.

Patients with COPD have hyperinflated lungs and flattened diaphragms due to airway obstruction, shortened inspiratory muscles and air trapping (Yamaguti et al, 2008). Due to the anatomical change in diaphragm position, a contraction of the diaphragm is inefficient due to the position of the muscle fibres on the length tension curve. The head-down tilt position causes the abdominal contents to push on the caudal part of the diaphragm cranially, thereby positioning it into a more normal anatomical position. The diaphragm therefore rests higher and is more mechanically efficient in this position (De Troyer, 1983). For patients with COPD, the head-down tilt position may give relief from dyspnoea due to functioning more effectively.

There would be a concurrent decrease in accessory muscle usage, minute ventilation and reduced upper chest breathing pattern (Dean, 2006). Patients that experience abnormal pathology in their lung bases may benefit from a head-down tilt position as this would then favour a better ventilation perfusion matching and would allow expiratory flow rates to improve by eight percent (Dean, 2006).

The head-down tilt position is not suitable for everyone and if it is used in clinical practice individuals should be monitored closely for any adverse effects. Patients with respiratory muscle fatigue may have increased respiratory muscle distress due to the added restrictive loading on the diaphragm due to the weight of the abdominal contents. Body positions therefore need to be prescribed on an individual basis. Considerations should be taken into account of the multiple factors that impair oxygenation as well as improve it prior to performing head-down tilting. The above mentioned research literature however demonstrates that head-down tilt positions are often used by cardiopulmonary physiotherapists to achieve specific aims. It is however not known if a head-down tilt position can be utilised to facilitate a stretch of the diaphragm.

2.4 THE INFLUENCE OF STRETCH ON MUSCLE LENGTH

The position of the body affects the respiratory muscles' ability to function. A quick stretch of the intercostal muscles in a supine or semi recumbent position influences both inspiratory and expiratory muscles thereby affecting the respiratory system's functioning (Puckree, Cerney & Bishop, 2002). Gaseous exchange and breathing pattern change continuously and are influenced by the body's position as well as length of the respiratory muscles. In all skeletal muscles, an optimal muscle length allows not only an optimal range of muscle extensibility and joint motion but also optimal tendon length, an overlap of contractile tissue fragments and overall muscle thickness so that the muscles can generate the amount of active and passive tension required during function (Weppler & Magnusson, 2010).

There are many view points when it comes to offering an explanation for skeletal muscle extensibility after an intermittent stretch on a muscle. These include visco-elastic deformation, plastic deformation, increased length of sarcomeres in the series, neuromuscular relaxation and sensory theory (Weppler & Magnusson, 2010). Skeletal muscle is visco-elastic which

means that it resumes its original length once the tensile force is removed. However, skeletal muscles responses are time and rate dependant as well as dependant on the muscles intrinsic elasticity (Ozkaya, 1999; Magnussson, 1998). Studies on the hamstring and plantar flexors in human subjects have demonstrated that the changes in length on these skeletal muscles vary depending on the duration that the stretch is applied (McNair et al, 2001; Duong et al, 2001). Therefore the longer the stretch is applied the greater the elongation that occurs. This elongation is however dependent on the type of stretch as well as the intrinsic property of the muscle itself.

Plastic deformation is the permanent deformation of connective tissue (Chang et al, 2001). This would require a stretch with intensity to pull the muscle fibres past the elastic limit and into the plastic region. The muscle would therefore not return to its original length but would remain permanently lengthened (Enoka, 2002). For plastic deformation to take place a longer duration and an increased stretching force would be required compared to visco-elastic deformation. However, results are inconclusive whether this increased length by plastic deformation is actually the anatomical length for that muscle. If the muscle is stretched beyond its normal length, an increased functioning does not correspond to an increased length.

An increased muscle length that is generated by a stretch has been proposed by increasing the number of sarcomeres, the unit that the muscles are comprised of. Animal studies show that prolonged immobilisation in fully extended positions does increase sarcomeres but suggests no change in muscle length as the increase in sarcomere numbers is offset by the decrease in sarcomere length (Weppler & Magnusson, 2010). The neuromuscular relaxation theory suggests an involuntary contraction of a muscle due to a ‘stretch reflex’. Therefore the quicker a stretch is applied, the more a muscle involuntarily tenses and actually shortens. This can limit muscle elongation therefore a slow applied stretch involves relaxation of the muscle being stretched (Nelson & Bandy, 2004; Winters et al, 2004; Depino et al, 2000). A slow stretch appears to generate increased elongation compared to a quick stretch.

Modified sensation causes an increase in elongation of the muscle. The length gained during a stretching programme is only transient but there is increased muscle extensibility which can be due to modified sensation. The subjective perception of the stretch therefore changes,

allowing the person to increase range of motion because of a cognitive change of sensation (Weppler & Magnusson, 2010). This theory may explain why an ankle stretch on a spinal cord patient does not change range of motion as the sensation cannot be felt by the patient (Harvey et al, 2000).

Stretching has been used by physiotherapists for many decades. Skeletal muscles are the most commonly stretched muscles. This is done to improve the length of a muscle and therefore the range of motion of the corresponding joint. Reed and McNair (2011) found that a simple stretching exercise programme was effective in the long term management of older adults with knee osteoarthritis as a way of improving range of motion. It is well known that if a muscle is not used it becomes shortened with decreased extensibility and accompanied joint stiffness as demonstrated by Feland et al (2001) using the hamstring muscle as an example. If a muscle such as the hamstring is shortened improvements can be made to this muscle in both the short and long term by a stretching programme (Gajdosik et al, 2005; Feland et al, 2001). Stretching has also been used successfully in patients with a neurological condition.

Stretching can reduce spasticity following traumatic brain injury. After a brain injury there is often spasticity due to the disruption of signals from the damaged area. A prolonged muscle stretch of 10 to 30 minutes duration is effective in reducing the spasticity immediately and for 35 minutes post stretch in children with brain injury (Leong, 2002). This would allow the muscle to regain a more normal anatomical length and therefore allow more range at the affected joints allowing a more normal functioning for that muscle. However not all stretching has proved to be beneficial.

Pre-exercise stretching decreases muscle force and reduce muscle power. A static stretch of duration greater than 60 seconds has detrimental effects on muscle performance. Shorter duration stretches can be performed as a pre-exercise warm up without compromising maximal muscle performance (Kay & Blazevich, 2012).

Active and passive stretching programmes have proven to be equally beneficial in normal healthy individuals. There is no greater change in length or duration of change in length, when an individual received a stretch from an external source or provides the stretch sensation by themselves. A randomised trial tested hip flexor active stretching versus passive

stretching and found it was equally effective in improving hip extension range of motion (Winters et al, 2004). Both the passive and active stretches were held for 30 seconds and repeated 10 times. This is important with regard to the current research as the diaphragm would be passively stretched by the abdominal contents without the volunteer feeling a stretch or being aware of any change in length to the diaphragm.

The current research chose a duration of 30 seconds and two minutes based on current stretching procedures for other skeletal muscles. The fact that the stretch would be passive was not thought to influence the results obtained compared to an active stretch.

The diaphragm as well as the intercostal muscles contains muscle spindles. These muscle spindles are sensory and respond to elongation. As the muscle is elongated a signal is sent to the anterior horn cell in the spinal cord. The neurons in the anterior horn cell recruits more fibres to contract. This increases the strength of the contraction of the muscle. This may be useful when there is decreased compliance or increased airway resistance. Hypothetically stretching the diaphragm and ribs may activate this stretch reflex and help a patient take a deeper breath. This could be measured by their peak expiratory flow rate (PEFR) as they exhaled the increased volume. Research has not been done in the past to prove the therapeutic role of proprioreceptive neuro-facilitation technique based on the stretch reflex theory changing pulmonary function (Frownfelter & Dean, 2006).

Stretching the intercostal muscles enhances diaphragm activity. The intercostal muscles are part of the respiratory musculature; when they are stretched they influence the remainder of the respiratory muscles to adapt as well. Stretching of the third and eighth intercostal spaces during inspiration lengthened the diaphragm as shown by EMG amplitude (Puckree et al, 2002). This facilitation could result from muscle spindle input projecting to both levels on the neural axis or from excitation of the phrenic nerve. In conscious humans, it is also possible that cortical influences play a role as both central pattern generator and central rhythm generator are influenced by stretch (Puckree et al, 2002).

Stretching of the intercostal muscles improves lung capacity. This is as a result of increased muscle length and improved power which may improve oxygenation and ventilation (Crowe et al, 2005). A stiff chest wall with decreased range of motion implies abnormal biomechanics.

This leads to an increased functional residual capacity (FRC) as well as an increase in residual volume (RV) in patients with COPD (Scanalan, 1995). When there is a decreased compliance of the rib cage, there is usually atrophy of the diaphragm as well as intercostal muscles. This leads to rib cage immobility, shortness of breath as well as a decrease in spontaneous breathing (Leelarungrayub et al, 2009), as seen commonly in patients suffering from COPD. Thoracic expansion was therefore measured to assess whether the increased muscle length of the diaphragm improved thoracic mobility which should in turn improve lung capacity.

Postural changes are commonly found amongst the population suffering from obstructive airway disease. They include reduced peripheral muscle strength, poor muscle endurance, muscle fibre atrophy and changes in rib cage configuration as well as vertebral deformities (Heneghan et al, 2012). A short pectoralis major muscle is often found pulling the humerus medially, and influencing the scapulae. A hold relax technique specifically to the pectoralis major muscle is capable of increasing its range of motion but also of increasing vital capacity thereby improving the restrictive component of COPD (O Shea et al, 2004; Casabuti et al, 2004). Patients with COPD have a barrel shaped chest with lungs that are usually hyperinflated. The diaphragm is shortened, decreasing the dome shape and leading to air trapping as well as increased reserve (Kang et al, 2011). Some management strategies suggested to increasing its length include musculoskeletal techniques aiming to increase flexibility of muscles, such as passive stretching, contraction of the agonist against resistance, self-stretching, passive mobilisation, and massage (Potter, 2002; Vibbek, 1991). These strategies aim to return the diaphragm to a normal anatomical position.

Thoracic movement disorders can result from prolonged mechanical ventilation. The air trapping and hyperinflation that is often ventilator induced, causes the intercostals to lengthen as well as the diaphragm to weaken and shorten especially if continuous mandatory ventilation mode is used (Hussain et al, 2010). This weakness is due to not only mechanical ventilation but the ICU stay itself which leads to a decrease in exercise tolerance and an overall disuse of the skeletal muscles (Fink et al, 2008; Winkleman, 2008). Active participation is the ideal in a critical care unit but when not possible passive stretching and mobilisation is the start of an early rehabilitation programme (Gosselink et al, 2008). Passive movements and stretches have been described as movements without volitional control and

are commonly used in the critical care setting. They increase the metabolic and hemodynamic demands as well as increasing venous return and stroke volume (Boulain et al, 2002, Muraki et al, 2000).

The shortened and weak muscles of ICU patients are often attributed to protein loss and fibre atrophy. Muscle training and stretches have shown to be beneficial in preventing this atrophy (Chang et al, 2005). A number of mechanisms exist that may help explain why stretch and movement prevents atrophy. The integrin receptors on the cell surface and the associated intracellular cytoskeletal microtubular system may permit direct transmission from the extracellular matrix to intracellular protein synthesis. A second reason may be that the influx of sodium and calcium through the stretch activated channels with intracellular signal may initiate mechanotransduction. Lastly, the secondary messengers especially adenylate cyclise and phospholipase C from membrane bound enzyme complexes may stimulate early gene and cell replication (Grifiths, 1997). The above mentioned research literature demonstrates that a stretch is often used by physiotherapists to achieve specific aims. It is however not known if stretching the diaphragm can be achieved by using a head-down tilt position.

2.5 THE DIAPHRAGM

The diaphragm is a musculo-tendinous structure that separates the thoracic and abdominal contents and is therefore vital to both compartments' functioning. Embryologically, it arises from the pleural-peritoneal membranes and body wall, the dorsal mesentery of the oesophagus and the septum transversum. It originates from the chest and abdominal wall circumferentially and converges to a long central tendon at the apex of the dome which is fused to the pericardium above. It arises from the posterior aspect of the first to third lumbar vertebrae, laterally from the inner surface of the seventh to twelfth ribs as well as the lateral abdominal muscles bilaterally. The xiphisternum provides the anterior attachment. The posterior attachments are therefore lower than those anteriorly and the right dome lies higher than the left. It is pierced at the crura by the inferior vena cava, oesophagus and aorta from anterior to posterior. It is covered by the parietal pleura and peritoneum except at the liver which lies adjacent to the diaphragm itself (Morgan, Watcyn-Jones & Garner, 2010). The diaphragm has an immediate anatomical relationship with the pleural space, lungs,

pericardium and heart above and with the liver, spleen, stomach and splenic flexure of the large intestines from below (Vovoda et al, 2011). It is the body's largest transverse muscle.

The diaphragm is required to work almost continually, unlike other skeletal muscles, such as the quadriceps muscles; there is no rest period or inactivity. As the diaphragm's main function is ventilation, and ventilation is a continuous process the diaphragm must be able to function on a continuous basis. It therefore needs to be more fatigue resistant than other skeletal muscles while managing to have long term rhythmical contractions. The muscle fibre composition is made up of 21 percent fast oxidative fibres, 24 percent fast glycotic fibres and 55 percent slow oxidative fibres (Polla et al, 2004). Endurance, fatigue resistance and continuous contractions of the diaphragm are of paramount importance to the body's survival. The composition of the muscle itself is therefore suitable to its function.

The diaphragm is the main muscle for inspiration. At rest in a healthy individual it generates tidal volume by moving in a cranial caudal direction. It is also responsible for 75 percent of thoracic movement (Voyvoda et al, 2011). Normal, quiet breathing is accomplished almost entirely by the upward and downward movement of the diaphragm. On exertion the elastic forces used in expiration are not rapid enough, thus extra force is required. The abdominal contents push upwards on the diaphragm which increases forced exhalation (Kantarci et al, 2004).

In the last few years, it has been possible to measure the diaphragm non-invasively by using diagnostic ultrasound. The diaphragm and its motion can be measured by an anterior subcostal approach via transverse scanning with the diagnostic ultrasound. A free-hand transducer is placed on the abdomen at the mid-clavicular line immediately below the costal margin (Testa et al, 2010). The diaphragm can be expected to move 10-20 millimetres at rest (Boussages et al, 09) and 70-110 millimetres on forceful breathing (Yamaguti et al, 2010; Gierada et al, 1995). The biggest limitation when using diagnostic ultrasound to measure diaphragm motion is the difficulty in observing the left hemidiaphraghm. This is due to the gastric contents of the stomach and the poor acoustic window given by the spleen (Scot, 2006). Diaphragm movement is not a constant for everyone.

Certain variables will influence the diaphragm's function and degree of flexibility. There are also said to be differences between the right and left sides. The degree of flexibility has been shown to be 49.23 millimetres (± 10.98 millimetres) on the right and comparatively 50.17 millimetres (± 11.73 millimetres) on the left (Kantarci et al, 2004). Diaphragm mobility has been found to be lower in women than in men ($p < 0.05$) (Boussuges et al, 2009). Mean diaphragm motion is also decreased in underweight versus normal weight, overweight or obese people. Waist circumference as well as age also influences factors for diaphragm mobility with a lower age and waist circumference leading to less diaphragm movement (Kantarci et al, 2004). Clearly an understanding of normal diaphragm mechanics is paramount so that we can detect a weak, paralysed or short diaphragm and its corresponding decreased respiratory capabilities.

Ventilation is brought about by pressure and volume changes in the lungs due to muscles contracting or relaxing. A change in pressure between the atmosphere and the alveoli allows air to flow between the two spaces. As the diaphragm moves downward, an increased volume occurs in the thoracic space causing a drop in pressure. This negative intrathoracic pressure during inspiration occurs due to contracture of the striated muscles which shorten and flatten the diaphragm. Atmospheric pressure therefore is higher than the pressure within the lungs and air moves into the respiratory system (Ruppel, 2009). This continuous change between negative and positive pressure in the lungs is dependent on muscular contraction, strength of the diaphragm, endurance as well as the role of the abdominal contents.

The abdominal contents, the diaphragm and the mechanics of respiration are intractably linked. When in supine, the weight of the abdominal contents forces the diaphragm into the thoracic cavity. During inspiration the muscle pull down twenty millimetres, increasing the volume of the thoracic area and compressing the abdominal contents. This can extend to 110 millimetres of muscle pull downwards during maximal inspiration (Testa et al, 2011).

Exhalation occurs as a result of diaphragm relaxation. The diaphragm elevates again to its resting position during exhalation which allows the abdominal contents to return to their normal position. Correlation between abdominal excursion and tidal volume was reported to be between 0.976-0.995 (Cohen, 1994). Consequently, the more the abdominal contents move, the greater the volume of air being delivered to the lungs. An increased mass of

abdominal contents due to ascites or an increased body mass index will influence the diaphragm by preventing its downward movement. This causes a decrease in lung volume which in turn causes a decrease in difference between atmospheric and alveoli pressure. This would negatively impact on ventilation causing a continually decreased lung volume. Conversely a continually increased lung volume is also detrimental to respiratory function.

2.6 FACTORS THAT INFLUENCE DIAPHRAGM STRUCTURE AND FUNCTION

A constant increase in lung volume as a result of certain diseases leads to a flattening of the diaphragm as mentioned earlier. This causes the lower ribs to be pulled in during inspiration and results in air trapping (Yamguti et al, 2008). As compensation, accessory muscles are used; however this increases the work of breathing and is less efficient than the normal anatomical configuration (Yamguti et al, 2008). The impaired respiratory muscle function primarily results from the abnormal flow volume performance of the lung, which decreases pulmonary compliance and imposes a mechanical strain on the inspiratory muscles (Yamaguti et al, 2008). The diaphragm does not sit in its anatomical position and therefore struggles to maintain its normal load. Hence the main function of the diaphragm becomes impaired as the volume of air that is inspired is decreased.

Weakness of the diaphragm can be multifactoral in origin. These problems may include intrinsic abnormalities of the diaphragm such as muscle dystrophy or result from a previous injury (Testa et al, 2011).The weakness may be as a result of processes occurring in the adjacent lung such as basal pulmonary atelectasis, pneumonia, tumour or masses in the lungs (Gerscovitch et al, 2001). A mass in the abdomen or peritoneum may also decrease diaphragm motion. Central nervous system diseases including infarction, tumour or injury to the phrenic nerve may impair diaphragm motion (Gerscovitch et al, 2001). Skeletal muscle wasting also causes weakness of both the general peripheral muscles as well as the muscles of ventilation. The skeletal muscles waste as a result of protein degradation or a decrease in protein synthesis or as a result of a combination of these factors (Bhatnagar & Kumar, 2012). Skeletal muscle wasting can be due to a variety of reasons such as ageing or chronic diseases or disuse (Jackman & Kandarian, 2004). Chronic diseases that result in skeletal muscle weakness are diabetes mellitus, COPD, heart failure, renal failure and cancer. Wasting of the skeletal muscles due to disuse can be further broken down into immobility,

denervation and unloading (Watson et al, 2001). There is no published evidence on whether immobility in isolation leads to specifically diaphragm or respiratory muscle weakness as opposed to general skeletal weakness.

The respiratory muscles form part of the skeletal muscles and are therefore subject to the changes that the rest of the skeletal muscles endure. The majority of the time, the respiratory muscles do not weaken in isolation to the rest of the body. Seventy percent of patients with sepsis and multiple organ failure develop neuromuscular weakness (Watson et al, 2001). Patients in the ICU showed marked skeletal muscle weakness as well as a loss of normal functioning. These patients are already at a marked disadvantage because of the loss of general function due to the decreased skeletal mass as a result of wasting and weakness. Immobility alone is not however the only factor when it comes to weakness.

The following paragraphs demonstrate how cardiorespiratory physiotherapists work with patients with trauma, acute conditions or with certain interventions such as mechanical ventilation deal with diaphragm dysfunction. If we evaluate how a head-down tilt affects diaphragm length, a stretching manoeuvre could possibly be used as a treatment modality in these groups of patients.

Corticosteroids and neuromuscular blockers influence the strength of the muscles, thus making them weaker. Both of these drugs while being lifesaving can also have substantial harmful effects on the musculoskeletal system. It must be noted however that while these drugs cause weakness, there is still significant weakness in a critical care setting even when these drugs are not a factor (Ochala et al, 2009). Sepsis and hyperglycaemia have also been shown to be major risk factors for muscle weakness (Latronico & Bolton, 2011). While having a general systemic effect, the weakness on the respiratory system is most strongly pronounced (Callahan, 2009). The same can also be said of weakness that results post surgery.

Thoracic or upper abdominal surgery causes weakness of the diaphragm due to pain. As a result the diaphragm works less efficiently. Less air descends into the basal segments of the lungs due to an increased apical pattern of breathing. Volume loss or atelectasis of the basal plates is common after upper abdominal or thoracic surgery. There is a decrease in

diaphragm strength within two to eight hours post operatively. The diaphragm does not go through its full range of motion as this causes pain over the wound site. A decreased tidal volume then negatively influences respiration. There is a return to normal values two weeks after surgery (Romanini et al, 2007). Patients who undergo abdominal or thoracic surgery often require mechanical ventilation post operatively.

Mechanical ventilation results in diaphragm weakness (Hermans et al, 2010). Studies indicate that mechanical ventilation induces diaphragm weakness and myofiber atrophy (Callahan & Supinski, 2010; Hermans et al, 2010; Hussain et al, 2010; Callahan, 2009). Diaphragm weakness, injury and atrophy occur rapidly and are significantly correlated with the duration of ventilator support (Jaber et al, 2011). Diaphragm weakness due to mechanical ventilation has severe consequences such as weaning difficulty (Gilette & Hess, 2001). Over the last decade, a trend to decrease tidal volume to prevent barotrauma has been well proven. This decreased lung volume results in a decreased diaphragm excursion. The combination of decreased diaphragm movement, which is passive, as well as the loss of strength resulting from the mechanical ventilation may lead to a shortened diaphragm. There is no current research however that proves that the diaphragm shortens with mechanical ventilation.

Mechanical ventilation, especially continuous mandatory ventilation, causes disuse atrophy this is due to the fact that continuous mandatory ventilation can be life saving but its detrimental effect on the diaphragm leads to severe weakness. This has been termed ‘ventilator induced diaphragm dysfunction’ (Hermans et al, 2010; Callahan, 2009). This is as continuous mandatory ventilation allows no spontaneous respiratory muscle activity. This mode therefore decreases diaphragm strength and causes muscle fibre atrophy as well as fibre remodelling. These changes are reflected microscopically (McClung et al, 2007).

Microscopic and molecular changes are noted post continuous mandatory ventilation. It follows that the weakness seen clinically is as a result of changes within the structure of the cell itself, namely decrease protein synthesis and increase protein breakdown (McClung et al, 2007). The changes that are seen are a decrease in fibre cross section and an increase in the development of oxidative stress. Prolonged continuous mandatory ventilation triggers activation of the autophagy pathway, which increases protein oxidation and increases

expression of FOX 01 gene resulting in diaphragm disuse (Hussain et al, 2010). Mechanical ventilation is not the only factor which causes diaphragm weakness.

Respiratory muscle weakness due to mechanical ventilation can increase the difficulty of weaning in animals (Ochala et al, 2009). This may result in respiratory failure post extubation. Mice that were mechanically ventilated for five days had a decrease in force generation and decreased size of diaphragm fibres which corresponded to increased weaning time (Callahan & Supinski, 2010). The longer one stays on the ventilator the more dependant one becomes and the harder it is to be successfully extubated. These findings are not isolated to animals; similar results have been seen in humans (Radell et al, 2004).

Prolonged time on mechanical ventilation, the longer it can be expected for the weaning process to take. This is due to the fact that the respiratory muscles become progressively weaker while the patient is being ventilated. Time spent on weaning is estimated at about 40 percent of total time spent on the ventilator (Hermans et al, 2010). It is therefore advisable to try and extubate a patient as early as possible to prevent all the associated complications of ventilation and the difficulty that will ensue if the respiratory muscles get progressively weaker and therefore work less efficiently (Jaber et al, 2011). However, weakness of the diaphragm is not isolated to only mechanically ventilated patients.

Increased time in an intensive care unit also contributes to a loss of strength in both ventilated and non ventilated patients. Patients in an intensive care unit have weaker diaphragms than those not in this environment although a specific diagnosis was not linked with the diaphragm weakness. Rather, an increased duration of intensive care unit stay contributes to loss of strength (Jaber et al, 2011). This is contradictory in terms of trying to improve a patient's condition as the longer the patient needs to stay in an intensive unit, because of other contributing factors that brought her/him in initially, the longer he/she is likely to remain as a result of progressive weakness of the diaphragm.

Respiratory muscle weakness can develop as a result of critical illness myopathy and polyneuropathy. Critical illness polyneuropathy is a distal axonal sensory-motor polyneuropathy affecting the limb and respiratory muscles. Low measurements on respiratory muscle strength correlate with limb muscle weakness and are associated with

delayed extubation, prolonged ventilation and unplanned readmission to an intensive care unit (Latronico & Bolton, 2011; De Jonghe et al, 2007). Consequently weak respiratory muscles correlate with a decrease in respiratory function.

A flattened diaphragm increases the work of breathing. A diaphragm that is flattened due to air trapping is required to operate at a mechanical disadvantage due to the abnormal position. Alterations in diaphragm position have been shown to change pulmonary function (Kang et al, 2011). The diaphragm is required to work harder to generate the same tidal volumes. When this becomes impossible the accessory muscles are also used, as well as substitution strategies such as increasing respiratory rate. This will in fact perpetuate the problem as faster breaths decrease tidal volume. Air thus does not reach the bases of the lungs resulting in further air trapping, hyperinflation and shortening of the diaphragm.

Weak respiratory muscles lead to decreased ventilation. As the muscles are working less, there is a decreased flow of air which results in air trapping. This can progress to hyperinflation which leads to an increased end expiratory volume. Diaphragm mobility directly correlates with airway obstruction, vital capacity and ventilator capacity as measured by functional vital capacity (Kang et al, 2011). Short inspiratory muscles are therefore responsible for the decrease in force generation. To maintain adequate supply for the demands of the body, increased work is needed.

A short diaphragm increases work of breathing. It can be hypothesised that by increasing its length by a quick stretch there would be a change in length which is closer to the anatomical normal. There would be a corresponding decrease in work of breathing and a return to normal respiratory muscle strength. This has shown to be the case in some surgeries (Gorman et al, 2005).

An increased diaphragm length occurs in lung volume reduction surgery. As the diseased lung is removed, it allows more space for the diaphragm to return to its previous dome shaped position. Increased diaphragm length results in lower motor unit firing rates and reduced breathing effort. This results in an improved quality of life and exercise performance following lung volume reduction surgery (Gorman et al, 2005). A change in diaphragm length has therefore been shown to exist with functional changes noted.

The previous paragraphs demonstrate that cardiorespiratory therapists work in both acute and chronic settings treating patients who suffer from diaphragm dysfunction due to a variety of causes. Ventilator induced diaphragm dysfunction has been well researched recently, conclusively proving that mechanical ventilation over a prolonged period weakens the diaphragm and leads to weaning difficulty (Gilette & Hess, 2001). The recent trend to give lower tidal volumes to prevent barotrauma could potentially cause a decreased diaphragm excursion. This is further exacerbated if the mode of ventilation is continuous mandatory ventilation as the movement is also passive. It can be postulated that the combination of decreased diaphragm excursion and weakness from mechanical ventilation may cause the diaphragm to shorten. However there is no published literature proving that mechanical ventilation causes diaphragm shortening. The head-down tilt position used as a stretching technique may be a useful adjunct to current treatment options in these patients.

2.7 CONCLUSION

From the information presented in the literature review it is reasonable to hypothesise that one could attempt to change the length of the diaphragm by stretching it in a head-down tilt position. Currently, there is no research to describe if stretching in this manner can influence the length and what time frame is necessary to achieve a stretch. Moreover, there is no evidence on whether this possible increase in length can influence respiratory parameters such as peak flow and thoracic expansion.

The next chapter in this research report will describe the methodology that was followed to conduct the data collection to answer the research question.

CHAPTER 3

3. METHODOLOGY

The methodology discussed in this chapter is based on the findings of the literature review discussed in Chapter 2. The study design, sample population, inclusion and exclusion criteria as well as instrumentation and data collection procedure used during the study are discussed in detail. An explanation of the pilot study, its aims, methodology, statistics as well as its implications on the main study is discussed. The main methods for data analysis are given as well as the ethical considerations that were taken into account when the study was conducted.

3.1 STUDY DESIGN

A quasi-experimental study design was used for the data collection process. Each participant underwent a baseline assessment as well as another four re-assessments after each change in position. The trial was completed in one session and no follow up sessions were needed with study participants. The different assessment positions were coded as follows:

Table 3.1 Numbers assigned to the different head down tilt positions and angles

Position	**No**
Initial at rest assessment	1
After lying for 30 seconds in a 15 degree head down tilt position	2
After lying for two minutes in a 15 degree head down tilt position	3
After lying for 30 seconds in a 30 degree head down tilt position	4
After lying for two minutes in a 30 degree head down tilt position	5

After each assessment position, study participants returned to the initial rest position and had readings taken before progressing to the next assessment position.

3.2 SUBJECTS

3.2.1 Source of subjects

Participants for this study were recruited from the Department of Physiotherapy at the University of the Witwatersrand. Undergraduate physiotherapy students were invited to participate in this study. The study sample consisted of first to fourth year physiotherapy students.

3.2.2 Sample size

The outcome measures of this study were mainly numerical variables. By convention ten subjects were included in the study for every outcome measured. There were seven outcome measures and therefore a minimum of 70 subjects were required. This power calculation was suggested by the statisticians involved with the study. The pilot study consisted of 10 percent of the minimum sample suggested, thus seven participants constituted the pilot study.

3.2.3.1 Inclusion criteria

Undergraduate physiotherapy students who attended the University of the Witwatersrand in 2012 were considered for inclusion in the study. Students had to be between the ages of 18 and 25 years and in general good health. Students were selected as they were all young adult participants within a narrow age range that minimised confounding the data collected with age-related changes in cardiovascular (CVS) and cardiopulmonary function.

3.2.3.2 Exclusion criteria

Postgraduate students were excluded as they were not available to be tested as easily as the undergraduate students. Graduate students were often older and also fell outside the age range of 25 years.

Undergraduate students were excluded from the study if they presented with any of the following:

- Any student with a body mass index (BMI) greater than 30 kg/m^2
- Any student with a headache on the day of testing
- A current or previous smoking history
- Known pregnancy
- A medical history of epilepsy
- Any known current CVS, cardiopulmonary, circulatory or endocrine problems.

3.2.3 Variables

3.2.3.1 Independent variables

Diaphragm length.

3.2.3.2 Dependent variables

Diaphragm displacement, thoracic expansion and peak expiratory flow rate.

3.2.3.3 Confounding variables

Heart rate, blood pressure, oxygen saturation, perceived breathlessness.

3.3 INSTRUMENTATION AND OUTCOME MEASURES

3.3.1. Diagnostic ultrasound machine

The ultrasound machine that was used was the DO-6600/DO-6500 digital ultrasonic diagnostic imaging system with a 35C50EA ultrasonic transducer by Shenzhen Mind Ray Bio Medical Electronics Company limited. This machine was used to visualise and measure the excursion of the diaphragm and its change of length via M-Mode ultrasound. This change in length was measured in millimetres. Prior to the pilot study, a tutorial was held with a musculo-skeletal physiotherapy lecturer at the University of the Witwatersrand who had recently completed her own PhD research using the same ultrasound machine. During the tutorial valuable practical information was gained such as saving of information, use of the transducer, set up as well as ease of capturing the picture. Practice sessions were also held prior to the pilot study. These sessions aimed at familiarising the researcher with the ultrasound machine as well as the procedures that would be followed once the pilot study was initiated. These sessions involved, the physiotherapy lecturer who had used the ultrasound machine in her doctorate, as well as the researcher's supervisor, the researcher and a family member who all acted as models.

In previous reports when using diagnostic ultrasound, there had been low intra observer variability($r = 0.96$, $p < 0.001$) (Boussuges et al, 2009; Houston et al, 1994). This is true for resting as well as forced breathing with the biggest variability being found by inexperienced operators ($p<0.01$) (Testa et al, 2011). The importance of a firm hand motion was stressed by Testa et al (2011) for reliability to be certain. The above mentioned tutorial sessions and the pilot study were therefore means of improving the intra-rater reliability of the researcher and lessening the variability in the technique when using the diagnostic ultrasound machine during the main study.

The M-mode technique was chosen over the B-mode, as it allowed the researcher to measure a change in length in one picture as opposed to having to take two images and then measure between them. The M-mode records a mono dimensional time dependent pattern of

the diaphragm's cranial caudal movement. This gives a reproducible permanent trace which other parameters can be more accurately measured on than a B-mode image (Yamaguti et al, 2007; Jiang et al, 2004; Li et al, 2004; Harris et al, 1983).

Ultrasonography by an anterior subcostal approach has been proven to be safe, feasible and reliable (Testa et al, 2011). It is a relatively easy and non-invasive way to assess the diaphragm. It proved possible for the researcher to visualise the diaphragm in this position and was therefore chosen as the measuring technique in this research study to evaluate diaphragm displacement following a head-down tilting stretch position.

The following steps were undertaken:

- Each individual was seated in a backless chair.
- The eighth intercostal space was exposed anteriorly and posteriorly.
- The ultrasound probe was placed between the midaxillary line and midclavicular line at the eighth intercostal space.
- Each individual was asked to breathe at their normal tidal volume.
- After five tidal breaths, the screen was frozen at the end of passive expiration.
- The leading edge of the diaphragm was marked on screen using an electronic marker.
- The position of the diaphragm at the end of inspiration was then marked electronically.
- The distance between the two was measured with built in electronic callipers in millimetres (Appendix 1).

3.3.2. Wright peak flow meter

The Wright peak flow meter was used to measure peak expiratory flow rate which is measured in litres per minute. The predicted peak expiratory flow rate was calculated for each individual based on their gender, height and age. The chart that was used was the European Union (EU) scale for normal peak expiratory flow rate (Appendix 2).

The participants were seated when all measurements were taken in order to standardise the procedure. However, neither sitting nor standing was shown to significantly alter peak expiratory flow rate (McCoy et al, 2010). There has been widespread inaccuracy between different peak flow devices. This is especially true of old versus new peak flow devices.

Caution was advised if interchanging different devices even of the same model as a difference of 69.3L/min was found when comparing an old versus new Wright peak flow meter (Nazir et al, 2005). Studies have shown that the Galemed® peak flow meter underestimates the actual value while the Air Zone® meters overestimate spirometric values (Takara et al, 2010). However it is suggested that if one peak flow unit is used throughout testing procedures it shows good validity (Nazir et al, 2005). Therefore the same Wright peak flow meter was used throughout the data collection period.

The EU Wright peak flow meter predictor was found to be as accurate as the American Thoracic Society (ATS) Wright peak flow predictor (Pesola et al, 2010). Both predicted peak flow rates have a bias compared to a pneumotachometer and read significantly higher than peak flows derived spirometrically (Pesola et al, 2010). The EU model showed height to be a better predictor of peak flow rate than age (Wun et al, 2013).

In the current study the same Wright peak flow meter was used throughout testing. It was new and not used in a clinical setting before the data collection period started. All predicted values were read off the EU chart for predicted peak expiratory flow rates and based on gender, age and height. Hygiene was maintained by using disposable mouthpieces for every candidate.

3.3.3 Tape measure

A non-stretch tape measure with interval levels in centimetres was used to measure thoracic expansion. The tape measure ran from zero to 150 centimetres. A tape measure was used to measure healthy males and found to be highly reliable in terms of intra as well as inter-rater reliability. It is suggested that measuring with a non-stretch tape measure is the most useful way of measuring changes in thoracic excursion when values are expected to be greater than 0.6 cm (Bockenhauer et al, 2007).

Measurements of the chest wall circumference are often used by physiotherapists as a way of envisioning the amount of thoracic expansion and thereby how much the lower sections of

the lungs expand while taking a deep breath. A study that investigated the reliability of this measurement in patients with COPD found that if the same person measured a participant twice in one day there was good reliability (r = 0.84 - 0.95). However if two different people measured the same participant on the same day there was only fair to good inter-rater reliability (r = 0.69 - 0.89). If one person measured and then re-measured the same participant two days later there was good reliability (r = 0.64-0.84). For this reason each participant was measured by the same researcher and finished the assessment procedure in one time slot never completing an assessment at a later stage.

The measuring of thoracic range of motion was shown to be reliable and repeatable when using a wire type linear encoder whose wire is wrapped around the thorax. Subjects increased their thoracic range of motion when given a biofeedback system (Ando et al, 2011). For this reason no feedback was given to each participant so as to not bias them into trying to take a deeper breath to improve their score at the next assessment position.

3.3.4 Modified Borg Dyspnoea Scale

The modified Borg dyspnoea scale was used to assess the participants' subjective breathlessness before and after the head-down tilt interventions. The Borg scale was initially developed to assess the rate of perceived exertion (Borg, 1982). It has also been used to measure the subjective intensity of shortness of breath in healthy subjects while exercising (Bauseweina et al, 2007). It is now the most commonly used format to assess shortness of breath (Bauseweina et al, 2007; Burdon et al, 1982). It is said that the modified Borg dyspnoea scale is more reproducible than the visual analogue scale (VAS) when evaluating shortness of breath (Wilson & Jones, 1989). It was therefore selected as the dyspnoea tool in this study (Appendix 3).

The modified Borg dyspnea scale was found to be both a valid and reliable tool for assessing dyspnea amongst people suffering from COPD. It correlates well with clinical parameters and is therefore useful when assessing and monitoring patients suffering from shortness of breath. Patients themselves rated the modified Borg dyspnea scale with a high degree of satisfaction in terms of language use as well as adequate ability to express their subjective dyspnea feelings (Hareendran et al, 2012). The modified Borg dyspnea scale was also found

to have significant correlation to the peak expiratory flow rates when used in individuals living with COPD. This was compared at initial assessment when subjects complained of dyspnea and the peak expiratory flow rate was measured and again after treatment. The peak expiratory flow rate increased in correlation to the number on the modified Borg dyspnea scale decreasing in patients with COPD (Kendrick et al, 2000). In contrast to this, children with asthma who were under seven as well as their care givers had a negative correlation when measuring perceived breathlessness using the modified Borg dyspnea scale with peak expiratory flow rates (Parente et al, 2011).

This research study composed of healthy adult individuals attending a tertiary education institution. It was felt that the modified Borg dyspnea scale was an easily understandable and reproducible tool to assess breathlessness in the current study participants.

3.3.5 Portable weight scale

A portable weight scale was used to measure the participants' mass in kilograms. A portable scale was chosen as it was necessary for the researcher to pack it away after use as the movement laboratory was used by others researchers during the testing period. The Beurer GmbH was used which has a maximum weight of 150kg and a specificity of 100g. During the pilot study, each participant was measured twice. When the values showed the scale to have good reliability during assessment, one measurement was taken during the main study.

3.3.6 Stadiometer

The Adams MDW-160m stadiometer was used to measure the participants' height in metres. This was done by standing the subject against a stadiometer holding their head in the Frankfurt plane with the shoulders, buttocks and heels pressed against the stadiometer (Buchholz & Bugaresti, 2005). The researcher had the option of measuring the participants' height with this stadiometer or by using a non-stretch tape measure. The stadiometer was chosen as the method for assessment as based on the guidelines of the American College of Sport Medicine (2010).

3.3.7 Automated blood pressure and heart rate monitor

The BP3AG1 Micro Life automatic blood pressure monitor was used to gather blood pressure as well as heart rate information.

A study comparing readings from an automated blood pressure versus a mercury sphygmomanometer found that the automated blood pressure machine was not as accurate as the mercury with systolic blood pressure above 140mmHg and diastolic levels above 90. It therefore was not recommended for hypertensive patients (Pavlik et al, 2000). Systolic blood pressure was found to measure 3.9 points lower on an automated machine in adult psychiatric patients (Suokhrie et al, 2013). It has been suggested that this slight difference that causes the systolic blood pressure to be higher in conventional readings may be due to the 'white coat effect'. Readings taken on a manual automated blood pressure tended to be lower when the patient was left alone with the device compared to when a doctor came into the room with a sphygmomanometer to measure the pressure (Myers, 2006). Automatic blood pressure measurements are not problematic in the general population and have been validated in population surveys (Myers et al, 2008). These results may vary slightly with age and pulse pressure (Ni et al, 2006).

Due to the sample of the current study being young healthy adults, an automated monitor was chosen for ease of use.

3.3.8 Pulse oximeter

The pulse oximeter was used to measure the participants' oxygen saturation. An H-10 finger oximeter was used to record the data. Each participant had the pulse oximeter placed on the index finger of the left hand to prevent inaccuracy from the blood pressure cuff inflating on the right side concurrently. The participants rested both hands on their thighs while the measurements were being taken.

Pulse oximetry has been reported to be accurate within five percent ± two percent in vitro oximetry (Kissinger et al, 1991). Pulse oximeters are most accurate in the 70 to 100 percent saturation range, where readings usually do not vary more than one or two percent from a

blood gas analysis (Jensen et al, 1998). Moreover obtaining oxygen saturation via a blood gas analysis is painful for the patient and does not provide immediate or continuous patient monitoring. For these reasons monitoring oxygenation via a pulse oximeter is the gold standard (Pierson, 1990). Pulse oximeters work based on the spectrophotometric principles which are based on the law of Beer-Lambert (Jubran & Tobin, 1994). Lightweight probes direct filtered light which has a specific wave length through a finger, toe or earlobe. The saturation is gathered by converting the absorption from the spectrophotometric beams as they pass through the finger into a percentage by a processor stored algorithm (Adams, 2009).

There are however instances when readings are difficult to obtain from pulse oximetry and it is not as accurate as when it is in motion (Mendelson, 1992) in daylight and incandescent light (Hanning & Alexander-Williams, 1995) if the haemoglobin level is severely reduced (Schnapp & Cohen, 1990) or some colours of nail polish (Ralston et al, 1990). Finger probes appear more accurate than nose or earlobe probes due to lower perfusion in these areas (Mengelkoch et al, 1994). For all of the above reasons the oximeter was placed on the index finger of the left hand and the participant was asked not to move while the measurements were taken. Neither the lighting nor the nail polish colour in certain subjects prevented a reading being taken from participants.

All equipment for all participants was kept the same throughout testing. This was done to minimise the change that another apparatus even with the same function would have added to the results.

3.3.9 Assessment forms

An assessment form was used to capture the participant's information while doing data collection. The face validity of the assessment form was reviewed by the researcher's supervisors (Appendix 4)

3.3.10 Testing set up

Two plinths were set up in the Movement laboratory at the Physiotherapy department of the University of the Witwatersrand. One at a 15 degree and one at a 30 degrees head-down tilt position (Appendix 5). This was done by lifting the foot of the bed with wooden platforms. The plinths were then photographed. These pictures were then put on a computer where the angle between the floor and the plinth was measured using a protractor. Adjustments were made until the angles were 15 and 30 degrees respectively.

The ultrasound machine was placed on a table between the plinths with two chairs. One chair was for the examiner and one backless chair for the participant. This chair was used during assessments. All other research equipment was left in the room but packed away so that it was available at following sessions but did not disturb other research activities that took place during this period in the Movement laboratory.

3.4 ETHICAL CONSIDERATIONS

Ethical clearance was granted by the University of the Witwatersrand Ethics committee for research on human subjects; clearance certificate number M110517 (Appendix 6). Permission was requested and received from the Head of the Physiotherapy department at the University of the Witwatersrand to invite participation of the undergraduate students as well as the use of the facilities such as the Movement laboratory (Appendix 7). All study participants gave informed consent prior to study participation.

The following additional considerations were undertaken during the study:

- Participants' data was coded so that the data captured was not linked to a name.
- Collected information was kept confidential at all times.
- Participants were free to leave the study at any time and refusal to participate would not negatively affect them in any way.

The following forms were used to provide the participants with information as well as to protect their identity.

- An information sheet. This contained the details about the study and what the participants could expect during and after testing procedures (Appendix 8).
- A consent form. This form was used for the participants to agree to the study (Appendix 9).
- Coding form. This allowed the identity of the participant to remain private. Only the coding form had both the name as well as the coding number on the same form. The evaluation document had only the coding number and the information sheet only had the participants' names (Appendix 10).

3.5 PROCEDURE

3.5.1 Pilot Study

3.5.1.1 Aim of the pilot study

The pilot study was conducted firstly in order to evaluate the intra-rater reliability of the researcher when using the different measuring instruments included in the study when gathering data. The pilot study also evaluated the reliability of the instruments when performing the different data collection procedures. Lastly, to evaluate the logistics related to performing the main study and identify any changes that needed to be implemented to ensure success of the main study.

3.5.1.2 Methodology of the pilot study

The researcher contacted the Head of the Department to ask permission to invite the students to participate in the pilot study. The coordinator for each year of study was also contacted and a time was made for the researcher to speak to each undergraduate class dependent on timetable availability. This was done during pre-clinical teaching weeks for the third and fourth year students and during the first week after registration for the first and second year students. At this meeting the researcher explained the study as well as the exclusion criteria which some of the students would fall into. The class representative was then given a timetable on which the class could fill in their names at respective time slots. The

third and fourth year students were tested during their pre-clinical teaching blocks while the first and second year students were tested before or after their classes.

After the participants had agreed to participate in the study, they were asked to rest well for 24 hours prior to being tested. They were asked to refrain from taking caffeinated drinks for 30 minutes prior to testing to decrease the caffeine's influence on the cardiorespiratory system. They were also asked to refrain from heavy exercise on the day of testing. This was done to attain a relaxed stable respiratory and hemodynamic baseline status.

The test was conducted in the Physiotherapy department's Movement laboratory at the University of the Witwatersrand. This is a closed room which is quiet and private. This quiet, private environment was selected to prevent increased anxiety and/or arousal in study participants that might have influenced hemodynamic variables. Participants entered the room and were asked to sit in an upright chair and quietly read the information sheet and then fill in the consent and coding forms. They were then asked to keep sitting still for duration of five minutes.

Participants were asked to remove shoes and heavy articles of clothing. They were asked to step onto the portable scale in the centre and stand looking forward with their hands down toward their sides looking straight ahead. Their weight was recorded on the evaluation document in kilograms. If participants requested their weight, they were told. Participants were then asked to stand against a stadiometer holding their head in the Frankfurt plane with the shoulders, buttocks and heels pressed against the stadiometer. Measurements for height were recorded in metres.

Participants then resumed their seat on the testing chair. An automated blood pressure cuff was placed two centimetres above the elbow on the right upper arm. It was left in this position during the entire testing process. The on/off button was used after the participant had returned to the seated position after each change in position. This on/off button started the cuff inflation. The same button was pushed once a reading had been taken for blood pressure and heart rate.

A pulse oximeter was placed on the index finger of the left hand. This was placed on the finger and left on throughout the testing procedure. When data needed to be collected, the on/off button was pushed. When a reading was generated, the oximeter was switched off but remained on the subject's finger.

Peak expiratory flow rate was taken by asking the participants to exhale as fast and as hard as possible into the disposable mouth piece after a maximal inspiration. This procedure was repeated three times. The best of three attempts were documented and used during data analysis (McCoy et al, 2010). During the testing procedure no feedback was given to participants, so as to not bias them into providing more or less effort to better their previous score. The participant's neck was kept in a neutral position to reduce variability related to tracheal shape during the testing procedure.

Thoracic expansion was measured by having the researcher place her hands over the posterolateral chest wall with her thumbs meeting at the T8 vertebra. The position of measurement was visualised and marked. The participant was then asked to exhale completely. The tape measure was secured. The participants were asked to inhale maximally. The change between maximal exhalation and inhalation was measured.

The change in diaphragm length was measured on the right and left side. The researcher exposed the eighth intercostal space anteriorly and posteriorly. The ultrasound probe was placed between the midaxillary line and midclavicular line at the eighth intercostal space. After five tidal breaths, the screen was frozen at the end of passive expiration. The leading edge of the diaphragm was marked on screen using an electronic marker. This was considered to be the position of the diaphragm at functional residual capacity. The position of the diaphragm at the end of inspiration was then marked electronically. The distance between the two was measured with built in electronic callipers (Boussages et al 2009; Boon et al 2008). This change in length was captured in millimetres.

Participants were assessed at rest while seated in a backless chair. They were then asked to lie down in a head down tilt position. This has been defined as a horizontal supine position (Ross et al, 2007). Participants lay in the 15 degree head-down tilt position plinth for 30 seconds. The participants were then returned to the chair where all the measurements were

repeated. Each participant then lay in a head-down tilt position of 15 degrees for two minutes, after which they again sat in the chair where all the measurements were taken again. This was followed by participants lying in a head-down tilt position of 30 degrees for 30 seconds. They then sat in the chair and measurements were taken. The last position that the participants lay in was a head-down tilt at 30 degrees for two minutes. Following this position they sat in the chair where measurements were recorded for the last time.

Each participant was placed in one of the head-down tilt positions as described above and tested. During the pilot study it was recorded how long it took for the participant's vital signs to return to normal baseline measurement following a head-down tilt position. This was done in order to find out how long a participant must wait between the changes in head-down tilt positions so as to minimize the influence of a previous head-down tilt position. It was found that the subjects returned to a baseline measurement within a resting period of one minute.

During the pilot study two measurements were taken. A full set of tests were recorded. Each individual rested in a seated position for two minutes and then were re-tested in all the positions. These results were then compared to each other.

Participants were thanked for their time. Feedback was given to them once the results had been analysed. All seven volunteers completed the full assessment, with no drop outs. However the researcher was not able to visualise the left diaphragm position and diaphragm excursion during ventilation in all participants. The difficulty visualising the left diaphragm is supported by literature as discussed in the literature review.

3.5.1.3 Statistical analysis related to results of the pilot study

The data was captured on the evaluation forms during data collection. This was then transferred to a data sheet in Microsoft Excel 2007. After all participants had completed the pilot study the information was imported to the IBM SPSS statistics 20 programme for analysis. The descriptive statistics were analysed to calculate a mean and standard deviation for each of the variables assessed.

A Spearman's correlation coefficient was chosen to analyse the data as it was felt that an outlier in the data would affect the Pearson's correlation coefficient more as the sample size of the pilot study was small (n = 7). A p-value less than 0.05 was considered significant.

3.5.1.4 Results of pilot study

Table 3.2 Baseline intrarater reliability values of study participants

Variable	n	Mean (SD)	r-value	p-value
Age	7	21.14 (± 1.46)		
Height	7	1.69 (± .68)	1.00	0.00
Weight	7	66.5 (±13.26)	1.00	0.00
Blood pressure	7			
• Systolic		123.71 (±13.28)	0.87	0.11
• Diastolic		88.93 (±7.66)	1.00	0.00
Diaphragm length				
• Left	4	28.14 (±8.12)	1.00	0.00
• Right	7	24.94 (±9.05)	0.99	0.00
Heart rate	7	87.00 (±5.35)	0.86	0.00
Oxygen saturation	7	96.87 (1.67)	1.00	0.00
Peak expiratory flow rate	7	392.14 (±61.43)	0.98	0.00
Thoracic expansion	7	1.86 (±.38)	1.00	0.00
Dyspnoea	7	0.7 (±1.11)	1.00	0.00

At rest, baseline measurements demonstrated high to very high correlations as well as significance. The systolic blood pressure had a strong association but was not statistically significant (p = 0.11).

The number of volunteers for the pilot study was seven participants. The researcher had difficulty visualising the diaphragm on the left side in three participants. Previous studies have also demonstrated the difficulty with visualisation of the left diaphragm (Testa et al, 2010). This is thought to be due to the different organs that the ultrasound passes through. On the right, the liver is dense and relatively immobile providing an easier viewing interface.

A great limitation to viewing the left hemi-diaphragm has commonly been reported because of gastric contents of the stomach and the poor acoustic window given by the spleen (Scott et al, 2006). The spleen is a relatively less dense organ as well as more mobile. These factors increase the difficulty of viewing this hemi-diaphragm as clearly as the right.

Table 3.3 Intrarater reliability values of study participants after 15 degrees head-down tilt position for 30 seconds.

Variable	N	Mean (SD)	r value	p value
Blood pressure	7			
• Systolic		124.79 (±12.00)	0.96	0.00
• Diastolic		84.64 (±9.34)	1.00	0.00
Diaphragm length				
• Left	4	37.6 (±15.62)	1.00	0.00
• Right	7	34.57(±12.58)	0.96	0.00
Heart rate	7	80.93 (±17.85)	0.96	0.00
Oxygen saturation	7	95.5 (±3.69)	0.86	0.00
Peak expiratory flow rate	7	419.23 (±65.16)	0.82	0.00
Thoracic expansion	7	2.18 (±.47)	1.00	0.00
Dyspnoea	7	0.29 (±.76)	1.00	0.00

These results showed high to very high correlations with strong associations between the variables which were all significant ($p<0.05$).

Table 3.4 Intrarater reliability values of study participants after 15 degrees head-down tilt position for two minutes

Variable	N	Mean (SD)	r value	p value
Blood pressure	7			
• Systolic		122 (±9.75)	0.96	0.00
• Diastolic		79.57(±6.6)	1.00	0.00
Diaphragm length				
• Left	4	42.54 (±7.15)	1.00	0.00
• Right	7	42.14(±7.15)	0.68	0.06
Heart rate	7	82.43 (±16.42)	0.99	0.00
Oxygen saturation	7	96.87 (±1.68)	0.71	0.14
Peak expiratory flow rate	7	421.43 (±67.5)	0.96	0.00
Thoracic expansion	7	2.17 (±.35)	0.90	0.00
Dyspnoea	7	0.29(± .76)	1.00	0.00

Oxygen saturation and diaphragm length on the left showed good correlation but was not significant. All the other values showed very high correlation and were all significant.

Table 3.5 Intrarater reliability values of study participants after 30 degrees head-down tilt position for 30 seconds

Variable	N	Mean (SD)	r value	p value
Blood pressure	7			
• Systolic		120.29 (±11.28)	0.88	0.01
• Diastolic		80.29(±7.9)	0.99	0.00
Diaphragm length				
• Left	4	37.63 (±2.39)	0.11	0.63
• Right	7	45.24(±9.11)	0.89	0.00
Heart rate	7	85.36 (±12.34)	0.96	0.00
Oxygen saturation	7	96.36 (±1.14)	0.86	0.02
Peak flow	7	419.29 (±63.6)	0.87	0.00
Thoracic expansion	7	2.2 (±.39)	0.97	0.00
Dyspnoea	7	0.286 (± .756)	1.00	0.00

The diaphragm length on the left in 30 degrees head-down tilt for 30 seconds was recorded on four participants. It showed a low degree of association that was not significant. Due to the small number of participants that were recorded this value needs to be reassessed in the full study to ascertain if there is still weak association. The weak association could be due to the diaphragm returning to its normal resting length prior to the researcher capturing the change in length. All the other values showed high to very high correlation and were significant.

Table 3.6 Intrarater reliability values of study participants after 30 degrees head-down tilt position for two minutes

Variable	N	Mean (SD)	r value	p value
Blood pressure	7			
• Systolic		120.14 (±13.64)	1.00	0.00
• Diastolic		79.57(±7.92)	0.85	0.00
Diaphragm length				
• Left	4	52.23 (±9.46)	1.00	0.01
• Right	7	45.48(±12.31)	0.96	0.00
Heart rate	7	85.93 (±14.82)	0.99	0.00
Oxygen saturation	7	97.5 (±.82)	0.63	0.72
Peak flow	7	412.86 (±68.2)	0.99	0.00
Thoracic expansion	7	2.45 (±.49)	0.58	0.05
Dyspnoea	7	0.29 (±.76)	1.00	0.00

After the participant lay in a head-down tilt of 30 degrees for two minutes, data was again collected in a seated position. The results obtained had a very strong association and were significant. Oxygen saturation had a good association but was not significant.

3.5.1.5 Implications of the results of the pilot study

The pilot study was beneficial in highlighting a number of challenges that the researcher needed to alter to facilitate improved execution of the main study. The evaluation sheet was changed from being three sheets to one sheet with a smaller font. This adjustment was made to ease the data capturing process by having each participant's data on one sheet.

It was more difficult to visualise the left hemi-diaphragm on the ultrasound compared to the right hemi-diaphragm. This was found in the same three individuals in all the testing positions. Thus it could be related to the anatomical differences in these subjects between the liver and spleen that affected visualisation and was less likely due to researcher technique. After discussion between the researcher and her supervisors, the decision was made to continue assessing both left and right hemi-diaphragms to ensure standardisation of assessment procedure.

Initially the researcher removed the blood pressure cuff and pulse oximeter while the participant lay in the various positions. This then wasted time as she needed to re-apply them to facilitate testing. The added time required to position the devices might have influenced the variables assessed. In light of this the decision was made not to remove the devices during the data collection procedure. All that was needed was then to push a button instead of re-applying the devices.

The researcher also learnt that it takes one minute for the subject to return to the baseline normal for their vital signs. The researcher waited two minutes between tests; this was therefore the time set aside for the minimum amount of time to wait between changes in position for the main study.

The pilot study proceeded smoothly. There were no problems with measuring participants' weight and height on the portable scale or with the stadiometer. The automated blood pressure, pulse oximeter, Wright peak flow meter and non-stretch tape measure all proved to be effective equipment which allowed reproducible results. The intra-rater reliability of the equipment proved high due to the high correlation that was seen in the pilot study. The equipment therefore proved to be reliable. The main problem was the amount of time each subject took to be tested, which was problematic as most participants were bound by a strict teaching timetable. It took initially between 45 minutes to an hour to assess and re-assess each participant for the pilot study. Each participant underwent the full set of tests and then underwent the full set of tests again. Participants' in the main study were not assessed twice, which cut down on testing time. The researcher also improved her technique for taking of measurements which aided in a quicker processing time for data collection.

3.5.2 Main Study

The main study followed the pilot study. The only differences between the pilot and main study procedures were that during the pilot study all measurements were taken twice to check for reliability of both the equipment that was being used as well as the researcher herself. After the pilot study, data was analysed and readings were established to be reliable. Measurements were only taken once during the main study. Secondly, the pulse oximeter and blood pressure cuff where not removed during testing procedure as stated above. The

pilot study took place in January 2012 with the main study taking place between January and April of 2012.

3.6 DATA ANALYSIS

Data captured during the main study were entered onto an Excel spreadsheet. Data analysis was performed with STATA 12 and IBM SPSS 20 software programmes. A statistician assisted with the data analysis of the main study. The data collected was all continuous variables except for gender. Data were evaluated for normal distribution to assist with selection of statistical tests. Females were assigned to number one and males were assigned number two. The continuous data allowed analysis of means and standard deviations.

Each subject had five different values taken, which were put into five different groups

Table 3.7 Numbers assigned to the different head down tilt positions and angles

Initial at rest assessment	1
After lying for 30 seconds in a 15 degree head down tilt position	2
After lying for two minutes in a 15 degree head down tilt position	3
After lying for 30 seconds in a 30 degree head down tilt position	4
After lying for two minutes in a 30 degree head down tilt position	5

These groups were analysed using a repeated measures ANOVA test. This is used to compare the equality of means of more than two samples. All of the variables had a normal distribution and therefore could be analysed with ANOVA except for shortness of breath. The modified Borg dyspnoea scale scores were highly skewed and a Kruskal Wallis test was used to analyse the data. This test is similar to the ANOVA in that it analyses more than two groups. A p value of <0.05 was considered significant.

A Bartlett's test was performed which compares the values within the five groups and shows which group had the most significant results, compared to the rest of the group. The Bonferroni correction was added which is an adjustment that is made to the p-value when several tests are performed simultaneously on a single data set. This decreases the chance of obtaining false positive results.

To compare the predicted peak expiratory flow rates (PEFR) and the measured PEFR that were obtained at rest a student's t-test (unpaired) was used which determines if the averages of two samples are significantly different.

The results and analysis of the data collected will be presented in Chapter 4.

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CHAPTER 4

4. RESULTS

This chapter describes the results obtained from the data collection process of the main study as described in the previous methodology chapter. Figures are used to present the study results for easier interpretation and understanding of the study outcomes. Standard deviations as well as p-values are rounded off to two decimal points.

4.1 INTRODUCTION

The pilot study provided preliminary results regarding whether a head-down tilt position had an effect on the diaphragm. The results were encouraging as it suggested that the diaphragm did lengthen in the various positions. The pilot study also allowed the researcher to become accustomed to using the diagnostic ultrasound machine during the data collection process. The study then proceeded into the main data collection phase.

The objectives of this study were as follows:

- To determine if there was an effect on diaphragm length before and after a head-down tilt intervention
- To determine which stretch position was most beneficial in improving diaphragm length
- To determine if there was an effect on thoracic expansion before and after a head-down tilt intervention
- To determine if there was an effect on peak expiratory flow rate before and after a head-down tilt intervention
- To assess blood pressure, oxygen saturation and heart rate changes before and after a head-down tilt intervention.
- To assess subjects' level of perceived breathlessness before and after a head-down tilt intervention

Table 4.1 presented below contains the referenced normal values that were used to evaluate the results of this study.

Table 4.1: Normal values for variables measured

Variable	Normal value	Reference
Change in diaphragm length (mm)	18.40 ±10	Testa et al, 2011
Peak expiratory flow rate (L/min)	300-600	Hough, 1996
Thoracic expansion (cm)	2.70-4.30	Wilkins, 2009
Heart rate (bpm)	60-100	Wilkins, 2009
Blood pressure (mmHg) • Systolic • Diastolic	 90-140 60-90	 Wilkins, 2009 Wilkins, 2009
Oxygen saturation (%)	<95	Jensen et al, 1998
Dyspnoea	0/10	Wilkins, 2009
Body mass index (BMI)	18.50-24.90	Hodgkin, 2009

mm=millimetres, L/min= litres per minute, cm=centimetres, bpm=beats per minute, mmHg= millimetres of mercury, %= percentage

4.2 DEMOGRAPHICS

The sample consisted of 75 participants with a gender ratio of 80.5% females (n=61) to 19.5% males (n=14).

There are more female physiotherapy undergraduate students than male students at the University of the Witwatersrand; therefore the unequal bias of females to males was expected as this was the population group chosen.

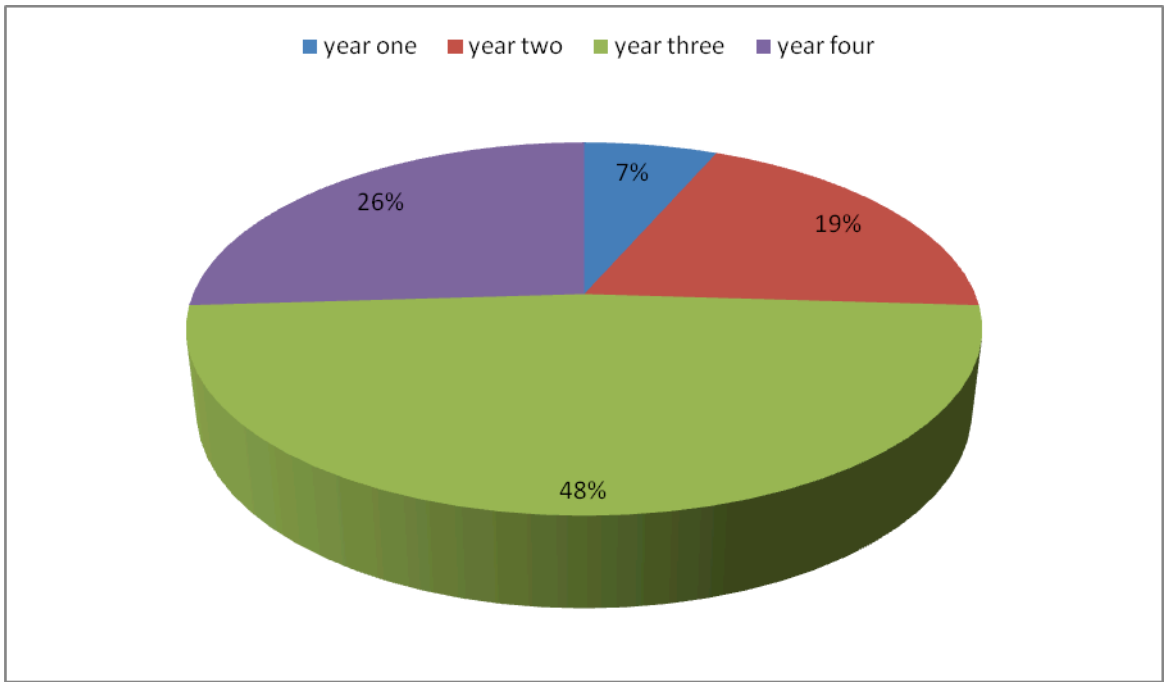


Figure 4.1: The distribution of percentage of students' per undergraduate year of study in the current study (n=75)

Almost half of the population group was made up of third year undergraduate students. This was because they were generally more available than the other students to participate in testing as their timetable placed them near the movement lab where the data collection was underway. In 2012, the third year class was also the largest student group amongst the first to fourth year physiotherapy students at the University of the Witwatersrand. The third years numbered 62 students as compared with 56, 33 and 41 of first, second and fourth years respectively.

Table 4.2 presented below contains additional information related to sample baseline parameters.

Table 4.2: The average age, height, weight and BMI of participants (n=75)

Variable	Mean	Standard deviation
Age (yrs)	20.91	± 2.5
Height (m)	1.66	± 0.80
Weight (kg)	64.08	± 11.83
BMI (kg/m^2)	23.10	± 3.77

yrs=years, m=metres, kg/m² =kilograms per metre squared

A BMI value of less than 25 is considered healthy and normal. The average BMI of the participants fell within this normal range.

4.2.1 Exclusion Criteria

Eighty three undergraduate students volunteered to partake in this study. Of these 75 had their data captured. The others were excluded due to a positive smoking history (4), asthma (3), a BMI lower or higher than the criteria (4) and age above the maximum criteria (1).

4.3 BASELINE VALUES AT REST (POSITION ONE)

The data presented in Table 4.3 below relates to the participants' variables at rest prior to being placed in a head-down tilt position. The minimal and maximum values of variables measured at baseline are also presented for review.

Table 4.3: The average heart rate, oxygen saturation, blood pressure and breathlessness scores at rest (n=75)

Variable	Mean (SD)	Min - Max
Heart rate (bpm)	81.20 (±16.65)	50-130
Oxygen saturation (percentage)	96.96 (±1.20)	93-99
Systolic blood pressure (mmHg)	124.82 (±19.25)	92-159
Diastolic blood pressure (mmHg)	80.00 (±11.91)	50-107
Breathlessness (0-10)	0.18 (±0.74)	0-4

mm=millimetres, L/min= litres per minute, cm=centimetres, bpm=beats per minute, mmHg= millimetres of mercury, %= percentage

The mean values for the participants at rest fell into the expected averages for healthy young individuals. Although the mean values fall into the normal category the minimum and maximum of most of the variables fall out of the normal range. This is clearly seen with the systolic blood pressure being hypertensive and the heart rate being high. Breathlessness was also experienced at rest which is unusual in a group of healthy individuals.

The data presented in Table 4.4 below relates to the participants' variables at rest prior to being placed in a head-down tilt position. The minimal and maximum values of variables measured at baseline are also presented for review.

Table 4.4: The average peak flow, right and left hemi-diaphragm length and thoracic expansion for study participants at rest

Variable	n	Mean (SD)	Min - Max
Peak expiratory flow rate (L/min)	75	423.75 (±95.16)	250-700
Predicted peak expiratory flow rate (L/min)	75	446 (±95.16)	410-590
Change in length of the left hemi-diaphragm (mm)	61	20.20 (±7.15)	6.90-39.70
Change in length of the right hemi-diaphragm (mm)	75	20.53 (±7.58)	7.85-43.80
Thoracic expansion (cm)	75	2.50 (±0.74)	0.50-3.50

mm=millimetres, L/min= litres per minute, cm=centimetres

The mean change in hemi-diaphragm length between inspiration and expiration was similar to previous research (Boussuges et al, 2009; Kantarci et al, 2004) which measured the diaphragm at rest. Mean thoracic expansion and mean peak expiratory flow rate were less than expected for the participants' respective age and height. All variables were measured for all participants except for the diaphragm length on the left. The researcher could only visualise the hemi-diaphragm in 81.3% (n = 61) of the subjects. There was a wide difference that was found between the minimum and maximum values for thoracic expansion and diaphragm movement between individuals.

4.4 VARIABLES AFTER HEAD-DOWN TILT POSITION TWO (15 DEGREES FOR 30 SECONDS)

The data presented in Table 4.5 below relates to the participants' variables after a head-down tilt position of 15 degrees for 30 seconds. The minimal and maximum values of variables measured at baseline are also presented for review

Table 4.5: The average heart rate, oxygen saturation, blood pressure and breathlessness scores after 15 degrees head-down tilt position for 30 seconds (n=75)

Variable	Mean (SD)	Min - Max
Heart rate (bpm)	79.69 (±17.01)	47-120
Oxygen saturation (percentage)	96.91 (±1.28)	92-99
Systolic blood pressure (mmHg)	125.21 (±14.02)	75-155
Diastolic blood pressure(mmHg)	77.90 (±10.41)	50-98
Breathlessness (0-10)	0.21 (±0.71)	0-4

mm=millimetres, L/min= litres per minute, cm=centimetres, bpm=beats per minute, mmHg= millimetres of mercury, %= percentage

The above mean values were all within normal range. The mean diastolic blood pressure had also dropped since the previous measurements done at rest but still fell in the normal range. The individual outliers as seen by the minimum and maximum values still fell outside the normal ranges, most notably systolic blood pressure, heart rate and perceived breathlessness.

The data presented in Table 4.6 below relates to the participants' variables at a 15 degrees head-down tilt position for 30 seconds. The minimal and maximum values of variables measured at baseline are also presented for review

Table 4.6: The average peak flow, right and left hemi-diaphragm length and thoracic expansion after 15 degrees head-down tilt position for 30 seconds

Variable	n	Mean (SD)	Min - Max
Peak expiratory flow rate (L/min)	75	423.75 (±95.16)	250-700
Change in length of the left hemi-diaphragm (mm)	62	27.62 (±8.95)	11.50-61.20
Change in length of the right hemi-diaphragm (mm)	75	30.01 (±9.75)	13.50-62
Thoracic expansion (cm)	75	2.26 (±0.83)	0.50-4

mm=millimetres, L/min= litres per minute, cm=centimetres

Mean peak expiratory flow rates as well as mean thoracic expansion are still lower than expected. The mean change of hemi-diaphragm length of both the right and left side has increased compared to the measurements at rest. Diaphragm length on the left was only measured in 82.7% (n = 62) of the participants due to difficulty in visualisation. If one reviews the minimal and maximum values measured at the left and right diaphragm more movement occurred compared to values at rest.

4.5 VARIABLES AFTER HEAD-DOWN TILT POSITION THREE (15 DEGREES FOR TWO MINUTES)

The data that follows (Tables 4.7 and 4.8) relates to position three which is the head-down tilt position at 15 degrees for two minutes. The minimal and maximum values of variables measured in position three are also presented for review.

Table 4.7: The average heart rate, oxygen saturation, blood pressure and breathlessness scores after 15 degrees head-down tilt position for two minutes (n=75)

Variable	Mean	Min - Max
Heart rate (bpm)	79.51 (± 15.95)	45-112
Oxygen saturation (percentage)	96.91 (±1.03)	95-99
Systolic blood pressure (mmHg)	121.08 (±13.30)	80-152
Diastolic blood pressure(mmHg)	76.85 (±11.11)	42-112
Breathlessness (0-10)	0.12 (±0.51)	0-3

mm=millimetres, L/min= litres per minute, cm=centimetres, bpm=beats per minute, mmHg= millimetres of mercury, %= percentage

The above mean values all fall within normal parameters. The outliers in all variables are still out of the normal parameters, although breathlessness had decreased from four out of 10 in the previous position to three out of 10. Systolic blood pressure has a maximum value above the normal maximum of 140mmHg as well as a minimum of lower than the expected 90mmHg. The minimum and maximum diastolic blood pressure values are also lower and higher than the expected values of 60-90mmHg.

Table 4.8: The average peak flow, right and left hemi-diaphragm length and thoracic expansion after 15 degrees head-down tilt position for two minutes

Variable	n	Mean (SD)	Min – Max
Peak expiratory flow rate(L/min)	75	424.66 (±96.87)	290-720
Change in length of the left hemi-diaphragm (mm)	60	33.43 (±9.48)	12.70-65.20
Change in length of the right hemi-diaphragm (mm)	75	36.28 (±10.92)	18.30-68.10
Thoracic expansion (cm)	75	2.35 (±0.83)	0.50-4.50

mm=millimetres, L/min= litres per minute, cm=centimetres

Mean peak expiratory flow rate is still below the predicted result but when reviewing the minimum and maximum values measured an increase was found at both points. The mean change in diaphragm length for both the left and right side has increased since the previous measurements and this was also demonstrated by an increased miminum and maximum value measured. However the researcher could only visualise 80% (n=60) of participants' left hemi-diaphragms.

4.6 VARIABLES AFTER HEAD-DOWN TILT POSITION FOUR (30 DEGREES FOR 30 SECONDS)

The data presented here (Tables 4.9 and 4.10) is related to the information gathered after participants had laid in a head-down tilt position of 30 degrees for 30 seconds. The minimal and maximum values of variables measured after position four are also presented for review.

Table 4.9: The average heart rate, oxygen saturation, blood pressure and breathlessness scores after 30 degrees head-down tilt position for 30 seconds (n=75)

Variable	Mean (SD)	Min - Max
Heart rate (bpm)	80.55 (±15.57)	50-120
Oxygen saturation (percentage)	96.93 (±1.17)	94-100
Systolic blood pressure (mmHg)	119.00 (±15.36)	81-154
Diastolic blood pressure(mmHg)	83.76 (±9.37)	52-107
Breathlessness (0-10)	0.17 (±0.61)	0-3

mm=millimetres, L/min= litres per minute, cm=centimetres, bpm=beats per minute, mmHg= millimetres of mercury, %= percentage

All mean values fell within the normal ranges for healthy adult individuals. The mean systolic blood pressure decreased to 119mmHg. The minimum and maximum values for individuals within the group still represented values outside the accepted normal levels for heart rate, blood pressure and breathlessness.

Table 4.10: The average peak flow, right and left hemi-diaphragm length and thoracic expansion after 30 degrees head-down tilt position for 30 seconds

Variable	n	Mean (SD)	Min – Max
Peak expiratory flow rate (L/min)	75	428.94 (±95.01)	300-720
Change in length of the left hemi-diaphragm (mm)	62	37.39 (±9.72)	14.00-74.70
Change in length of the right hemi-diaphragm (mm)	75	39.98 (±11.28)	17.90-80.30
Thoracic expansion (cm)	75	2.42 (±0.84)	0.50-4.50

mm=millimetres, L/min= litres per minute, cm=centimetres

Mean peak expiratory flow rate and mean thoracic expansion were still below expected values and had not changed significantly since the last measurement. The mean change in diaphragm length of both the right and left side had increased from the last measurements. The researcher managed to visualise 82.6% (n = 62) of the subjects' left hemi-diaphragm changes in length. Variables for individual subjects as seen by the minimum and maximum still fell outside the accepted normal values. Minimum and maximum values measured concerning diaphragm length on the left and right had increased from the previous position's measurement.

4.7 VARIABLES MEASURED AFTER HEAD-DOWN TILT POSITION FIVE (30 DEGREES FOR TWO MINUTES)

The data presented here in Tables 4.11 and 4.12 relate to information gathered after the participants lay in a head-down tilt position of 30 degrees for two minutes. The minimal and maximum values of variables measured after position five are also presented for review.

Table 4.11: The average heart rate, oxygen saturation, blood pressure and breathlessness scores after 30 degrees head-down tilt position for two minutes (n=75)

Variable	n	Mean (SD)	Min – Max
Heart rate (bpm)	75	80.48 (±15.80)	49-140
Oxygen saturation (percentage)	75	97.47 (±1.01)	95-99
Systolic blood pressure (mmHg)	75	117.79 (±14.49)	85-162
Diastolic blood pressure(mmHg)	75	75.48 (±9.39)	50-104
Breathlessness (0-10)	75	0.14 (±0.48)	0-2

bpm (beats per minute), mmHg (millimetres of mercury)

All of the mean values fall within the normal ranges. Both mean systolic and diastolic blood pressures have decreased from the previous readings. The outliers for individuals within the group still fall out of the normal values, especially heart rate, systolic and diastolic blood pressure. Perceived breathlessness dropped from three out of 10 to two out of 10 since the last measurements were recorded.

Table 4.12: The average peak flow, right and left hemi-diaphragm length and thoracic expansion after 30 degrees head-down tilt position for two minutes

Variable	n	Mean (SD)	Min – Max
Peak expiratory flow rate (L/min)	75	428.94 (±95.01)	300-720
Change in length of the left hemi-diaphragm (mm)	61	38.78 (±11.51)	12.00-72.00
Change in length of the right hemi-diaphragm (mm)	75	39.38 (±11.92)	18.30-77.70
Thoracic expansion (cm)	75	2.48 (±0.86)	0.50-4.50

L/min (litres per minute), mm (millimetres), cm (centimetres)

Mean peak expiratory flow rate and mean thoracic expansion did not change significantly from the last measurements. The mean value for diaphragm change of length on the left increased slightly since the previous measurements. The mean value for change in length on the right hand side decreased since the last measurements. All variables were measured and recorded except for diaphragm change in length on the left where only 81.3 % (n = 61) of the participants' values were collected.

Throughout all the positions there was one individual who consistently had a low blood pressure as well as heart rate. This individual had a low weight and height as well as small bone structure.

4.8 VARIABLES COMPARED ACROSS ALL THE CHANGES IN POSITION

In this section each variable will be compared across the different positions and time spent in each position compared to the "at rest" measurement so that a trend can be seen for each variable. Each position will be evaluated as a group. This will attempt to show an interpretation of the methodology described in chapter three based on the ANOVA statistical analysis which measures the mean changes between the different groups for the different variables at each position.

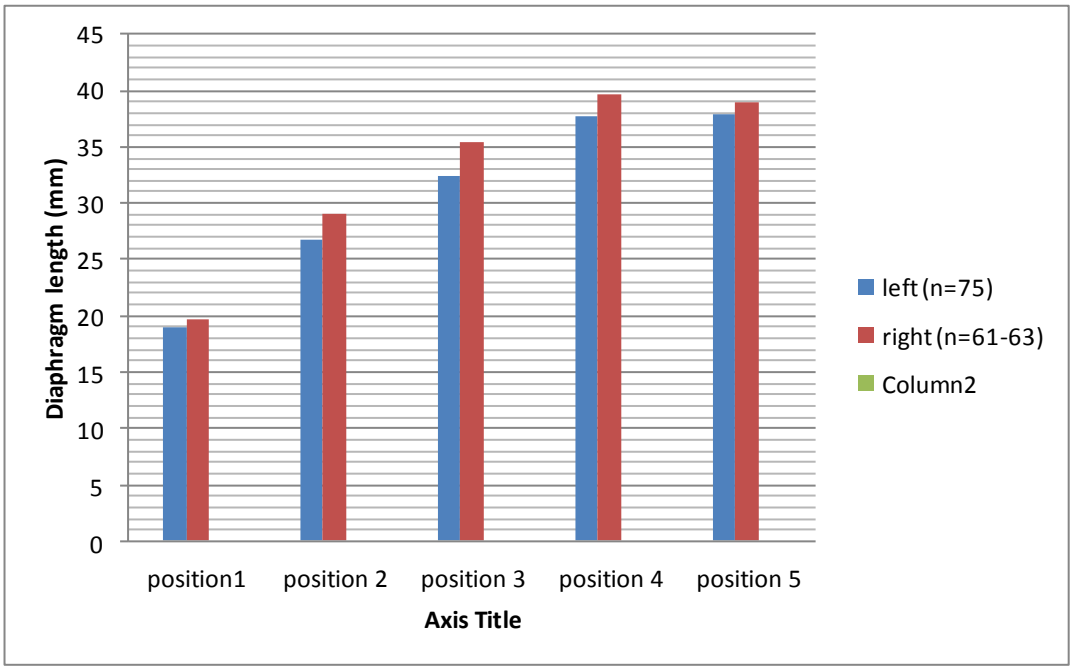


Figure 4.2: Comparisons of diaphragm length in different head-down tilt positions

A change in both left and right hemi-diaphragm length was clearly seen as participants moved from one position to another. This change was gradual with the largest mean change occurring between positions one and two and between positions one and three before increasing slightly at position four and five. The graph therefore showed a gradual increase which then started to plateau at position four and five. The greatest change occurred at a head-down tilt position of 30 degrees for two minutes for the left hemi-diaphragm and a head-down tilt position of 30 degrees for 30 seconds for the right hemi-diaphragm. These changes from the "at rest" position were significant for both the right and left side with a p value of 0.00.

The change in diaphragm length on the left side showed a clear difference between groups one and two, two and three and three and four. The values for groups four and five were very similar and were not as clearly distinct as seen between the other separate groups.

The change in diaphragm length on the right showed clear differences between groups one and two as well as two and three. However there was not a clear difference between the results obtained from positions three, four and five.

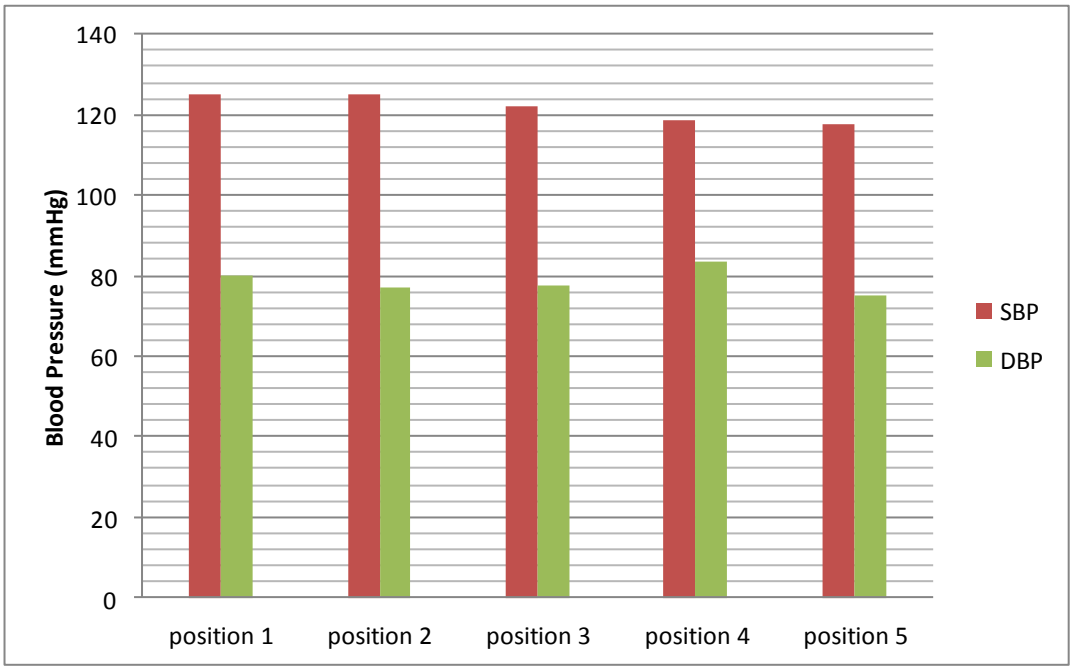


Figure 4.3: Comparisons of systolic blood pressure and diastolic blood pressure in different positions (n=75)

Systolic blood pressure did change throughout the study (see Figure 4.3). Between positions one and two it showed the closest similarity. Between groups two and three as well as three and four and four and five it changed significantly (p=0.00). The greatest change was between the "at rest" measurement and the measurement after the participant lay in position five (30 degree head down tilt for two minutes). The graph therefore started as a plateau with a gradually decreasing slope.

Diastolic blood pressure was not consistent. It initially decreased between positions one and two. Positions two and three were very similar. It then increased higher than the initial "at rest" reading for position four and dropped again at position five. The biggest change from the "at rest" measurement was at position five (30 degree head-down tilt for two minutes). However even at this position the change was not significant (p=0.64).

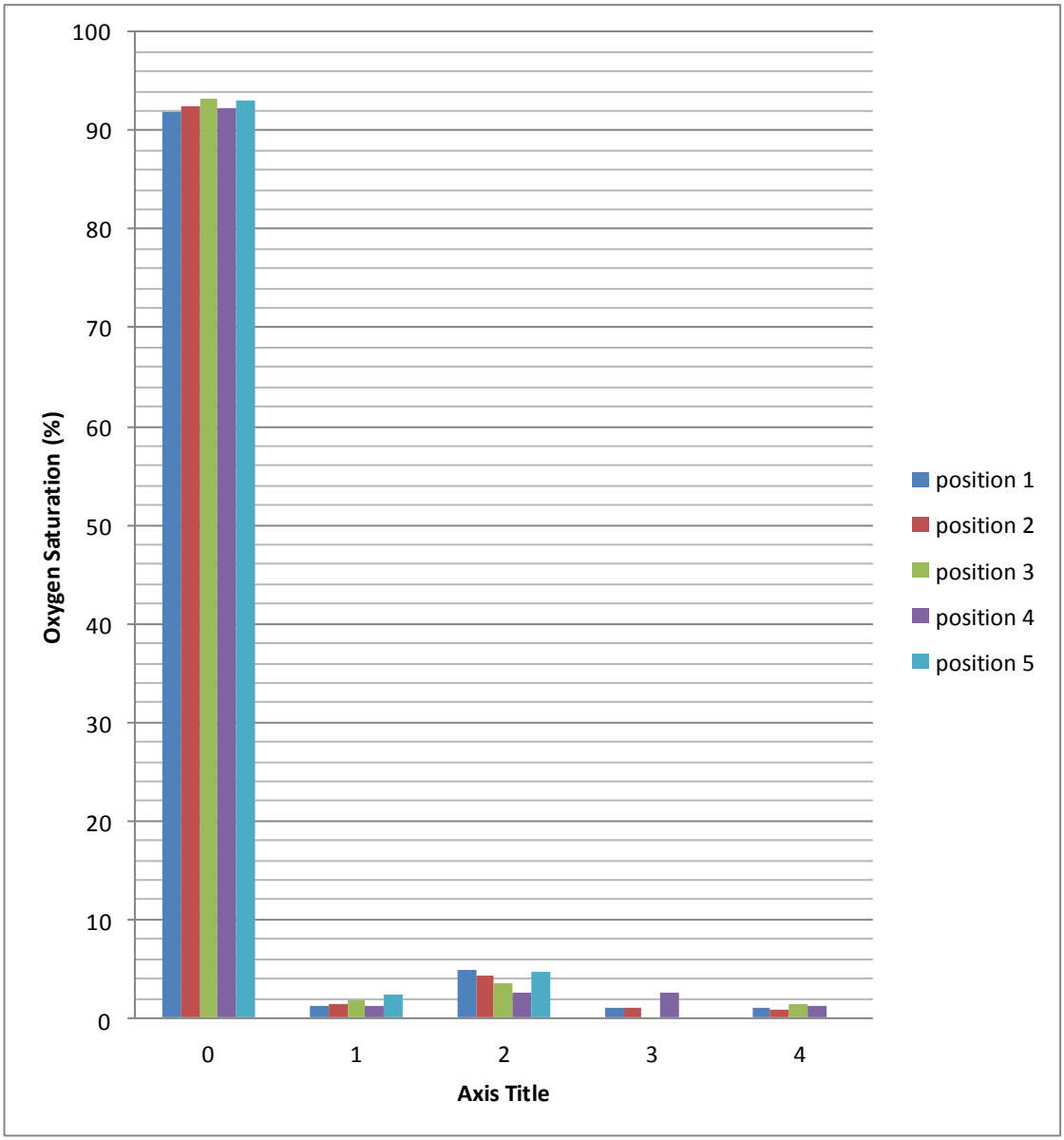


Figure 4.4 Sensation of breathlessness measured with the Modified Borg Dyspnoea Scale in the different positions (n=75)

There was not an even distribution for sensation of breathlessness. Between 91.93% (n = 69) to 93.24% (n =70) of all participants did not experience any breathlessness throughout all the positional changes. Participants who recorded feeling 'very slight' breathlessness (1/10) were between 1.22% (n = 1) to 2.4% (n =2). The greatest change for feeling 'very slight' breathlessness was between positions one and five with the maximum 'slight breathlessness' being experienced at position five.

Participants who felt ‘slight’ breathlessness (2/10) varied from 2.6% to 4.89% percent of all subjects. The greatest change occurred between positions one when participants felt the most ‘slight breathlessness’ and four.

A small number of participants (0%-0.98%) reported feeling moderately breathless (3/10) at positions one, two and four. These positions were “at rest” and in the 15 degree head-down tilt position for two minutes as well as the 30 degree head-down tilt position for 30 seconds. The least moderate breathless position was position three with the greatest number of participants having moderate breathlessness occurring at position one. The greatest overall change occurred between position one, where 0.98% felt breathless and position five where there were no complaints of moderate breathlessness.

‘Somewhat severe’ breathlessness (4/10) was felt by 0% to 1.35% of the participants. This was greatest in position three and least felt in position five.

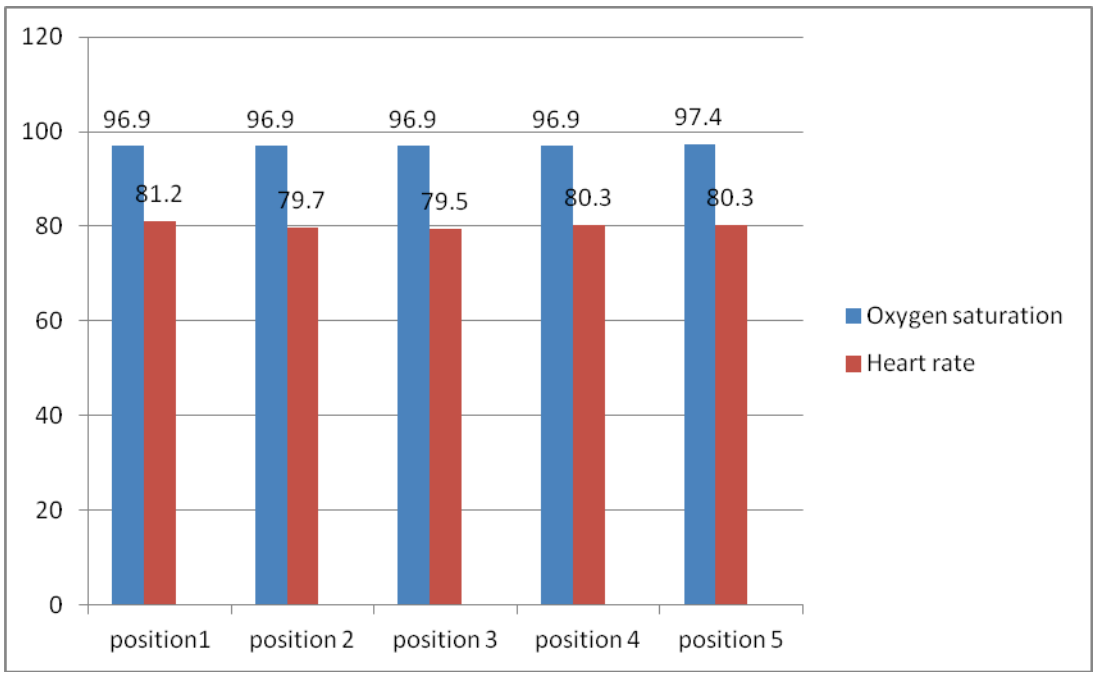


Figure 4.5: Oxygen saturation and heart rate in the different positions (n=75)

Oxygen saturation showed no change in the group of participants between positions one to four. It increased at position five. This change was statistically significant (p = 0.02) but not clinically.

Heart rate did not show a clear pattern of underlying behavior throughout the changes in position. The change was not significant (p = 0.99). The highest heart rate was recorded at position one with the lowest heart rate being seen at position three. Heart rate at positions four and five was identical and fluctuated between the minimum and maximum means.

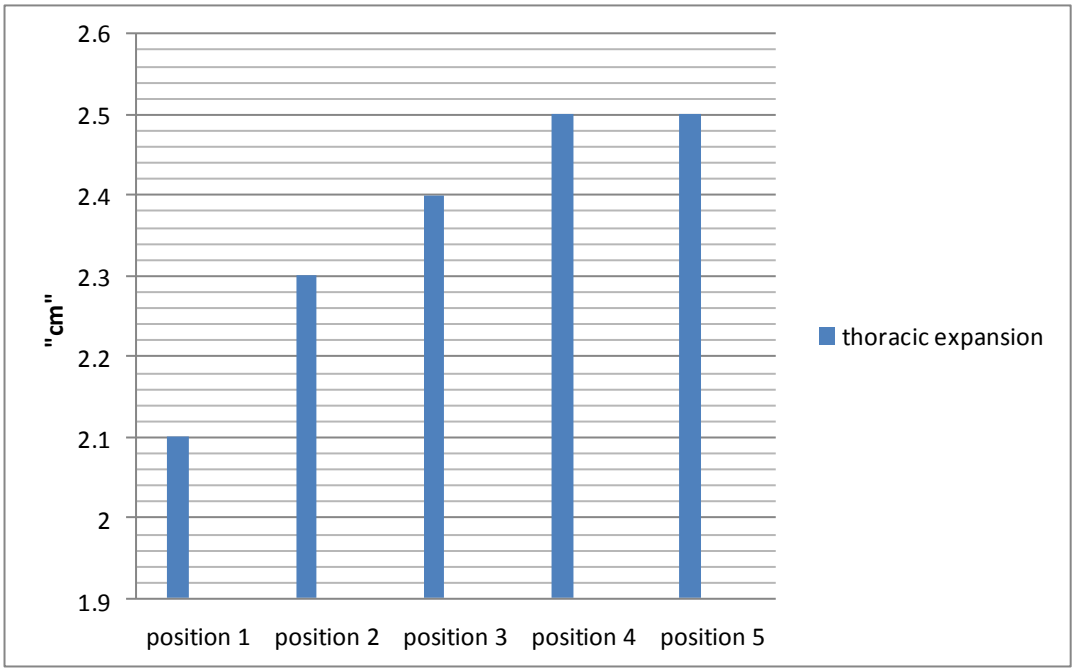


Fig 4.6: Changes in thoracic expansion in the different positions (n=75)

Thoracic expansion showed a gradual change between the different positions with the greatest mean change being experienced between position one and two. There was a less noticeable change between position two and three as well as position three and four. Between position four and five there was no change. The greatest change throughout occurred between position one and position four/five, these changes were not significant (p= 0.54).

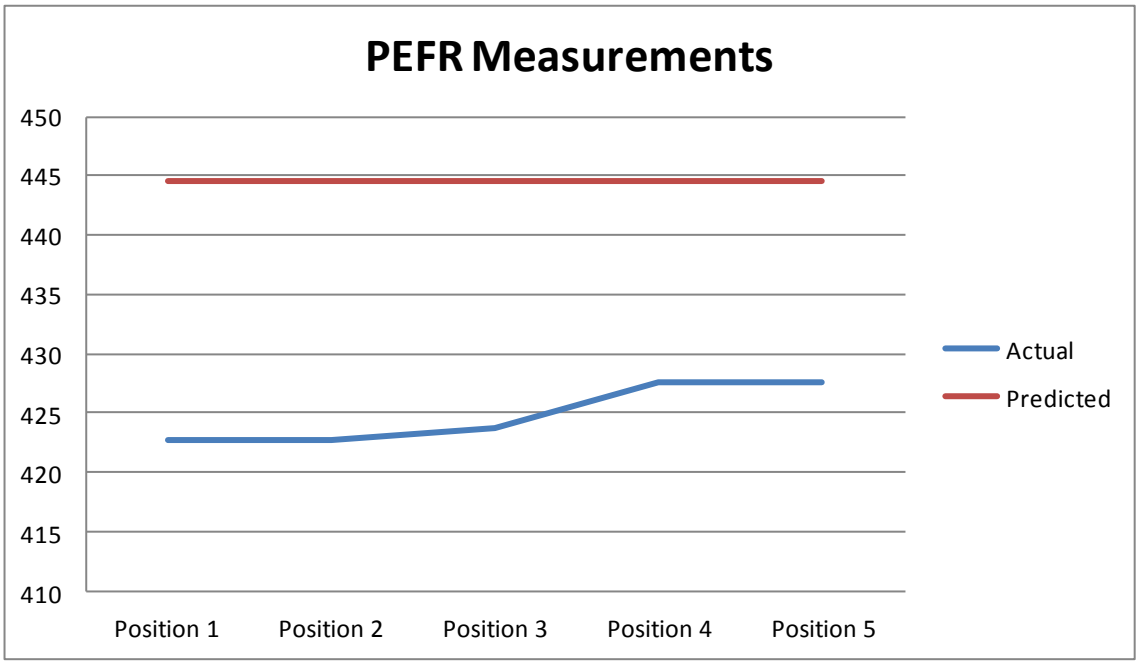


Figure 4.7: Peak expiratory flow rate measurements in different positions and compared to the predicted peak flow expiratory rate (n=75)

The peak expiratory flow rate increased gradually throughout the changes in position. There was no change between positions one and two. A gradual change was then seen between positions two and three as well as between positions three and four. Positions four and five did not show any changes in peak flow rate measurement. The greatest change between positions occurred between positions three and four, while the greatest overall change occurred between position one and five. These changes were not significant (p=0.98).

Predicted peak expiratory flow rate is calculated based on gender, age and height. The predicted peak expiratory flow rate that was calculated was higher than the mean peak expiratory flow rate that was generated by the participants but not significantly so (p= 0.07).

The results will be discussed and analysed in chapter five.

CHAPTER 5

5. DISCUSSION

5.1 INTRODUCTION

The aim of this study was to determine if the length of the diaphragm could be altered by a head-down tilt position in an attempt to use the abdominal contents to facilitate a cephalic stretch on the diaphragm muscle. The objectives of the study were to find out which position gave the greatest stretch and whether the greater length of the diaphragm translated to a change in respiratory mechanics such as thoracic expansion and peak expiratory flow rate in study participants. Cardiovascular parameters and perception of participant's dyspnoea levels were also monitored during the intervention positions to identify if any adverse reactions occurred with each head-down tilt position. This section will discuss the results obtained in chapter four. The relevance for future research will be highlighted and the limitations of the current study presented.

5.2 DEMOGRAPHICS

5.2.1 Gender

This study comprised of more females than males which can be explained by the uneven distribution of female to male physiotherapy students enrolled in the undergraduate course in the Physiotherapy department at the University of the Witwatersrand.

Demographic parameters were not thought to influence diaphragm length when assessed by Testa et al (2011). He used both B and M mode ultrasonography in healthy adults and the measurements were taken via the subcostal anterior area while in a semi recumbent position.

5.2.2 Distribution between years of study

The study did not consist of an equal distribution of volunteers between the undergraduate classes. Most of the participants were from the third year undergraduate class. This class was proportionally larger than the other undergraduate classes. These students were also more readily available for testing as their pre-clinical timetable coincided with the timing of the data collection period. This was in contrast to the first year undergraduates who had the majority of their classes on the main campus of the University and were therefore not as easily available for testing.

5.2.3 Exclusion criteria

Participants were chosen that had a narrow age range to minimise confounding data from age related changes, such as reduced lung volumes, flow rates, a propensity toward airway closure and ventilation/ perfusion mismatch (Jones & Dean, 2004). Kantarci et al (2004) found that participants who were under the age of 30 had a smaller diaphragm excursion. This finding may be as a result of the fact that people under 30 are generally healthy with no co-morbidities or related pathology. Their respiratory systems are therefore working well without an increased effort from the diaphragm to bring about adequate tidal volume. The diaphragm would therefore not measure a large change as the tidal volume is adequate without as much force being generated from the main inspiratory muscle.

A high body mass index (BMI) with an increase in abdominal contents will exaggerate the effects of a head-down tilt position due to the larger mass pushing on the diaphragm surface. The “at rest” measurements of a person with a large BMI is also different from a person with a normal BMI due to the abdominal viscera impinging on the underside of the diaphragm and not allowing the diaphragm to descend into the abdominal cavity. This will influence the length tension and force velocity relationship as well as the normal three dimensional movement of the chest wall which would be restricted (Jones & Dean, 2004). For these reasons the participants in the current study were limited to individuals with BMI’s lower than 30kg/m^2. BMI and age were controlled by limiting the participants’ inclusion criteria thereby minimising confounding variables so as to ascertain a more accurate understanding of how a head-down tilt position alone will influence a change in diaphragm length.

For this same reason the exclusion criteria also included anyone who had cardiovascular or pulmonary problems and were smokers.

5.3 THE INFLUENCE OF A HEAD-DOWN TILT ON DIAPHRAGM LENGTH

The diaphragm's change in length was successfully measured in 100% of participants on the right hand side compared to only 81.3% of participants on the left hand side. This visualisation is less than what Testa et al (2011) reported, where they obtained a reading in 95% of cases. However it is more than Boussagus et al (2009), where 97.5% were measured on the right and only 21.4% were seen on the left. Our "at rest" diaphragm length measurements (20.20 millimetres to 20.53 millimetres) were in line with the results found "at rest" by Testa et al (2011) who found a resting length of 18.4 millimetres. However our results were higher than those found by Boussuges et al (2011) who showed an "at rest" change of nine to 10 millimetres.

The diaphragm showed a change in length on both the right and left side compared to the initial "at rest" position. The greatest change in length from rest for the left side was seen at a 30 degree head-down tilt position for two minutes, while the right showed the greatest change at a 30 degree head-down tilt position for 30 seconds. The right side therefore reached its maximum change in length quicker than the left. This could be explained by the anatomical differences between the two sides. On the left below the diaphragm lies the stomach and spleen; which are both hollow and relatively lightweight structures. The spleen weighs on average 0.15 kilograms (Stewart & McKenzie, 2002) with the stomach weighing 0.9 kilograms. Their total mass would therefore be less than the liver which weighs 1.5 kilograms (Moore et al, 2011). Comparatively, the right has the liver lying underneath the diaphragm. This is a much denser and heavy structure. The weight of the liver would therefore be more than the stomach and spleen resulting in a greater force being placed on the right side of the diaphragm when in a head-down tilt position. Moreover the diaphragm is connected to the liver on the right hand side without an intermediary parietal pleura (Morgan et al, 2010). The liver therefore has a closer anatomical connection to the diaphragm than the stomach and spleen, thereby causing a greater influence over the right side of the diaphragm than the left in a shorter amount of time.

Cadaveric studies demonstrate that the pressure required to rupture the diaphragm is less on the left than on the right due to the relative weakness on the left from the lumbocostal trigone and the point of embryological fusion (Morgan et al, 2010). The current research did not find that the left diaphragm stretched quicker due to this embryological weak point. This might be due to the fact that when an individual assumed a head-down tilt position a slow gradual increase in pressure occurred with accompanied muscle stretch and not a rapid increase in pressure as would be felt during a motor vehicle accident when wearing a constricting seat belt over the abdominal wall.

The stomach can change its weight based on its contents. If someone has just eaten, the stomach will be heavier. Most of the participants had their data recorded during the students' lunch or tea time between classes. They therefore might not have eaten; their stomachs would have been empty resulting in less weight pushing down on the left side of the diaphragm when in a head-down tilt position. This would help to explain why the left hemi-diaphragm needed a longer time than the right to reach its maximum change in length.

Although the change in length was reached sooner on the right hemi-diaphragm than the left, the change between positions four and five, for both the right and left side, was minimal. The right side of the diaphragm reached its maximum change in length earlier than the left possibly due to the weight of the liver providing a greater stretch. However it can be hypothesized that this increased weight may have become detrimental to the functioning of the acini in the lung bases. As the liver pushes down on these small lung units they could have become compressed. Therefore the improvement from an increased diaphragm length could be possibly cancelled out by the compression of the small functional units of the lung. This was however not noted in the current study as individuals PEFR measurements increased gradually from rest to the final testing position. It could be suggested that if the testing positions were maintained for longer periods of time it might have resulted in reduced PEFR readings due to affecting ventilation negatively.

One participant presented with a unilateral diaphragm that did not show any movement throughout the change in positions. She did not experience any shortness of breath with activities of daily living but it was thought that she may have a paralysed diaphragm or a

problem with the phrenic nerve on the affected side. It was recommended that she speak to her doctor regarding the findings.

The amount that the diaphragm length changed was not equal among the participants. There were large differences between the minimum and maximum values between the study subjects. The minimum value changed from 6.9 millimetres in position one to 18.3 millimetres in position five, a change of only 11.4 millimetres. While the maximum value changed from 43.8 millimetres at position one to 80.3 millimetres at position four, a change of 36.5 millimetres. This would imply that certain individuals have a greater propensity for a change in length through stretching the diaphragm than others. The individual who throughout testing had a lower than average diaphragm excursion was a small female with a small waist circumference. This would relate to the results found by Kantarci et al (2004) who found that those with a waist circumference of less than 70 centimetres had decreased diaphragm movements.

5.4 THE INFLUENCE OF A HEAD-DOWN TILT ON PEAK EXPIRATORY FLOW RATE

The participants in this study had a mean peak expiratory flow rate of 422.7 L/min at rest. This is lower than the mean predicted peak expiratory flow rate (444.6 L/min) of the study sample. This predicted value is generated using the individuals' age, gender and height when reviewing a peak expiratory flow rate chart (Appendix 1). The third year students, who constituted a large percentage of the study participants, had pre-clinical teaching from 08h00 to 17h00 for a duration of four weeks while the data collection process was occuring. This teaching milieu would have enforced a sedentary lifestyle on participants. This may have decreased their forced exhalation effort as a result of weak respiratory muscle strength caused by the sedentary period which would result in the poorer than predicted peak expiratory flow rate at rest (Menezes et al, 2012).

In a head-down tilt position the functional residual capacity decreases as does the expiratory reserve volume (Frownfelter & Dean, 1996). This is thought to be due to the abdominal contents shifting cranially which might lengthen the diaphragm but could concurrently compress the basal alveoli. This compression may therefore cause the distal airways to collapse. This could explain the fact that there was no significant change in peak expiratory

flow rate after a head-down tilt position even though the diaphragm did show a greater change in length between inspiration and expiration. It is unknown whether this would be a good position for patients with COPD as it would need to be evaluated in future research.

5.5 THE INFLUENCE OF A HEAD-DOWN TILT ON THORACIC EXPANSION

The respiratory muscles as well as the shape of the diaphragm generally lead to a potentially greater expansion at the lung bases than apically. Expansion of the lower chest wall is usually 50% greater than the upper chest wall (Wilkins et al, 2009). The action of the diaphragm preferentially inflates the lower lobes of the lungs, implying that the thorax will expand which can be measured by thoracic expansion. The average expansion in healthy adult individuals is three to five centimeters (Wilkins et al, 2009) which our study did not find. Other researchers have found lower values of thoracic expansion at the distal chest wall. Adedoayan et al (2012) found these values to be 2.7 centimetres in females and 4.3 centimetres in males. The values found in the current research study were lower than those seen by Wilkins et al (2009) and Adedoyan et al (2012).

The mean thoracic expansion was 2.10 centimetres at rest. This increased to a maximum of 2.50 centimetres at its greatest expansion but the change was not significant; however an upward trend was seen. All the participants in this study were healthy individuals without any known pulmonary conditions. It would be expected that their diaphragms would therefore be sitting in their anatomically functional position. Weppler & Magnusson (2010) stated that an optimal muscle length allows a muscle to generate the correct amount of active and passive tension required during optimal functioning. However since the results of the peak expiratory flow rates were also lower than expected it is possible that a stiff thorax could have caused a restrictive pattern in study participants. The stiff thorax would have resulted in decreased thoracic expansion values and/or the added possible weak respiratory muscles as discussed above could have resulted in the low thoracic expansion measurements noted in the study.

The reading for thoracic expansion was taken at the T8 level, based on the standard recommended method of measuring thoracic expansion (Wilkins, 2009). It is noteworthy that thoracic expansion at the xiphisternum and T8 does not always relate to inspiratory capacity however inspiratory capacity is said to relate to measurements taken at the abdominal level

(Malaquti et al, 2009). It is possible that if measurements were taken at the abdominal level, the results would have shown a change following the head-down tilt position. This study that recommends measuring at the abdominal level is not the gold standard for measuring thoracic expansion. It is accepted to measure thoracic expansion at the T8 level and therefore this methodology was followed in the current research. A measurement at the abdominal level would have shown a more anteriorly displaced diaphragm, indicating a greater diaphragm contraction but not necessarily a change in movement at the thorax.

5.6 THE INFLUENCE OF A HEAD-DOWN TILT POSITION ON HEART RATE, OXYGEN SATURATION, BLOOD PRESSURE AND DYSPNOEA

The above variables were measured to monitor safety and cardiovascular stability throughout testing.

Systolic blood pressure showed a decrease from a maximum of 125.17mmHg at position two to 117.39mmHg at position five. No significant change was noted in diastolic blood pressure. The change in systolic blood pressure is thought to be due to the response of the carotid sinus baroreceptors picking up an increase in venous return when a person is placed head down. Jones & Dean (2004) found a decrease in sympathetic response which is noted by a decrease in systolic blood pressure as well as heart rate. Our study found statistically significant change in systolic blood pressure which did not translate into clinical significance and no change in heart rate was observed. This was thought to be due to the body's compensatory mechanism to maintain cardiac output. As these were healthy volunteers, we were not expecting any significant cardiovascular changes and even when patients with severe heart disease were tested by others, they were reported to tolerate a head-down tilt position (Naylor et al, 2006).

The change in oxygen saturation was statistically significant but not clinically so as the variations were between 96.9% and 97.4%. More than 92% of the participants had no shortness of breath throughout the study with only 0.98% to 1.3% reporting on "moderate" to "somewhat severe" shortness of breath. A head-down tilt position can decrease the functional reserve capacity (Lumb & Nunn, 1999) as well as possibly compress the distal airways. This would not cause adverse effects in a healthy adult individual for a short period of time but

may be the cause of some participants complaining of shortness of breath. Of the participants who experienced some shortness of breath, 60% had BMI's between the ranges of 25-30.Therefore when tilting someone with a BMI of greater than 25, closer monitoring of the individuals breathlessness is recommended.

5.7 CONCLUSION OF THE STUDY

The researcher undertook to examine if the diaphragm's length between inspiration and expiration could be altered in healthy adult individuals. The study indicated that both the right and left side of the diaphragm could be lengthened by applying a head-down tilt and using the person's own abdominal contents to provide a stretch. The left hemi-diaphragm was more difficult to visualise with ultrasonography due to the spleen and stomach being more mobile than the liver on the right side. This improved with the number of persons tested due to the researcher's technique which improved with practice. Both hemi-diaphragms responded to the stretch in a head-down tilt position with the preferred head-down angle being 30 degrees. The right hemi-diaphragm responded faster, reaching its maximum length in 30 seconds with a head-down tilt of 30 degrees while the left hemi-diaphragm took two minutes in the 30 degrees head-down tilt position.

The head-down tilt proved to be a safe modality with no adverse cardiovascular changes noted. A slight drop in sympathetic response was noted which may be of importance in non healthy individuals especially those with cardiovascular complications.

Shortness of breath was experienced by few participants. The test was generally felt to be comfortable and easy for the volunteers to be involved in. Neither thoracic expansion nor peak expiratory flow rate showed a significant change. However thoracic expansion showed an increasing trend which could offer value for future research.

In conclusion, the research has demonstrated that an increasing change in length is possible by stretching the diaphragm using a head down tilt position. No adverse effects were found. However there was not a significant improvement with respiratory function as measured by thoracic expansion and peak expiratory flow rate.

5.8 LIMITATIONS OF THE STUDY

The study was conducted at the University of the Witwatersrand Physiotherapy department. There are more female students than male students, which was demonstrated with the gender distribution. This may influence the results as females' diaphragm excursion is said to be less than males.

Due to the timetable and class schedules, the majority of the students that were tested were third year undergraduate students. There was not an equal distribution throughout the years.

While collecting the data, the researcher tested every participant in a standardised manner. Therefore they were first tested at rest, then after being placed in a head-down tilt position of 15 degrees for 30 seconds, then 15 degrees for two minutes, then 30 degrees head-down for 30 seconds and lastly 30 degrees head-down for two minutes. The testing positions were not randomised. Therefore a previous position may unduly influence the results obtained in the following position. In future studies it might be suggested to randomly assign the order of positions when performing the testing procedure, so that the order would have been different for the different participants to cancel out the possible accumulative effect.

The diaphragm length, peak flow and thoracic expansion values were not retested after the data was collected in order to ascertain how long the changes remained before returning to baseline. This would be useful information to ascertain if the changes are clinically significant.

Student's stomach contents are not identical; therefore the stomachs weights and therefore stretch applied to the diaphragms are not uniform.

5.9 RECOMMENDATIONS FOR FUTURE RESEARCH

This study demonstrated that a change in length of the diaphragm between inspiration and expiration is possible when performing a head-down tilt position especially when tilting individuals at a 30 degree angle. Normal healthy individuals were used as the subjects in order to obtain a baseline measurement. Future studies could assess patients with already

shortened diaphragms such as those with COPD or patients who are mechanically ventilated for prolonged periods of time or have been mechanically ventilated in the recent past. Findings in these groups of patients can then be compared to the results found in the current study that consisted of healthy adult volunteers. This would be important as those subjects may have diaphragms that enable a greater stretch to take place as the start position of the diaphragm would already be shortened. This may cause a greater influence in peak expiratory flow rate and thoracic expansion then the current research found.

The aim of the current study was not to identify how long the diaphragm length change was maintained in study subjects. Future research could therefore investigate how long a change in diaphragm length is maintained. Variables such as thoracic expansion and peak flow could also be measured to see if the length corresponded to a change in these values.

6. REFERENCES:

Adedoyin RA, Adeleke OE, Fehintola, AO, Erhabor GE, Bisiriyu LA 2012 Reference values for chest expansion among adult residents in Ile-Ife. J Yoga Phys Therapy. 2:113.

Ando T, Kawamura K, Fujitani J, Koike T, Fujimoto M, Fujie MG 2011 Thoracic ROM measurement system with visual bio-feedback: system design and biofeedback evaluation. Conf Proc IEEE Eng Med Biol Soc 1272-4.

Bauseweina C, Farquhara M, Booth S,Gyselsa M, Higginsonal J.2007Measurement of breathlessness in advanced disease: A systematic review. RespMed. 101: 399–410.

Berney S, Denehy L, Pretto J 2004 Head-down tilt and manual hyperinflation enhance sputum clearance in patients who are intubated and ventilated. Aust J Physiother. 50: 9–14.

Bhatnagar S, Kumar A 2012The TWEAK-Fn14 system: breaking the silence of cytokine-induced skeletal muscle wasting. Mo Med 12: 3-13.

Bockenhauer SE, Chen H, Julliard KN, Weedon J. 2007 Measuring thoracic excursion: reliability of the cloth tape measure technique. J Am Osteopath Assoc. 107: 191-6.

Boon AJ, Kais MD, Sharifial, Harper CM, Smith J 2008 Ultrasound-guided needle EMG of the diaphragm: technique description and case report. Muscle nerve 238: 1623–1626

Borg GA 1982 Psychophysical bases of perceived exertion. Med Sci Sports Exerc 14:377–81.

Boulain T, Achard JM, Teboul JL, Richard C, Perrotin D, Ginies G.2002 Changes in BP induced by passive leg raising predict response to fluid loading in critically ill patients. Chest 121:1245–52.

Boussuges A, Gole Y, Blanc P.2009 Diaphragmatic motion studied by M-Mode ultrasonography: methods, reproducibility and normal values. Chest 135: 391-400.

Buchholz AC, Bugaresti JM.2005 A review of body mass index and waist circumference as markers of obesity and coronary heart disease risk in persons with chronic spinal cord injury. Spinal Cord. 43: 513–518.

Burdon J, Juniper E, Killian K, Hargreave F, Campbell E 1982 The perception of breathlessness in asthma. Am Rev Respir Disease. 126:825–8.

Button BM, Heine RG, Catto Smith AG, Olinsky A, Phelan PD, Ditchfield MR.2005 Chest physiotherapy in infants with cystic fibrosis: to tip or not? A five year study. Pediat Pulmonol. 35: 208-213.

Callahan LA, Supinski GS 2010 Diaphragm weakness and mechanical ventilation- what's the critical issue? Critical Care.14:187.

Casaburi R, Bhasin S, Cosentino L 2004 Effects of testosterone and resistance training in men with Chronic Obstructive Pulmonary Disease. Am J Respir Crit Care Med.170:870-8.

Cecins NM, Jenkins SC, Pengelley J,Ryan G 1999 The active cycle of breathing techniques: To tip or not to tip? Resp Med. 93: 660–665.

Chan SP, Hong Y, Robinson PD 2001 Flexibility and passive resistance of the hamstrings of young adults using two different static stretching protocols. Scand J Med Sci Sports.11:81–86.

Chang AT, Boots RJ, Brown MG,Paratz J, Hodges PW.2005 Reduced inspiratory muscle endurance following successful weaning from prolonged mechanical ventilation. Chest .128; 553-559.

Cohen E, Mier A, Heywood P, Murphy K, Boultbee J, Guz A 1994 Excursion-volume relation of the right hemidiaphraghm measured by Ultrasonography and respiratory airflow measurements. Thorax. 29:885–889.

Crowe, J., Reid, W.D., Geddes, E. 2005Inspiratory muscle training compared other rehabilitation interventions in adults with chronic obstructive pulmonary disease: a systematic literature review and meta-analysis. COPD. 3: 329.

De Jonghe B, Bastuji-Garin S, Durand MC 2007 Respiratory weakness is associated with limb weakness and delayed weaning in critical illness. Crit Care Med. 35**:** 2007–15.

De Troyer 1983 Mechanical role of the abdominal muscle sin relation to posture. Pharmacol Res. 53: 341-353.

Dean E. 1997 Oxygen transport deficits in systemic disease and implications for physical therapy. Phys Ther. ;77:187-202.

Dean E 2006 Cardiopulmonary Physiology. In: Frownfelter D, Dean E (ed) *Cardiovascular and Pulmonary Physical therapy: evidence and practice.* Pp74, Mosby Elsevier

Dean E 2006 Body positioning. In: Frownfelter D, Dean E. *Cardiovascular and Pulmonary physical therapy: evidence and practice, pp 317* Mosby Elsevier

Depino GM, Webright WG, Arnold BL 2000 Duration of maintained hamstring flexibility after cessation of an acute static stretching protocol. J Athl Train. 35:56 –59.

Dorman S, Byrne A, Edwards A 2007 Which measurement scales should we use to measure breathlessness in palliative care? A systematic review. Palliat Med. 21 177-91.

Duong B, Low M, Moseley AM 2001. Time course of stress relaxation and recovery in human ankles. Clin Biomech. 16:601–607.

Enoka RM 2002 Neuromechanics of Human Movement. 3rd ed. Champaign, IL: Human

Kinetics Publishers

Enright, SJ, Unnithan VB, Heward C, Withnall L, Davies DH, 2006 Effect of high intensity inspiratory muscle training on lung volumes, diaphragm thickness, and exercise capacity in subjects who are healthy. Phys. Ther. 86: 345–354.

Feland J, Myrer J, Schulthies S, Fellingham G, Meason G 2001 The effect of duration of stretching of the hamstring muscle group for increasing range of motion in people aged 65 years or older. Phys Ther. 8MS: 1100-1117.

Fink H, Helming M, Unterbuchner C, Lenz A, Neff F, Martyn JA 2008 Systemic inflammatory response syndrome increases immobility-induced neuromuscular weakness. Crit Care Med. 36: 910–6.

Gajdosik R, Vander Linden D, McNair P, Williams A, Riggin T2008 Effects of an eight week stretching programme on the passive elastic properties and function of calf muscles in older women. Clin Biomech.20(9): 973-983.

Gerscovich EO, Cronan M, McGahan JP, Jain K, Jones CD, McDonald C 2001 Ultrasonographic evaluation of diaphragmatic motion. J Ultrasound Med. 20(6): 597-604.

Gierada DS, Curti JJ, Erickson SJ, Prost RW, Strandt JA, Goodman LR 1995 Diaphragmatic motion: Fast gradient-recalled-echo MR imaging in healthy subjects. Radiology. 194:879–884.

Gillette MA, Hess DR 2001 Ventilator-induced lung injury and the evolution of lung-protective strategies in acute respiratory distress syndrome. Respir Care. 46(2):130-48.

Gorman RB, McKenzie DK, Butler JE, Tolman JF, Gandevia SC 2005 Diaphragm length and neural drive after lung volume reduction surgery. Am J Respir Crit Care Med. 172(10):1259-66.

Gosselink R, Bott J, Johnson M, Dean E, Nava S, Norrenberg M, Schonhofer B, Stiller K, van de Leur H, Vincent JL 2008 Physiotherapy for adult patients with critical illness: recommendations of the European Respiratory Society and European Society of Intensive Care Medicine Task Force on Physiotherapy for Critically Ill Patients. Intensive Care Med. 34:1188–99.

Griffiths R 1997 Effect of passive stretching on the wasting of muscles in the critically ill: background. Nutrition .13:71-74.

Griffiths LA, McConnell AK 2007 The influence of inspiratory and expiratory muscle training upon rowing performance. Eur. J. Appl. Physiol. 99: 457–466.

Gutierrez CJ, Stevens C, Merritt J, Pope C, Tanasescu M, Curtiss G.Trendelenburg chest optimisation prolongs spontaneous breathing trials in ventilator-dependant patients with low cervical spinal cord injury. J Rehabil Res Dev. 2010; 47(3)261-272.

Hanekom S, Louw QA, Cotzee AR. Implementation of a protocol facilities evidence based physiotherapy practice in intensive care units. Physiotherapy 2012. http://dx.doi.org/10.1016/j.physio.2012.05.005

Hareendran A, Leidy NK, Monz BU, Winnette R, Becker K, Mahler DA 2012 Proposing a standardized method for evaluating patient report of the intensity of dyspnea during exercise testing in COPD. Int J Chron Obstruct Pulmon Dis. 7:345-55.

Harris R, Giovannetti M, Kim BK 1983. Normal ventilatory movement of the right hemidiaphragm studied by ultrasonography and pneumotachography. Radiology.146:141–144.

Harvey LA, Batty J, Crosbie J, Poulter S,Herbert RD 2000 A randomised trial assessing the effects of four weeks of daily stretching on ankle mobility in patients with spinal cord injuries. Arch Phys Med Rehabil. 81:1340-7.

Heneghan NR, Adab P, Balanos GM, Jordan RE 2012 Manual therapy for chronic obstructive airway disease: A systemic review of current evidence. Manual Therapy. 17: 507-518.

Hermans G, Agten A, Testelmans D, Decramer M, Gayan-Ramirz G 2010 Increased duration of mechanical ventilation is associated with decreased diaphragmatic force: a prospective observational study. Crit Care.14: R127.

Hodgkin GE 2009 Nutrition assessment. In: Wilkins RL, Stoller JK, Kackmarek RM (ed) *Egans fundamentals of respiratory care ninth edition*. Elsevier Mosby

Hough A 1996 Physiotherapy in respiratory care a problem solving approach to respiratory and cardiac management 2nd ed, pp 43 Stanley thornes publishers ltd

Houston JG, Morris AD, Howie CA, Reid JL, McMillan N 1992 Technical report: Quantitative assessment of diaphragmatic movement – A reproducible method using ultrasound. Clin Radiol. 46: 405–407.

Hussain SNA, Mofarrahi M, Sigala I, Kim HC, Vassilakopoulos, Maltais F 2010 Mechanical ventilation- induced diaphragm disuse in humans triggers autophagy. Am J Respir Crit Care Med.182; 1377-1386.

Jaber S, Petrof BJ, Jung B, Chanques G, Berthet JP, Rabuel C 2011 Rapidly progressive diaphragmatic weakness and injury during mechanical ventilation in humans. Am J Respir Crit Care Med. 183:367-371.

Jackman RW, Kandarian SC 2004 The molecular basis of skeletal muscle atrophy. Am J Physiol Cell Physiol.287:C834-43.

Jensen LA, Onyskiw JE, Prasad NGN 1998 Meta analysis of arterial oxygen saturation monitoring by pulse oximetry in adults. Heart Lung .27:387-408.

Jiang JR, Tsai TH, Jerng JS, Yu CJ,Wu HD, Yang PC 2004 Ultrasonographic evaluation of liver/spleen movements and extubation outcome. Chest.126:179–185.

Jones AYM, Dean E 2004 Body position change and its effect on haemodynamic and metabolic status. Heart and Lung 33:281-290.

Jubran A, Tobin MJ 1994 Monitoring gas exchange during mechanical ventilation. In: Tobin MJ (ed) *Principles and practice of mechanical ventilation*. New York: McGraw-Hill

Kang HW, Kim TO, Lee BR, Yu JY, Chi SY, Ban HJ, Oh IJ,Kim KS,Kwon YS,Kim YI,Kim YC,Lim SC 2011 Influence of diaphragm mobility on hypercapnia in patients with chronic obstructive pulmonary disease. J Korean Med Sci .26:1209-1213.

Kantarci F, Mihmanli I, Demirel MK, Harmanci K, Akman C, Aydogan F 2004 Normal diaphragmatic motion and the effects of body composition. J Ultrasound Med. 23:255-260.

Kay AD, Blazevich AJ 2012 Effect of acute static stretch on maximal muscle performance: a systematic review. Med Sci Sports Exerc.44(1):154-64.

Kendrick KR, Baxi SC, Smith RM 2000 Usefulness of the modified 0-10 Borg scale in assessing the degree of dyspnea in patients with COPD and asthma. J Emerg Nurs. 26 (3): 216-22.

Kissinger DP, Hamilton IN, Rozycki GS 1991 The current practice of pulse oximetry and capnometry/ capnography in the prehospital setting. Emerg care quart 7:44-50.

Latronico N, Bolton CF 2011 Critical illness polyneuropathy and myopathy: a major cause of muscle weakness and paralysis. Lancet Neurol. 10:931-41.

Leelarungrayun D, Pothongsunun P, Yankai A, Pratanaphon S 2009 Acute clinical benefits of chest wall stretching exercise on expired tidal volume, dyspnea, and chest expansion in a patient with chronic obstructive pulmonary disease: a single case study. J Bodyw Mov Ther. 2009.13: 338-343.

Leong B 2002 Critical review of passive muscle stretch: implications for the treatment of children in vegetative and minimally conscious states. Brain Injury. 16(2):169-183.

Lewis LK, Williams MT, Olds TS 2012 The active cycle of breathing technique: A systematic review and meta analysis. Resp Med.106:155-172.

Li B, Wu YT, Tsai SJ, Tseng FF, Lin CY, Ding H 2004 Comparison of ultrasonographic renal excursion to fluoroscopic diaphragmatic excursion for the assessment of diaphragmatic function in patients with high cervical cord injury. Arch Phys Med Rehabil.85:65–69.

Lumb A, Nunn JF 1999 Nunn's *applied respiratory physiology*. 5th ed. London: Elsevier.

Magnusson SP 1998 Passive properties of human skeletal muscle during stretch maneuvers: a review. Scand J Med Sci Sports. 8:65–77.

Malaguti C, Rondelli RR, de Souza LM, Domingues M, Dal Corso S 2009 Reliability of chest wall mobility and its correlation with pulmonary function in patients with chronic obstructive pulmonary disease. Respir Care. 54 (12) 1703-11.

Maxwell L,Ellis E 2002 The effects of three manual hyperinflation techniques on pattern of ventilation in a test lung model. Anaesth Intensive Care.30: 283–288.

McClung JM, Kavazis AN, DeRuisseau KC, Falk DJ, Deering MA, Lee Y, Sugiura T, Powers SK 2007 Caspase-3 regulation of diaphragm myonuclear domain during mechanical ventilation-induced atrophy. Am J Respir Crit Care Med .175:150–159.

McCoy EK, Thomas JL, Sowell RS, George C, Finch CK, Tolley EA, Self TH 2010 An evaluation of peak expiratory flow monitoring: a comparison of sitting versus standing measurements. J Am Board Fam Med.23(2):166-70.

McNair PJ, Dombroski EW, Hewson DJ, Stanley SN 2001 Stretching at the ankle joint: viscoelastic responses to holds and continuous passive motion. Med Sci Sports Exerc. 33:354–358.

Mendelson Y 1992 Pulse oximetry: theory and applications for noninvasive monitoring. Clin Chem. 38: 1601-1607.

Menezes AMB, Wehrmeister FC, Muniz LC, Perez-Padilla R, Noal RB, Silva MC, Gonclaves H, Hallal PC 2012 Physical activity and lung function in adolescents: the 1993 Pelotas (Brazil) birth cohort study. J Adolesc Health. 51: S27-S31.

Mengelkoch LJ, Martin D, Lawlor J. 1994 A review of the principles of pulse oximetry and accuracy of pulse oximeter estimates during exercise. Phys Ther. 74: 40-49.

Moore KL, Agur AM, Dalley AF 2011 In: *Essential Clinical Anatomy 4th ed*.Lippincott Williams & Wilkins

Morgan BS, Watcyn-Jones T, Garner JP 2010 Traumatic diaphragmatic injury. JR Army Med Corps. 156 (3):139-149.

Myers MG 2006 Automated blood pressure measurement in routine clinical practice. Blood Press Monit. 11(2):59-62.

Myers MG, McInnis NH, Fodor GJ, Leenen FH 2008 Comparison between an automated and manual sphygmomanometer in a population survey. Am J Hypertens. 21(3):280-3.

Muraki S, Ehara Y, Yamasaki M 2000 Cardiovascular responses at the onset of passive leg cycle exercise in paraplegics with spinal cord injury. Eur J Appl Physiol. 81:271–4.

Naylor JM, Chow CM, McLean AS, Heard R, Avolio A 2005 Cardiovascular responses to short-term head-down positioning in healthy young and older adults. Physiother Res Int. 10: 44–5950: 9–14.

Naylor JM, McLean A, Chow CM, Heard R, Ting I, Avolio A 2006. A modified postural drainage position produces less cardiovascular stress than a head down position in patients with severe heart disease: A quasi experimental study. Aust J Physiother 52:52.

Nazir Z, Razaq S, Mir S, Anwar M, Mawlawi GA, Saiad M 2005 Revisiting the accuracy of peak flow meters: a double-blind study using formal methods of agreement. Resp Med. 99 (5): 592-595.

Nelson RT, Bandy WD 2004 Eccentric Training and static stretching improve hamstring flexibility of high school males. J Athl Train.39:254–258.

Ni H, Wu C, Prineas R, Shea S, Liu K, Kronmal R 2006 Comparison of Dinamap PRO-100 and mercury sphygmomanometer blood pressure measurements in a population-based study. Am J Hypertens.19(4):353-60.

Nixon JV, Murray G, Leonard PD, Mitchell JH, Blomqvist CG 1982 Effect of large variations in preload on left ventricular performance characteristics in normal subjects. Circulation. 65: 698–703.

Norsk P, Stadeager C, Johanson LB, Warberg J, Bie P, Foldager N , Christenson NJ 1993 Volume-homeostatic mechanisms in humans during a 12-h posture change. J Appl Physiol.75: 349–356.

Ochala J, Llano-Diez M, Larsson L 2009 Diaphragm muscle weakness in an experimental intensive care unit model. Neuromuscular disorders. 19: 543-660.

Olive JL, McCully KK, Dudley GA.Olive JL, McCully KK, Dudley GA 2002 Blood flow response in individuals with incomplete spinal cord injuries. Spinal Cord. 40(12):639-45.

O'Shea S, Taylor N, Paratz J 2004 Peripheral muscle strength training for patients with chronic obstructive pulmonary disease: a systematic review. Chest.126:903-14.

O¨ zkaya N, Nordin M 1999 *Fundamentals of Biomechanics: Equilibrium, Motion, and Deformation.* 2nd ed. New York, NY: Springer

Parente AA, March MF, Evangelista LA, Cunha AL 2011 Perception of dyspnea in childhood asthma crisis by the patients and those in charge of them. J Pediatr. 87(6):541-6.

Pavlik VN, Hyman DJ, Toronjo C 2000 Comparison of Automated and Mercury Column Blood Pressure Measurements in Health Care Settings. J Clin Hypertens.2(2):81-86.

Pesola GR, O'Donnell P, Pesola GR Jr, Chinchilli VM, Magari RT, Saari AF 2010 Comparison of the ATS versus EU mini Wright peak flow meter in normal volunteers. J Asthma. 47(10): 1067-71.

Pierson DJ 1990 Pulse oximetry versus arterial blood gas specimens in long term oxygen therapy. Lung.168: 782-788.

Polla B, D'Antona G, Bottinelli R, Reggiani C 2004 Respiratory muscle fibres: specialisation and plasticity. Thorax. 59:808–817.

Potter HM. Musculoskeletal dysfunction in respiratory disease 2002 In: Pryor JA, Prasad SA, (ed) *Physiotherapy for respiratory and cardiac problems. Pp 161-170* 3rd ed. London: Churchill Livingstone

Puckree T, Cerny F, Bishop B 2002 Does intercostal stretch alter breathing patten and respiratory muscle activity in conscious adults. Physiother. 2: 89-97.

Radell P, Edstrom L, Stibler H, Eriksson LI, Ansved T. 2004 Changes in diaphragm structure following prolonged mechanical ventilation in piglets. Acta Anaesthesiol Scand. 48:430–437.

Reid DA, McNair PJ 2011 Effects of a six week lower limb stretching programme on range of motion, peak passive torque and stiffness in people with and without osteoarthritis of the knee. NZ J Physiother. 39(1) 05-12.

Romainini W, Muller AP, de Carvalho KAT, Olandoski M, Faria-Neto JR, Mendes FL 2007 The effects of intermittent positive pressure and incentive spirometry in the postoperative myocardial revascularisation. Arq Bras Cardiol. 89(2): 94-99.

Ross J, Dean E, Abboud RT 1992 The effect of postural drainage positioning on ventilation homogeneity in healthy subjects. Phys Ther. 72: 794-799.

Ross EZ, Alexander V, Nowicky, McConnell AK 2007 Influence of acute inspiratory loading upon diaphragm motor-evoked potentials in healthy humans. J Appl Phys. 102 (5):1883-1890.

Ruppel GL 2009 Ventilation 2009 .In: Wilkins RL, Stoller JK, Kackmarek RM (ed) *Egan's Fundamentals of Respiratory Care pp 216-221* Mosby Elsevier

Scanlan, C.L 1995 Pattern of cardiopulmonary dysfunction. In: Scanlan, C.L., Spearman, C.B., Sheldon, R.L (ed) Egan's Fundamentals of Respiratory Care, sixth ed. Pp 357 Mosby, Wiesbaden

Scott S, Fuld JP, Carter R, McEntegart M, MacFarlane NG 2006 Diaphragm ultrasonography as an alternative to whole-body plethysmography in pulmonary function testing. J Ultrasound Med. 25:225–232.

Selsby D, Jones J 1990 Some physiological and clinical aspects of chest physiotherapy. Br J Anaesth. 64: 621–631.

Slack RS, Shucart W 1994 Respiratory dysfunction associated with traumatic injury to the central nervous system. Clin Chest Med.15(4):739-49.

Stewart IB, McKenzie DC 2002 The human spleen during physiological stress. Sports med. 32(6):361-9.

Stiller K, Jenkins S, Grant R, Geake T, Taylor J, Hall B 1996 Acute lobar atelectasis: A comparison of five physiotherapy regimens. Physiotherapy Theory Pract.12: 197–209.

Suokhrie LN, Reed CR, Emory C, White R, Moriarity CT, Mayberry J 2013 Differences in automated and manual blood pressure measurement in hospitalized psychiatric patients. J Psychosoc Nurs Ment Health Serv.51(3):32-7.

Sutton P, Pavia D, Bateman J, Clarke S 1992 Chest physiotherapy: A review. Eur J Respir Dis. 66: 233–239.

Takara GN, Ruas G, Pessoa BV, Jamami LK, Di Lorenzo VAP, Jamami M 2010 Comparison of five portable peak flow meters. Clinics. 265(5):469-74.

Testa A, Soldati G, Giannuzzi R, Berardi S, Portale G, O Gentiloni 2011 Ultrasound m-mode assessment of diaphragmatic kinetics by anterior transverse scanning in healthy subjects. Ultrasound in med. & biol. 37(1):44–52.

Vibekk P 1991 Chest mobilisation and respiratory function. In: Pryor JA (ed) *Resp care.* Pp 103-19 London: Churchill Livingstone

Voyvoda N, Yucel C, Karatas G, Oguzulgen I, Oktar S 2011 An evaluation of diaphragmatic movements in hemiplegic patients. Br J Radiol. 1-4.

Watson AC, Hughes PD, Harris ML, Hart N, Ware RJ, Wendon J, Green M, Moxham J 2001 .Measurement of twitch transdiaphragmatic, esophageal and endotracheal tube pressure with bilateral anterolateral magnetic phrenic nerve stimulation in patients in the intensive care unit. Crit Care Med. 29 (7):1325-1331.

Weppler CH, Magnusson SP 2010 Increasing muscle extensibility: a matter of increasing length or modifying sensation? Phys Ther. 90:438-449.

Wilkins RL 2009 Bedside assessment of the patient. In: Wilkins RL, Stoller JK, Kackmarek RM (ed) Egan's Fundamentals of Respiratory Care ninth edition. Pp 333-4 Mosby, Elsevier

Winkelman C 2004 Inactivity and inflammation: selected cytokines as biologic mediators in muscle dysfunction during critical illness. AACN Clin Issues.15:74–82.

Winslow C, Rozovsky J 2003 Effect of spinal cord injury on the respiratory system. Am J Phys Med Rehabil. 82(10): 803-14.

Winters MV, Blake CG, Trost JS 2004 Passive versus active stretching of hip flexor muscles in subjects with limited hip extension: a randomized clinical trial. Phys Ther.84:800–807.

Wilson RC, Jones PW 1989 A comparison of the visual analogue scale and modified Borg scale for the measurement of dyspnoea during exercise. Clin Sci. 76(3):277–82.

Wun YT, Chan MS, Wong NM, Kong AY, Lam TP 2013 A curvilinear nomogram of peak expiratory flow rate for the young. J Asthma. 50(1):39-44.

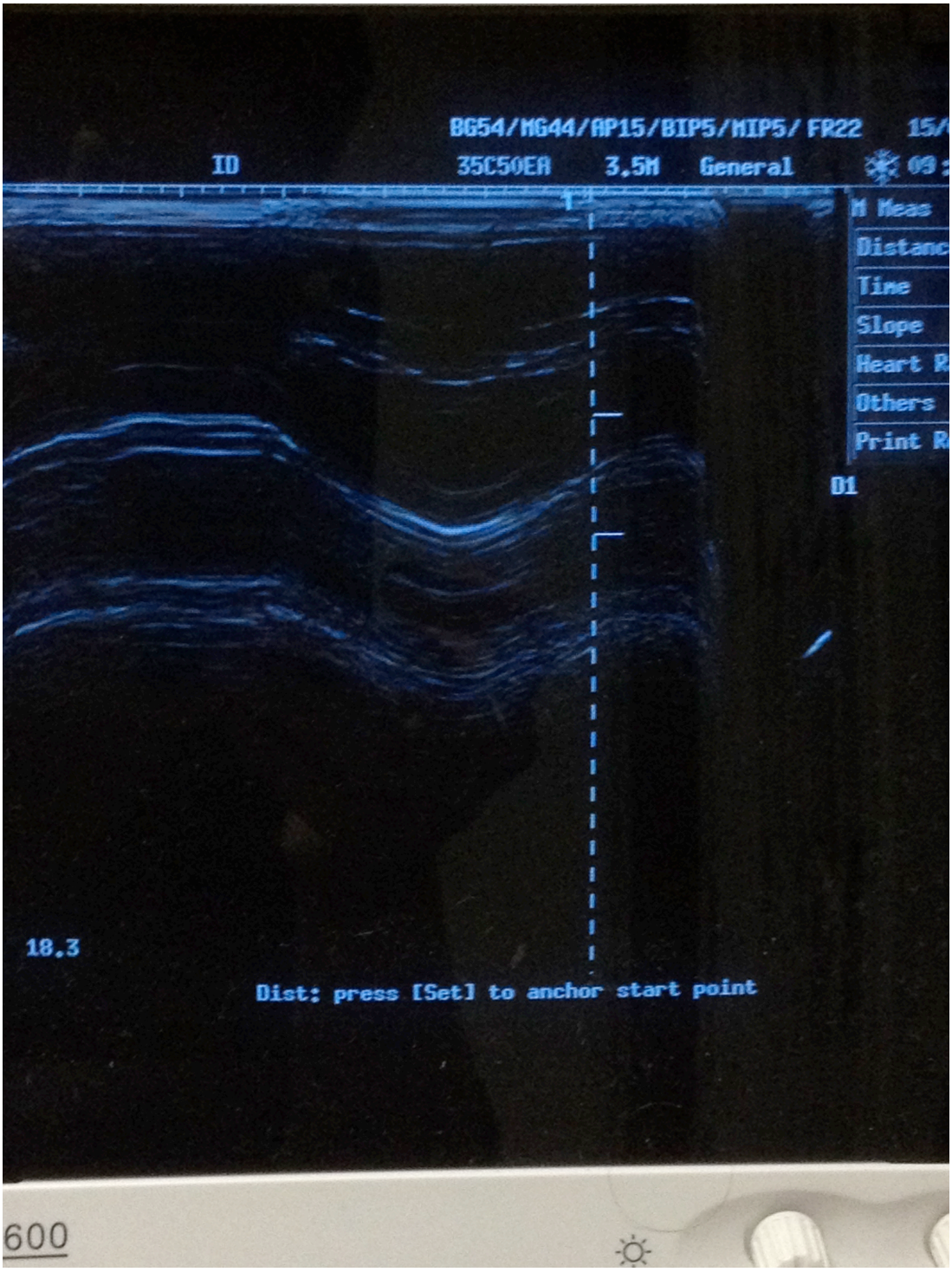
Yamaguti WPS, Paulin E, Shibao S, Kodaira S, Chammas MC, Carvalho CRF 2007 Ultrasound evaluation of diaphragmatic mobility in different postures in healthy subjects. J Bras Pneumol.33: 407–413.

Yamaguti DS, Shibao S, Chammas MC, Salge JM, Ribeiro M, Cukier A 2008 Air trapping: the major factor limiting diaphragm mobility in chronic obstructive pulmonary disease patients. Respirology. 13: 138-144.

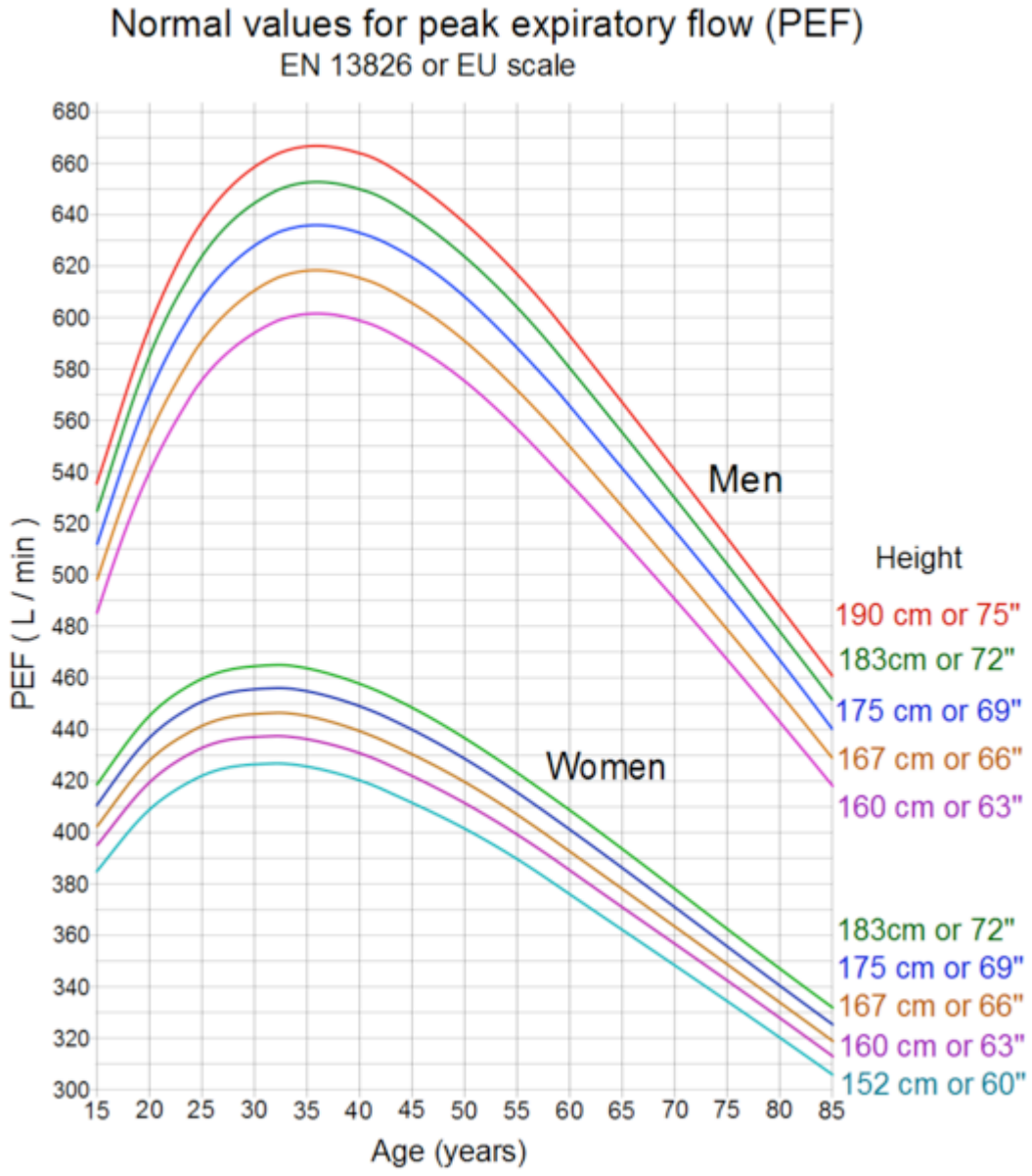
Yamaguti DS, Sakamoto ET, Panazzolo D, da Cunha, Peixoto C, Cerri GG 2010 Diaphragmatic mobility in healthy subjects during incentive spirometry with a flow orientated device and with a volume orientated device. J Bras Pneumol. 36 (6):738-745.

APPENDIX 1

Picture of the ultrasound picture taken measuring the change in diaphragm length between inspiration and expiration



APPENDIX 2


Normal values for peak expiratory flow (PEF)
EN 13826 or EU scale
PEF (L / min)
680
660
640
620
600
580
560
540
520
500
480
460
440
420
400
380
360
340
320
300
15 20 25 30 35 40 45 50 55 60 65 70 75 80 85
Age (years)
Men
Women
Height
190 cm or 75"
183cm or 72"
175 cm or 69"
167 cm or 66"
160 cm or 63"
183cm or 72"
175 cm or 69"
167 cm or 66"
160 cm or 63"
152 cm or 60"

APPENDIX 3

Modified Borg Dyspnoea chart

SCALE	SEVERITY
0	No Breathlessness* At All
0.5	Very Very Slight (Just Noticeable)
1	Very Slight
2	Slight Breathlessness
3	Moderate
4	Some What Severe
5	Severe Breathlessness
6	
7	Very Severe Breathlessness
8	
9	Very Very Severe (Almost Maximum)
10	Maximum

From Burdon JGW, Juniper EF, Killian KJ, Hargrave FE, Campbell EJM. The perception of breathlessness in asthma. Am Rev Respir Dis 1982;126:825-8. Official Journal of the American Thoracic Society. © by the American Lung Association.)

APPENDIX 4

Evaluation Document

Participant no: Age:

Height: Weight:

Heart Rate: (bpm)

At rest	Thirty seconds, fifteen degrees	At rest	Two min, fifteen degrees	At rest	Thirty sec, thirty degrees	At rest	Two minutes, thirty degrees

Oxygen Saturation (%):

At rest	Thirty seconds, fifteen degrees	At rest	Two min, fifteen degrees	At rest	Thirty sec, thirty degrees	At rest	Two minutes, thirty degrees

Blood Pressure:

At rest	Thirty seconds, fifteen degrees	At rest	Two min, fifteen degrees	At rest	Thirty sec, thirty degrees	At rest	Two minutes, thirty degrees

Diaphragm length:

At rest	Thirty seconds, fifteen degrees	At rest	Two min, fifteen degrees	At rest	Thirty sec, thirty degrees	At rest	Two minutes, thirty degrees

PEFR:

At rest	Thirty seconds, fifteen degrees	At rest	Two min, fifteen degrees	At rest	Thirty sec, thirty degrees	At rest	Two minutes, thirty degrees

Thoracic Expansion:

At rest	Thirty seconds, fifteen degrees	At rest	Two min, fifteen degrees	At rest	Thirty sec, thirty degrees	At rest	Two minutes, thirty degrees

Modified Borg scale for breathlessness:

At rest	Thirty seconds, fifteen degrees	At rest	Two min, fifteen degrees	At rest	Thirty sec, thirty degrees	At rest	Two minutes, thirty degrees

APPENDIX 5A Picture of the bed at a 15 degree head-down tilt position

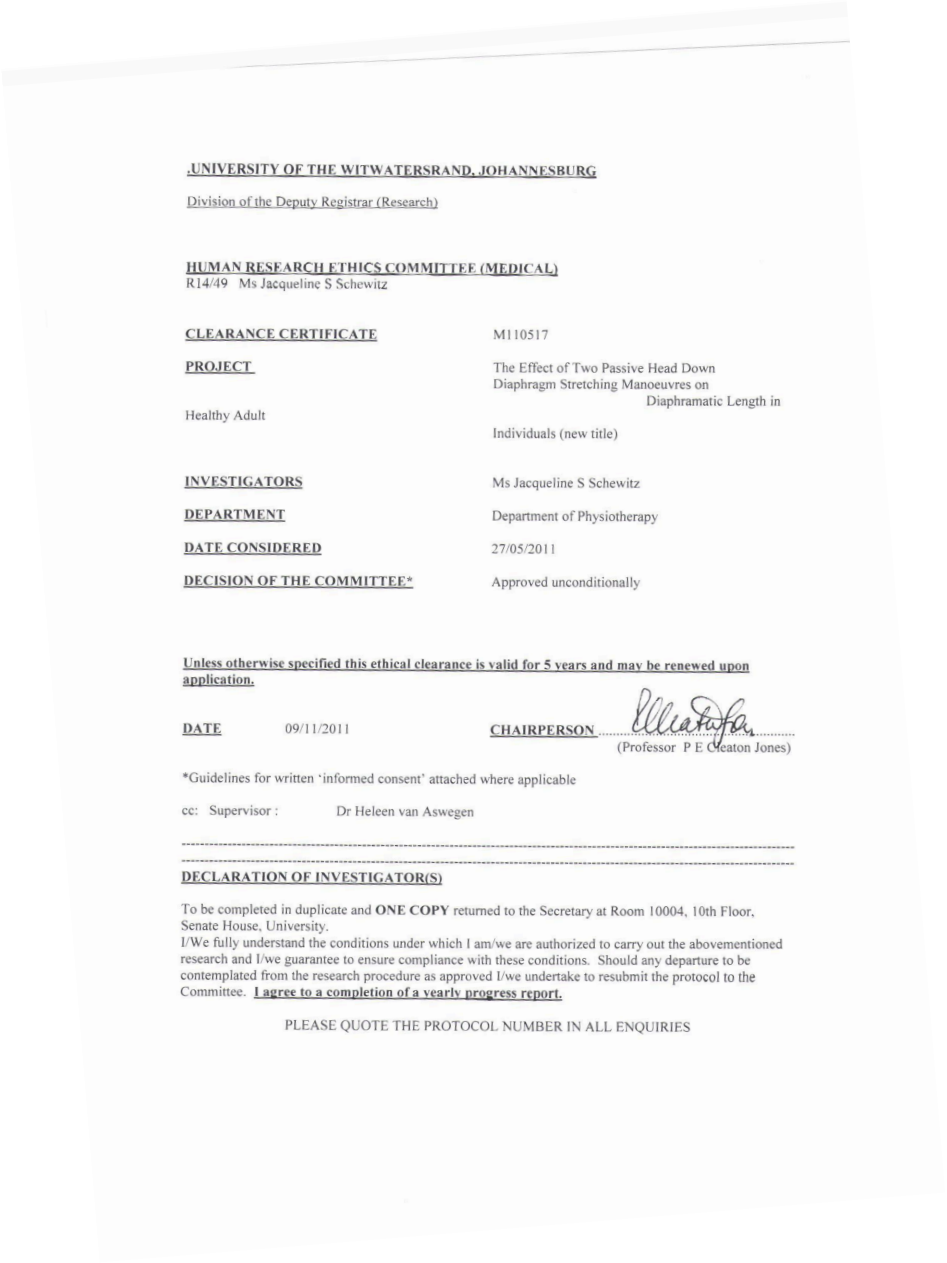


APPENDIX 5B Picture of the bed at a 30 degree head-down tilt position



APPENDIX 6

Ethical clearance certificate



UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Ms Jacqueline S Schewitz

CLEARANCE CERTIFICATE	M110517
PROJECT	The Effect of Two Passive Head Down Diaphragm Stretching Manoeuvres on Diaphramatic Length in Healthy Adult Individuals (new title)
INVESTIGATORS	Ms Jacqueline S Schewitz
DEPARTMENT	Department of Physiotherapy
DATE CONSIDERED	27/05/2011
DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 09/11/2011 CHAIRPERSON .....
(Professor P E Cleaton Jones)

*Guidelines for written 'informed consent' attached where applicable

cc: Supervisor : Dr Heleen van Aswegen

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX 7

Permission from the head of the Physiotherapy department to use the facilities at the University as well as allow the undergraduate students to partake in the research

Physiotherapy

Faculty of Health Sciences · Private Bag 3, Wits, 2050, South Africa
Tel: +27 11 717 3702 · Fax : 27 11 717 3719 · E-mail: hellen.myezwa@wits.ac.za

03-05-2011

To the ethics committee

Ref Jacqueline Sharon Schewitz, student no 0001310Y

This letter serves to confirm that Ms Schewitz has the persmission to conduct her research within the Department of physiotherapy using subjects recruited from our body of students on a voluntary basis. Details of the study are given below. The pilot study will be conducrted in July and August 2011 and the main research will be carried out January- march 2012 .Ms Schwewitz will be using equipment that is already in the Physiotherapy Department namely: diagnostic ultrasound, peak expiratory flow, non stretchable tape measure, heart rate and blood pressure monitoring equipment and pulse oxymeter.

The research study:
The purpose of this study is to identify if there is a measurable change in diaphragm function and therefore on respiration following the testing maneuver. A cross sectional experimental study will be done by consecutive sampling in physiotherapy students aged 19 to 22 years. The maneuver will involve placing the participant in a head down tilt position at specified degrees and times. Following the intervention measurements of diaphragm length, peak expiratory flow and thoracic expansion will be taken to measure change.
By testing healthy individuals and determining the most appropriate angle for head down tilting and time required for tilting in order to facilitate stretching of the diaphragm, the information collected from this study will serve as a basis for further research in determining the effect of stretching of the diaphragm with head down tilting in mechanically ventilated patients or patients recovering from prolonged mechanical ventilation.

Dr Hellen Myezwa
HOD
Physiotherapy Department
School of Therapeutic sciences

APPENDIX 8

Information sheet

Good Day

My name is Jacqui Schewitz. I am a master's student at the University of the Witwatersrand. I am carrying out research on the effect of diaphragm stretching in the healthy adult population. I would be very grateful if you would be able to assist me by participating in my research.

Why is this study important?

As physiotherapists we aim to minimize dysfunction within our patients. In hospital patients spend a large amount of time in a stationery position that is putting their diaphragm in a shortened position and therefore impact on their breathing and respiratory function. I want to see if changing the length and position of their diaphragm (main muscle of inspiration) will affect their respiration.

What would you be expected to do?

You would have a baseline measurement for heart rate, oxygen concentration, blood pressure, peak inspiratory pressure, thoracic expansion, diaphragm length and your state of breathlessness. You would then be asked to lie in different position for certain periods of time, such as:

15 degrees head down for30 seconds

15 degrees head down for two minutes

30 degrees head down for 30 seconds

30 degrees head down for two minutes

After each position all the above measurements would be retaken.

What are the benefits to the participants?

Information gathered will be analysed. These findings will impact our treatment of patients who have a decreased exercise tolerance and have decreased mobility. Information gathered here may be used as part of future research into the effect of stretching the respiratory muscles in in- hospital patients. Feedback on the findings will be shared with the participants in the form of handouts.

What about confidentiality?

The names of all participants will only occur once, on the consent form. This will be kept separately from all other data taken. The ethics committee has approved the study and can be contacted +2711 717 1252.

For more information, or if you have any queries, please don't hesitate to contact me on 083-638-0890

If you are willing to participate in this study, please fill in the demographic sheet and sign the consent form

Thanking you in advance

Jacqui Schewitz

BSc Physiotherapy (Wits)

APPENDIX 9

Consent Form

I _____

Hereby agree to participate in the study testing the effect of two maneuvers on diaphragm length in healthy adult individuals.

I have read the information sheet and understand what will be required of me. I am satisfied that all my questions relating to this study have been answered.

By signing this form I am agreeing to be tested before and after the interventions mentioned in the information sheet.

I understand that there is no monetary reward and I am free to withdraw from the data collection at any given time.

Date: _____

Signature of participant: _____

APPENDIX 10

Coding Form

Participation code:

Name:	
e- mail address	
Cellphone no	
Age:	
Year of study:	