The effect of osteopathic manipulative techniques on diaphragm movement and respiratory function in asymptomatic subjects

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A research project submitted in partial fulfilment of the requirements for the degree of Master of Osteopathy, Unitec Institute of Technology, 2009

Declaration

Name of candidate: Sharon Wendy Hosking

This Research Project titled **"The effect of osteopathic manipulative techniques on diaphragm movement and respiratory function in asymptomatic subjects"** is submitted in partial fulfilment for the requirements for the Unitec degree of Master of Osteopathy.

CANDIDATE'S DECLARATION

I confirm that:

- This research project represents my own work.
- The contribution of supervisors and others to this work was consistent with the Unitec Regulations and Policies.
- Research for this work has been conducted in accordance with the Unitec research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.

Research Ethics Committee Approval Number: 2008.847

Candidate Signature:..Date:...................................

Student ID Number: 1131243

Acknowledgments

This project was every bit the challenge I expected. It tested all aspects of my personality and revealed a little more! As much as I dreaded the undertaking of this research paper; completion was equally rewarding.

This project would not have started, let alone been completed, without the help and assistance from the following; therefore I wish to thank:

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Study is now complete..........I have realised my dream.........I am an Osteopath.

FANTASTIC

Table of Contents

Overview

The following research project is divided into three sections:

1) The literature review with emphasis on:

- The anatomy of the diaphragm and physiology of respiration
- Respiratory disease
- Respiratory dysfunction
- The effects of respiratory dysfunction and associated musculoskeletal dysfunction on health
- Musculoskeletal dysfunction, respiratory dysfunction and disease
- Osteopathic manipulative techniques and treatment for musculoskeletal dysfunction relating to breathing
- Osteopathic manipulative techniques and the diaphragm

2) A manuscript in the format specified for submission to the *International Journal of Osteopathic Medicine.*

3) Appendices that include ethics approval, participant information sheet, consent form, medical history form and the guidelines for authors to *International Journal of Osteopathic Medicine (IJOM).*

***Note**:* Ventilation and respiration are often used interchangeably in breathing literature. For the purpose of this study the term 'ventilation' will relate to the mechanical structures of breathing and respiration, to gas exchange at the cellular level.

Introduction to Thesis

For years researchers have been investigating physiological mechanisms and biomechanical functions of breathing with some investigations dating back as far as the late 1800's . Stone (1999), states that "the diaphragm is one of the most remarkable areas of the body in that it has so much influence and the consequences of its dysfunction can manifest anywhere from the head to the toes".

The purpose of section one of this dissertation is to review the importance of the diaphragm to breathing and the importance of breathing to well being. According to Courtney (2009), dysfunctional breathing is "when the person is unable to breath efficiently or when breathing is inappropriate, unhelpful or inefficient in responding to environmental conditions and the changing needs of the individual"

In a medically challenged individual (genetically, anatomically or by cause of disease) respiratory function is compromised and continues to be of interest to the medical profession (Gandevia, Butler, Hodges, & Taylor, 2002; Lewit, 1980; Loveridge, West, Anthonisen, & Kryger, 1984; Thomas, McKinley, Freeman, & Foy, 2001). However, individuals who may have respiratory dysfunction but do not display respiratory distress are of less interest to the medical profession. This is reflected in health care research where respiratory disease studies are common but the effects of dysfunctional breathing remain poorly understood. This is understandable given that respiratory diseases such as asthma and chronic obstructive pulmonary disease (COPD) are associated with high morbidity whereas dysfunctional breathing is not. In asthma and COPD, to maintain the lung functions of ventilation and gas exchange, breathing patterns may change from abdominal breathing to upper chest breathing (Courtney, 2009). Dysfunctional breathing may be caused by musculoskeletal changes, such as altered rib movement, which can alter the mechanical mechanisms of breathing. Equally, prolonged changes in breathing patterns can cause musculoskeletal changes and dysfunction. Sammut and Searle-Barnes (1998) state that hypertonicity[1] is commonly observed in the scalenes, sternocleidomastoid, diaphragm and the internal intercostal muscles of asthmatic patients. Although asthma and dysfunctional breathing are closely interrelated (Bartley & Clifton-Smith, 2006), the medical profession has

[1] Abnormally increased muscle tone (Stedman's, 2001, p. 703).

conducted considerably more studies relating to respiratory disease such as asthma and COPD (Bockenhauer, Julliard, Lo, Huang, & Sheth, 2002; Dos Santos Yamaguti et al., 2008; Galobardes, McCarron, Jeffreys, & Davey Smith, 2008; Guiney, Chou, Vianna, & Lovenheim, 2005) than to dysfunctional breathing (Courtney, 2009).

Breathing not only involves oxygen exchange from the lungs to the blood stream but it plays an important role in systems such as the cardiovascular and musculoskeletal system and their related functions (Bartley & Clifton-Smith, 2006; Lee, Lee, Lee, Cornelissen, Otsuka, Halberg, 2003; Parsons & Marcer, 2005; Stone, 1999). It has been recently suggested by Bartley and Clifton-Smith (2006) that dysfunctional breathing may be part of the clinical picture in a wide range of disorders including asthma, allergy, heart disease, headaches, facial pain, anxiety, depression, jaw pain and lower back pain.

The interconnectedness between all body systems in health is of importance to osteopathic practice and philosophy (Parsons & Marcer, 2005; Seffinger, king, ward, Jones III, Rogers, Patterson, 2003). Seffinger et al (2003), writing about osteopathic principles states "When all parts of the body are in line we have health. When they are not the effect is disease." Osteopaths have long held an interest in the abdominal diaphragm not only for its role in breathing, but also for the role it plays in intrathoracic and abdominal pressure gradients and circulation, lymphatic flow and postural support (Hruby, 2003). In osteopathy, there is a view that dysfunction of normal breathing biomechanics or anatomical structures relating to diaphragm movement may alter breathing, which in turn may influence a person's health and well being (Chaitow, Bradley, & Gilbert, 2002).

Although a number of muscles contribute to forced ventilation, it is the abdominal diaphragm that makes the greatest contribution. The motion of the diaphragm creates morphological and functional alterations in the thoracic and abdominal cavities, resulting in inspiration and expiration (Pacia & Aldrich, 1998; Poole, Sexton, Farkas, Powers, & Reid, 1997). Chaitow et al (2002) describe how the diaphragm contributes to spinal and pelvic stabilization and the interconnectedness with intra-abdominal pressure. Biomechanical changes such as rib and spine immobility are thought to contribute to increased work load on the diaphragm. Dysfunction of the diaphragm may have far reaching health consequences, including reductions in health and quality of life (Kuchera & Kuchera, 1994). It is important to establish correct movement and function of the diaphragm, which enables adequate structural support and fluid dynamics (e.g. venous return and lymphatic flow) necessary for optimal health (Stone, 1999; Towns, 2003). It is therefore clear that maintaining the function of the diaphragm is important in achieving optimal health.

In osteopathy there is a strong emphasis on musculoskeletal function and its interaction with other physiology. Towns (2003) states the musculoskeletal system is approximately 75% of the body mass; providing stability in health and clues to dysfunction and disease. Respiratory disease, caused by pathologies (Galobardes et al., 2008) such as asthma or COPD may result in associated musculoskeletal dysfunction which may, in turn, cause additional respiratory problems and problems 'down-stream'[2] affecting pressure gradients, lymphatic flow, blood flow, gas exchange (Courtney, 2009). Osteopathy does not claim to be able to completely resolve such disturbances but may be able to improve musculoskeletal function thereby improving respiratory function, preventing down-stream problems. When respiratory dysfunction may be caused by musculoskeletal dysfunction the application of osteopathic techniques that act on diaphragm movement may be clinically useful in addressing respiratory dysfunction. However, when respiratory and associated musculoskeletal dysfunction is caused by pathologies, such as asthma or COPD, osteopathic techniques applied may only alleviate musculoskeletal dysfunction. Therefore osteopathic techniques applied to areas that directly relate to the diaphragm in the presence or absence of pathology could plausibly provide comfort, solve or alleviate respiratory problems.

The theoretical basis for diaphragm treatment by osteopaths is documented by numerous authors (DiGiovanna, Schiowitz, & Dowling, 2005; Greenman, 2003; Parsons & Marcer, 2005). However, there has been minimal investigation to date into whether osteopathic manipulative (OM) techniques, commonly used in clinical practice to treat the diaphragm, result in improved diaphragm function and consequently breathing. Therefore, further research that investigates the effect of OM techniques on diaphragm movement is required.

[2] Physiological changes caused by diaphragmatic movement at a molecular level.

Section 1: Literature Review

Introduction

The purpose of this literature review is to provide a theoretical basis from which to support the experimental investigation reported in section two of this dissertation. This literature review outlines:

- the anatomy of the diaphragm and physiology of respiration
- respiratory disease
- respiratory dysfunction
- the effects of respiratory dysfunction and associated musculoskeletal dysfunction on health
- musculoskeletal dysfunction, respiratory dysfunction and disease
- osteopathic manipulative techniques and treatment for musculoskeletal dysfunction relating to breathing
- osteopathic manipulative techniques and the diaphragm

There are many studies investigating pathologies such as asthma, chronic obstructive pulmonary disease (COPD) or trauma in relation to respiratory disease. However, little research has been published to date that relates to breathing or breathing dysfunction and its association to the diaphragm. The theoretical basis regarding osteopathic techniques used to treat the diaphragm has been documented in text books (DiGiovanna et al., 2005; Greenman, 2003; Hartman, 2001). Osteopaths believe that diaphragm movement plays a key role in ventilation efficiency, respiratory capacity and as a fluid pump. Osteopathic techniques have therefore been developed to influence diaphragm function. Although the techniques that are said to influence diaphragm function are commonly practiced within the osteopathic profession, and are known to other manual therapists such as chiropractors and physiotherapists, there is minimal research to substantiate the effectiveness of such techniques or the theoretical basis for their application.

Anatomy of the diaphragm and physiology of respiration

The diaphragm has long been of interest to the medical profession, with literature dating back to the late 1800's when Sewall and Pollard (1890) investigated the relationship of movement between the thoracic cage and the diaphragm. Anatomical attachments of the diaphragm play an important role in breathing. A recent review by Courtney (2009) discusses the function of breathing and the role it plays in the physiological regulation of oxygen, carbon dioxide and pH. Courtney (2009) also discusses how impairment of the functions of breathing affects people's quality of life, challenging homeostasis and compromising health. A study has been conducted investigating the interrelationship of respiratory function in healthy individuals (Engel & Vemulpad, 2007). However, the majority of studies involve symptomatic individuals with pathologies such as COPD (Dos Santos Yamaguti et al., 2008; Gorman, McKenzie, Pride, Tolman, & Gandevia, 2002; Verheul & Dekhuijzen, 2003).

Smith, Weiss and Lehmkuhl (1996) describe the diaphragm as a musculotendinous dome that separates the thoracic and abdominal cavities. It contains perforations (hiatus, foramina and arches), permitting passage of the aorta, inferior vena cava, oesophagus, nerves, psoas and quadratus lumborum muscles. Anatomical attachments of the diaphragm include: the xiphoid process of the sternum, lower six ribs, first three lumbar vertebrae, the central tendon and myofascial connections with the psoas and quadratus lumborum muscles (see Figure 1). Innervation of the diaphragm is from the phrenic nerve originating from cervical spine segments C3-4-5 (Standring, 2005).

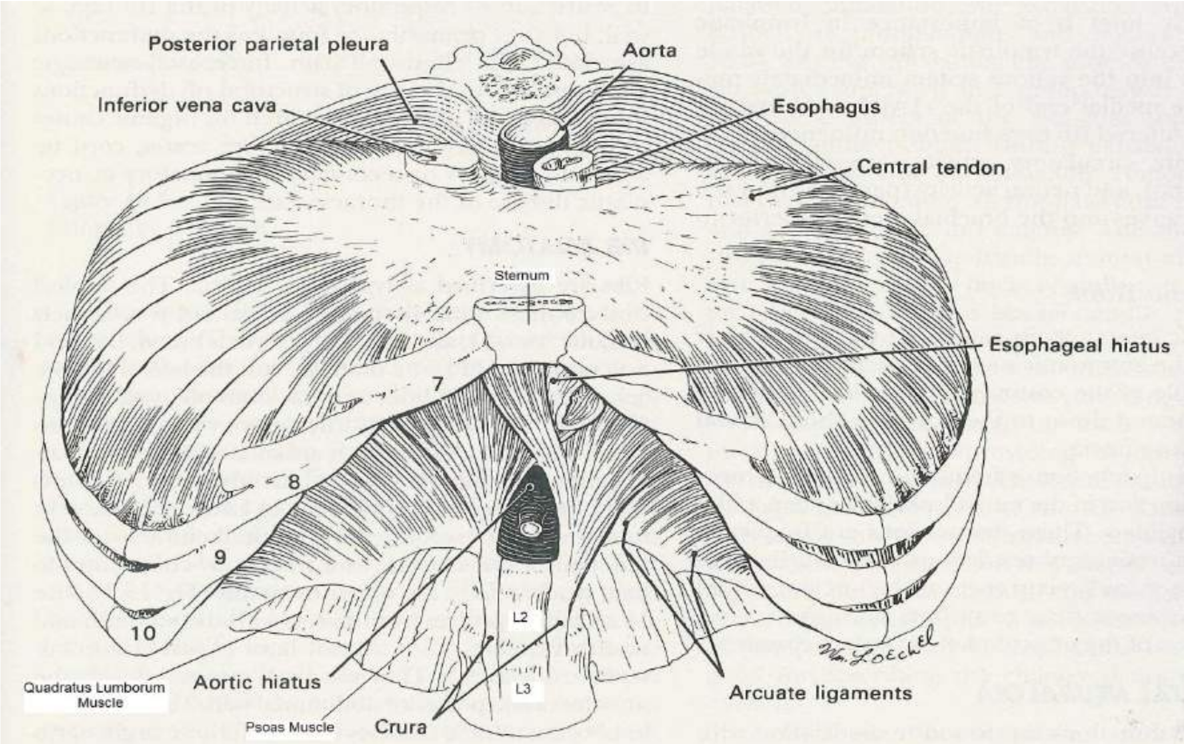

Figure 1. Superior view of the diaphragm. *Reproduced by kind permission of Lippincott, Willaims & Wilkins (Greenman, 2003, p.261).* The anatomical attachments of the diaphragm. Crura attachment to lumbar vertebrae L2, L3, ribs 7,8,9,&10, sternum & central tendon. Also showing myofascial connections of quadratus lumborum and psoas muscles.

There are several studies investigating inspiratory and expiratory muscle strength and mechanics. A quantitative analysis of respiratory muscle mechanics was reported by Ratnovsky and Elad (2005). Their study showed that the diaphragm muscle generates forces the same as those generated by other inspiratory muscles, but performs 60-80% of the total inspiratory work even at low efforts, unlike other respiratory muscles. Ratnovsky and Elad (2005) also reported that inspiratory muscles reach their maximal force towards the end of inspiration, while expiratory muscles reach their maximal force at mid-expiration. Understanding the fact that the diaphragm performs up to 80% of inspiratory work highlights the importance of the diaphragm and reinforces the basic premise for the continuation of research in this area.

The terms ‘ventilation’ and’ respiration’ are sometimes used interchangeably, or used in the same context as **‘**breathing’. Ventilation as defined by Porth (2002) is a mechanical event which relies on a system of open airways and the movement of respiratory muscles to create pressure gradients. Ventilation consists of inspiration and expiration and is concerned with the movement of gases into and out of the lungs but does not participate in gas exchange. Sammut and Searle-Barnes (1998) describe ventilation as “the process of exchange of air between the lungs and the ambient air”. Respiration is dependent on ventilation and relates to gas exchange. Gas exchange takes place in the respiratory air-ways of the lung, where gases diffuse between the lungs and the blood that flows through the pulmonary capillaries (Porth, 2002). Respiration involves the transport of oxygen to lung tissues and the reaction of this with metabolic fuels and the subsequent carbon dioxide returning to the lungs for expiration. The diaphragm plays an important role in ventilation and respiration.

The diaphragm is the ‘primary muscle of respiration’ and is responsible for producing pressure gradients between the thoracic and abdominal cavities important for efficient respiratory and circulatory functions (Hruby, 2003). The normal phasic respiratory action of this large dome shaped muscle is to descend and flatten during inhalation whilst lifting and widening the lower six ribs, resulting in a slight anterior motion of the abdomen (Courtney, 2009). When the diaphragm contracts with inhalation it pulls the lower surfaces of the lungs inferiorly and on exhalation it relaxes and allows elastic recoil of the lungs (D'Alonzo & Krachman, 2003; Greenman, 2003). Normal tidal breathing at rest is accomplished almost entirely by downward and upward movement of the diaphragm to lengthen and shorten the vertical diameter of the chest cavity (Ratnovsky & Elad, 2005).

Additional expansion and contraction of the lungs is achieved by elevation and depression of the ribs to further increase and decrease the diameter of the chest cavity. Diaphragm movement is often described as a ‘pump-like’ action. It is assisted by upper rib movement, referred to as ‘pump handle’, and lower rib movement, referred to as ‘bucket handle’ (Hruby, 2003). The ‘pump-like’ action is thought to become impaired in the presence of diseases such as COPD and asthma (De Troyer & Estenne, 1988). However, there may also be changes in normal breathing mechanics in apparently asymptomatic individuals, which are related to changes in diaphragm and rib movement and may contribute to breathing dysfunction.

Respiratory disease

There is growing interest in the prevalence of respiratory disease. This is supported by the increase in the amount of research conducted recently (Dos Santos Yamaguti et al., 2008; Galobardes et al., 2008; Iwasawa et al., 2002; Moore et al., 2006; Slader et al., 2006).

A study by Dos Santos Yamaguti et al. (2008) investigated 54 COPD subjects and 20 healthy subjects. Diaphragm mobility was measured using ultrasound to measure the craniocaudal displacement of the left branch of the portal vein and found that individuals with COPD have less diaphragm mobility than healthy subjects. Their results lead to the conclusion that diaphragm mobility was inversely and weakly correlated with pulmonary hyperinflation ($r=-0.28$, $P=0.04$). However, a previous study by Iwasawa, Kagei, Goto, Yoshiike, Matusuhita et al. (2002) investigated 27 subjects (12 healthy, 6 control and 9 with severe emphysema) and reported a significant positive correlation between diaphragm mobility and pulmonary hyperinflation ($r=0.91$, $P<0.001$). Iwasawa et al. (2002) failed to provide correlation coefficients, therefore it is unclear how the term ‘significant’ is being interpreted in their study. Although both Dos Santos Yamaguti et al. (2008) and Iwasawa et al. (2002) investigated diaphragm mobility and pulmonary hyperinflation in healthy subjects and subjects with COPD, the results of both studies may have been affected by internal and external validity. For example, both studies evaluated a small number of subjects, affecting power and possibly generalisability. The investigation by Dos Santos Yamaguti et al. (2008) may also have been biased by selective inclusion of outcome measure values, i.e. three measurements were performed for diaphragm mobility however, only the best value obtained was recorded.

Respiratory dysfunction

While impairment of diaphragm function has been well documented in symptomatic patients such as those with asthma or COPD, there may be changes in normal breathing mechanics in apparently healthy individuals which are related to musculoskeletal changes that result in altered diaphragm and rib movement. For example, with a dysfunctional diaphragm, the abdominal muscles may alter their pattern of respiratory activity causing other respiratory muscles to change their function and often become overloaded (Courtney, 2009). Courtney (2009) highlights the lack of research conducted in relation to breathing dysfunction in apparently asymptomatic people. The majority of literature has focused on respiratory pathologies such as asthma and COPD (Dos Santos Yamaguti et al., 2008; Girodo, Ekstrand, & Metivier, 1992; Gorman et al., 2002; Slader et al., 2006; Thomas et al., 2003), the effects on respiration (D'Alonzo & Krachman, 2003; Engel & Vemulpad, 2007; Hauge, 1973; Porth, 2002) and on health and quality of life (Bartley & Clifton-Smith, 2006; Courtney, 2009; Lee et al., 2003).

Bartley and Clifton-Smith (2006) describe three main breathing patterns: apical (upper chest), lateral costal (sideways) and abdominal ('diaphragmatic'). According to Bartley and Clifton-Smith,(2006) upper chest breathing can expend up to 30% of body energy, as this type of breathing uses accessory muscles of respiration such as sternocleidomastoid and the scaleni. The authors consider that in comparison, diaphragmatic breathing requires less than five percent of body energy and they therefore consider this to be an optimal breathing pattern.

Effects of respiratory dysfunction and associated musculoskeletal dysfunction on health

There has been considerable interest in the concepts of dysfunctional breathing and asthma (Thomas et al., 2001). Breathing has been, and still is, of interest to medical and allied health professions, scientific researchers and complementary and alternative medicine (CAM) professions. There is recognition within several professions that changes in breathing patterns influence and contribute to emotional imbalance, hyperventilation and anxiety disorders. Osteopathy (Chaitow et al., 2002; Courtney, 2009), physiotherapy (Pitman, 1995; Walker & Shepherd, 2001) , psychology (Boiten, 1998; Meuret, Rosenfield, Hofmann, Suvak, & Roth, 2009), behavioural biology (Wilhelm, Gevirtz, & Roth, 2001a), and exercise disciplines such as yoga (Kjellgren, Bood, Axelsson, Norlander, & Saatcioglu, 2007; Sovik, 2000) acknowledge that breathing can affect mental and physical well-being. Evidence has demonstrated that the effect of emotions on breathing patterns may lead to changes in respiratory function that are independent of metabolic feedback mechanisms (Boiten, 1998; Grossman, 1992; Homma & Masaoka, 2008; Manning et al., 1992; Wientjes, 1992).

Breathing not only involves gas exchange to and from the lungs and blood stream but it plays an important role in body systems such as cardiovascular and musculoskeletal systems and the interrelationship of their functions (Parsons & Marcer, 2005; Stone, 1999). Bartley and Clifton-Smith (2006) describe three components to breathing and diaphragm movement: inhalation, exhalation and an exhalation pause or rest. They also suggest that prolonged exhalation plays a role in relaxation with slow abdominal breathing being physiologically advantageous (e.g. positively influencing venous return, blood flow, and heart rate) and promoting a recovery response to injury or ill health in body systems.

Stone (1999) claims that diaphragm movement may influence the movement of the heart as the pericardial sac is connected to the diaphragm by phrenicopericardial ligaments. Furthermore, Stone claims that a lack of diaphragm movement may reduce heart contractility and blood circulation throughout the body. Although the variability of heart rate is complex, with a number of physiological mechanisms involved, the diaphragm plays a vital role as inhalation causes an increase in heart rate and exhalation a decrease in heart rate (Yasuma & Hayano, 2004). The breathing cycle reflects the balance between the parasympathetic and sympathetic divisions of the autonomic nervous systems with fluctuations in heart rate variability (HRV) being associated with improved oxygen uptake (Stauss, 2003). D'Alonzo & Krachman (2003) have shown that poor diaphragm biomechanics may lead to decreased cardiac output. As stated by Still (Ettlinger, 2003), the founder of osteopathy,

> "He cannot expect blood to quietly pass through the diaphragm if impeded by muscular constriction around the aorta, vena cava, or thoracic duct. The diaphragm is often pulled down on both the vena cava and thoracic duct, obstructing blood and chyle (lymph) from returning to the heart"(p. 1132).

Contraction of the abdominal diaphragm can also produce changes in the thoracic and abdominal cavities affecting pressure gradients and lymphatic flow (Degenhardt & Kuchera, 1996; Stone, 1999). Increasing the compliance of the diaphragm may enhance diaphragm movement and improve lymphatic flow. Degenhardt and Kuchera (1996) describe how pressure gradients created by the movement of the diaphragm can influence lymphatic flow dynamics and affect gastrointestinal and cardiovascular systems. The influence of lymphatic flow, created by the diaphragm, is based on early research recognizing that lymph flow is influenced by myofascial compression and is consistent with the basic osteopathic concepts relating to homeostasis and the inter-relationship of body systems (Wallace, McPartland, Jones, Kuchera, & Buser, 2003).

Several studies have investigated the effects of biomechanical diaphragm function and physiological changes in body systems. Lee et al., (2003) investigated the effects of 'diaphragmatic breathing'[3] on blood pressure (BP) and heart rate (HR) in a single case study where BP and HR recordings were recorded over a three week period. The authors compared normal breathing with diaphragmatic breathing and reported that diaphragmatic breathing was associated with a statistically significant reduction in systolic and diastolic BP ($P<0.001$) but no change in HR. Physiological changes due to poor diaphragm biomechanics may also cause a follow-on effect of increased incidence of infection, prolonged healing time in an unhealthy person and heightened rates of mortality (Poole et al., 1997). If poor diaphragm mechanics are prolonged, psychological effects such as hyperarousal, anxiety, and panic disorder may be observed (Han, Stegen, De Valck, Clément, & Van de Woestijne, 1996; Jerath, Edry, Barnes, & Jerath, 2006; Wilhelm, Gevirtz, & Roth, 2001b).

Slader, Reddel, Spencer, Belousova, Armour, Bosnic-Anticevich, et al. (2006) conducted a double-blind-randomised controlled trial of two different breathing techniques in the management of asthma. They compared shallow nasal breathing and non-specific upper body exercises on asthma symptoms, inhaled corticosteroid dose and quality of life. Although the results of their study did not report significant physiological changes they did report a significant decrease in reliever use and inhaled corticosteroid dose by 86% ($p<0.0001$) and 50% ($p<0.0001$) respectively. Slader et al. (2006) attributed their findings to a very active placebo effect, stating that the improvements observed in quality of life measures were more likely the result of elements such as instruction of use than the breathing exercises themselves.

[3] 'Diaphragmatic breathing' as used in this study comprised three deep breaths (Lee et al., 2003).

Musculoskeletal dysfunction, respiratory dysfunction and disease

Musculoskeletal changes can cause mild respiratory dysfunction in seemingly asymptomatic people, but can also itself be caused by respiratory dysfunction and disease. These downstream musculoskeletal effects can further exacerbate breathing disorders.

In individuals with asthma and COPD, breathing patterns are different in comparison to asymptomatic individuals. The changes in breathing patterns are adjustments to maintain the lung functions of ventilation and gas exchange. D'Alonzo and Krachman (2003) assert that dysfunctional breathing contributes to structural musculoskeletal changes and poor posture, which may lead to further impairment of ventilation and respiration than that of dysfunctional breathing alone.

It has been stated by Poole et al.(1997) that poor biomechanics, such as dysfunction of the thoracic spine or ribs can cause flattening of the diaphragm reducing volume displacement and pressure gradients. If flattening of the diaphragm becomes severe enough it can decrease the movement of the lower ribs and reduce the efficiency of respiration, thereby reducing ventilation of the lungs (Ettlinger, 2003). In conditions such as asthma and COPD the diaphragm becomes shorter (flattened), reducing its curvature, power and efficiency (Courtney, 2009). Dysfunction of the diaphragm can create poor breathing patterns, which in turn alters normal respiratory pressure dynamics and can have detrimental effects on the function of the cardiovascular and lymphatic systems (Courtney, 2009).

Osteopathic manipulative techniques and treatment for musculoskeletal dysfunction relating to breathing

Osteopathic techniques are used for the treatment of breathing dysfunction in clinical practice (Chaitow et al., 2002; DiGiovanna et al., 2005) However, there has been minimal research investigating the effectiveness of osteopathic techniques which are purported to target the diaphragm.

In the 1880's Andrew Taylor Still began to develop his clinical understanding of osteopathy. Still placed emphasis on detailed knowledge of anatomy which became the basis for much of his diagnostic and clinical work, most notably palpatory diagnosis and manipulative treatment. Still also emphasized, for treatment to be effective, it needed to be tailored specifically for each patient's particular needs (Seffinger et al., 2003). Even as osteopathy continued to develop, the foundations of osteopathy remain the same. Paul Lee (2005) describes osteopathy as follows;

> Osteopathic medicine is a philosophy of health care and a distinctive art, supported by expanding scientific knowledge; its philosophy embraces the concept of the unity of the living organism's structure (anatomy) and function (physiology). Its art is the application of the philosophy in the practice of medicine and surgery and all its branches and specialties. Its science includes the behavioural, chemical, physical, spiritual and biological knowledge related to the establishment and maintenance of health as well as the prevention and alleviation of disease. Osteopathic concepts emphasize the following principles: 1) The human being is a dynamic unit of function; 2) The body possess self-regulatory mechanisms, which are self-healing in nature; 3) Structure and function are interrelated at all levels; 4) Rational treatment is based on these principles.

The practice of osteopathic medicine is, essentially, the potentiation of the intrinsic health-maintaining and health-restoring resources of the individual (Korr, 2003). A series of statements appear in every discussion of foundational osteopathic principles and include "*the body is a unit*" and "*structure and function are interrelated*" (Seffinger et al., 2003). These statements recognise an interrelationship between the various components of each body system. As the "primary muscle of respiration" (Hruby, 2003) the diaphragm is predominantly involved in breathing function. However, the diaphragm's extensive anatomical attachments and 'pump-like' action also contributes to pressure gradients, blood circulation, lymphatic flow, micturition, defecation, postural support and speech (DiGiovanna et al., 2005). Stone (1999) states "the diaphragm is one of the most remarkable areas of the body in that it has so much influence and the consequences of its dysfunction can manifest anywhere from the head to the toes". Chaitow et al. (2002) comment that if there is evidence of breathing dysfunction for any length of time, the primary focus of attention should be on musculature and joints associated with the breathing process to restore normal breathing patterns. In osteopathy, there is a view that dysfunction of anatomical structures that relate to the diaphragm may alter breathing patterns, which in turn may influence a person's health and well being. Courtney (2009) supports this view in stating, "impairment of the functions of breathing affects people's lives, challenging homeostasis, creating symptoms and compromising health".

Osteopathic manipulative techniques and the diaphragm

Manual techniques

One technique used to assist in release of diaphragm hypertonicity is high velocity/low amplitude (HVLA) thrust to the thoracolumbar vertebra (see Figure 2). A thrust technique is a method of specific joint mobilization which is indicated for the treatment of joint restriction (Kappler & J M Jones III, 2003). Manual medicine practitioners, including osteopaths, commonly consider that the anatomical attachments of the diaphragm relating to musculoskeletal structures, such as the left and right crura attachments to the upper two or three lumbar vertebrae respectively and their intervertebral discs, play a role in diaphragm movement (Hruby, 2003). Hruby (2003) state that application of osteopathic manipulation, such as HVLA, to anatomical areas relating to the diaphragm "can often restore or partially rehabilitate altered diaphragmatic function". However, there appears to be a lack of objective evidence about the role that HVLA might play in changing diaphragm function.

Figure 2. HVLA thrust manipulation of the lower thoracic/upper lumbar vertebrae. Subject lies on their back, practitioner places a towel between subjects elbows and practitioners epigastric area, practitioner supports the subjects' head and neck and places their hand as a fulcrum under the subjects lower thoracic/upper lumbar vertebra (T10-L2). Practitioner localizes fulcrum focus by transferring minimal body weight over targeted segment, subject is asked to inhale and exhale. At end of exhalation the practitioner applied a HVLA thrust to achieve joint cavitation.

Another OM technique designed to relax the resting state of the abdominal diaphragm is referred to as “doming of the diaphragm” (Chaitow et al., 2002) (see Figure 3). Within osteopathic literature there are claims that “increased tone”[4] of the diaphragm, tends to flatten the shape of the diaphragm, resulting in less efficient respiration and a decrease in pressure gradients required for optimal functioning of body systems (DiGiovanna et al., 2005; Ettlinger, 2003). Doming of the diaphragm is used to decrease the hypertonicity of the diaphragm by stretching it (DiGiovanna et al., 2005). Osteopaths believe that such doming techniques may indirectly engage the inferior surface of the diaphragm and increase its excursion during expiration (Wallace et al., 2003). These claims have not been adequately investigated and therefore remain as a hypothesis rather than a demonstrated fact.

Figure 3. Abdominal diaphragm ‘re-doming’. Subject lies on their back, practitioner stands to the side at subjects waist level and simultaneously places hands on either side of lower costal cage. Subject is instructed to “take a deep breath in and out”, practitioner applies resistance to thoracic movement. Maintaining resistance to the thoracolumbar region, the practitioner again instructs the subject to “breath in and out”. Resistance is maintained over three or four breath cycles. With practitioners resistance and subjects respiratory efforts, the diaphragm ‘re-domes’ itself.

‘Treatment’ vs ‘Technique’

For the purpose of this study, clarification of osteopathic techniques and treatment is required. In a short commentary, Patterson (2002) notes that there are essentially two types of studies of osteopathic manipulation; osteopathic manipulative *technique* and

[4] ‘Increased tone’ causes shortening of the diaphragm, a state of hypertonicity, the diaphragm becomes flattened instead of its elliptical cylinder shape capped by a dome (Poole et al., 1997)

osteopathic manipulative *treatment*. Osteopathic manipulative treatment studies are guided by the patient's condition and response to treatment, which then determine the techniques used. Osteopathic technique studies examine the effect of one or more specific osteopathic procedures. Patterson (2002) suggests that technique studies are valuable and necessary to determine the specific effects of a well defined technique on a target problem.

Theoretical basis for diaphragm treatment in osteopathy

The theoretical basis for osteopaths treating the diaphragm is well documented (DiGiovanna et al., 2005; Greenman, 2003; Parsons & Marcer, 2005). Hruby (2003) states that osteopathic treatment of the diaphragm increases its excursion subsequently improving breathing mechanics, venous blood flow and lymphatic flow. Degenhardt and Kuchera (1996) showed pressure gradient differentials were created by the thoracic diaphragm which influenced lymph flow when OM treatment was applied to the diaphragm. Degenhardt and Kuchera (1996) describe how facilitation of lymphatic flow in the bronchial tree is important, and may be enhanced through application of OM treatment. They also state that OM treatment to myofascial lymphatic support structures reduces congestion in the airways of patients with asthma. However, there has been minimal empirical investigation into whether OM *techniques* actually have an effect on the diaphragm.

Review of studies investigating manipulative techniques on respiratory function

A randomized control trial by Engel and Vemulpad (2007) explored the effect of combining "chiropractic manual therapy" with exercise on respiratory function in normal individuals. The chiropractic 'manual therapy' consisted of soft tissue therapy and nonspecific high-velocity low amplitude (HVLA) manipulation applied to the lower cervical, upper and middle thoracic spines, and associated ribs. Although it is unclear whether Engel and Vemulpad (2007) conducted a *treatment* or *technique* investigation, one could reasonably assume that a technique study was conducted, as participants were healthy and asymptomatic. Furthermore, the 'manual therapy' described by the authors is very similar to the description of techniques documented by Hartman (2001). Engel and Vemulpad's (2007) study reported that participants who received chiropractic manual therapy showed a significant increase in forced vital capacity (FVC) ($P<.001$) and forced expiratory volume in the first second (FEV_1) ($P=.001$) in respiratory function compared to the control group which reported no change in FVC or FEV_1. Engel and Vemulpad (2007) concluded that manual therapy appeared to increase the respiratory function in normal individuals, although they acknowledge that generalisability was limited by the small sample size (n=20).

Allen and D'Alonzo (1993) discussed how manipulative techniques aimed at increasing the motion of the thoracic cage, mobilizing the ribs and the thoracic spine, enhancing arterial supply and lymphatic return have been recommended for patients with a variety of obstructive airways diseases such as COPD. Further, a recent study by Noll, Degenhardt, Johnson and Burt (2008) investigated the immediate effects of osteopathic manipulative treatment in elderly patients with COPD. The protocol used by Noll et al. consisted of seven standardised osteopathic techniques and compared the response to a sham protocol comprised of light touch applied to the same anatomical regions for the same period of time. The efficacy of OM treatment is thought to be enhanced by using techniques in combination, where one technique works synergistically with another to achieve overall therapeutic effect (Kuchera & Kuchera, 1994).

Findings from the study by Noll et al (2008) supported their primary hypothesis that a single multitechnique OM treatment session produces measurable changes in pulmonary function. In addition to the quantitative results reported by Noll et al. (2008), a follow-up telephone survey was conducted to collect subjective feedback. Noll et al. (2008) stated that "Most subjects in both study groups reported their health benefited from receiving OM treatment and reported subjective improvement in their breathing", which implies there may have been a strong non-specific effect associated with the treatment protocol employed. The authors attributed the positive health benefits seen in both groups to a possible placebo effect, and acknowledged that the sham and OM treatment protocols were similar, i.e. touch to same anatomical regions for same duration of time. The results from Noll et al. (2008) did not conclusively support their hypothesis, and indeed may have somewhat refuted it, as the authors concluded that an overall worsening of some spirometry measures occurred – probably due to 'air trapping'. The authors speculated that this finding was possibly due to one particular technique that may have promoted a sudden rush of air into the lungs which cannot be fully exhaled by a COPD patient. One explanation for the 'worsening' of pulmonary function in the group may be the mismatch of the standardised techniques employed to specific patient diagnostic findings. This explanation is similar to the views expressed in the commentary by Patterson (2002) in that treatment should be guided by the patient's condition and response to treatment.

A similar investigation into restrictive airway diseases and OM treatment by Guiney et al., (2005) focused on the effects of OM treatment on pediatric patients with asthma. The results of this investigation showed a mean (±SD) increase of 4.8% (±10) in peak expiratory flow rates (PEFs) for patients in the OM treatment group compared to a mean increase of 1.4% (±11.1) in PEFs for patients in the control group. Although the authors claimed that the "design of a randomized controlled trial increases the validity of the study significantly", the omission of blinding of physicians responsible for measuring and recording patients PEFs may have influenced outcome measures. In a previous asthma study by Paul and Buser (1996) the authors also reported notable improvements (25% to 70%) in patient PEFs following the use of OM treatment and attributed this positive effect to mechanical improvements in chest wall motion. However, a pre-test-post-test cross over study by Bockenhauer, Julliard, Lo, Huang, and Sheth (2002) investigating the effects of four OM techniques, applied in sequential order, on patients with chronic asthma found no statistically significant difference between the OM procedure and the sham procedure. The authors partially attribute this outcome to the fact that OM treatment was not individualized to treat each patient's "pattern of strain" – which is common practice when used in clinical settings. The study by Bockenhauer et al. (2002) is another example of some of the difficulties around investigating osteopathic manipulative therapy using standardised protocol. Instead of matching techniques to patient condition, as described by Patterson (2002), a set protocol of techniques was employed and all subjects were treated for exhalation restrictions of the lower ribs which may have required a different OM technique. Osteopathic manipulative treatment studies are guided by the patient's condition and response to treatment, which then determine the techniques used. The pre-test post-test study by Bockenhauer et al. (2002) was a pilot study and only recruited ten subjects. Although the authors report their findings as "not statistically significant" it is likely that given the small sample size (n=10) the study was not adequately powered to detect small to moderate treatment effects. The observed effect size for the main outcome measure (PEF) was 0.4. Assuming an alpha = 0.05 and desired power =0.8, the necessary sample size would be 100 subjects per group. The observed power in Bockenhauer, et al. (2002) study was 0.14 which is clearly insufficient to be able to draw definitive conclusions.

Breathing retraining

A study by Thomas, McKinley, Freeman, Foy, Prodger and Price (2003) investigated the effectiveness of physiotherapy based breathing retraining for patients treated for asthma who had symptoms suggestive of dysfunctional breathing. The authors found clinically relevant increase in quality of life measures seen in over 50% of subjects at one month, and in over 25% of subjects at the six month follow up. However, the authors acknowledge that the physiological mechanism for such improvement was not addressed in their study. Thomas, McKinley et al. (2003) claim that non-specific placebo mechanisms related to anxiety may have influenced results and that breathing retraining had a positive effect on well-being independent of non-specific effects on anxiety and depression indices.

Conclusion

The diaphragm is recognised as the primary muscle of respiration which plays an important role in breathing and physiological regulation. Dysfunction of the diaphragm can create poor breathing patterns, disrupt physiological balance and have detrimental effects on the inter-relationship of body systems such as gastrointestinal, cardiovascular and lymphatic systems. Several studies have investigated the effects of diaphragm movement and physiological changes in the presence of disease. However, little research has been conducted investigating the effect of OM techniques on diaphragm movement in asymptomatic subjects. Therefore research was undertaken to establish if OM techniques applied to anatomical attachment areas of the diaphragm has an effect on diaphragm movement in asymptomatic individuals.

Section two of this dissertation reports on an investigation into the effects of OM techniques on diaphragm movement.

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Section 2: Manuscript

Note
This manuscript has been prepared in accordance with the Instructions for Authors for the *International Journal of Osteopathic Medicine* [see Appendix E].

The effect of osteopathic manipulative techniques on diaphragm movement and respiratory function in asymptomatic subjects

The effect of osteopathic manipulative techniques on diaphragm movement and respiratory function in asymptomatic subjects

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Abstract

Title: The effect of osteopathic manipulative techniques on diaphragm movement and respiratory function in asymptomatic subjects.

Objective: To examine the effect of osteopathic manipulative (OM) techniques on diaphragm movement in asymptomatic subjects.

Methods: A randomized, controlled, pre and post-test experimental design was conducted on 30 healthy individuals (15 males and 15 females; age range 20-45 years, (Mean ± SD) 27.7 ± 4.5y. The OM technique protocol consisted of three standardized OM techniques applied to anatomical attachment areas of the diaphragm. The control group did not receive any technique, but were required to lie quietly for seven minutes, the same length of time it took to perform the OM techniques. Ultrasound and spirometry measures were taken before and after OM techniques and control procedures. Data from pre and post-test measurements of the control group was used to establish a baseline.

Results: Data from 28 subjects was analyzed and showed a substantial increase in effect size in the treatment group compared to the control. Ultrasound measures in the treatment group showed a 'large' effect in breathing rate (Br/min) and a 'moderate' effect in pause (P) phase. Spirometry measures in the treatment group showed a 'large' effect in TV and a 'moderate' effect in PEF. The control group showed 'small' and 'trivial' effects across all ultrasound and spirometry measures.

Conclusion: Three standardized OM techniques applied to anatomical attachment areas of the diaphragm produced substantial changes in diaphragm rate of movement measured by ultrasound and spirometry measures in asymptomatic individuals. Although the current study was underpowered, the observed effects demonstrate that improvements were achieved.

Key words: ultrasound, spirometry, abdominal diaphragm, thoracic diaphragm, manipulation, osteopathic manipulation

Note to Reader

The use of square brackets in this manuscript indicates where reference is made to another section of the dissertation. The content indicated by square brackets does not constitute part of the journal manuscript.

Introduction

The diaphragm is often referred to as the 'primary muscle of respiration' by osteopaths and other medical professions.[1-4] In recent years the diaphragm has gained interest within the medical field for its unique anatomy, link with spinal stabilization and lower back pain[5], role in thoracic and abdominal partial pressure gradients, breathing dysfunction and general wellbeing.[6, 7] Within osteopathy anecdotal claims have been made regarding the effects of OM treatment on altered diaphragm function.[1, 2] Di Giovanna et al.,[1] Greenman[8] and D'Alonzo and Krachman[9] claim that OM treatment for diaphragm dysfunction is effective and can improve breathing mechanics, enhance venous blood return, lymphatic flow and may be helpful in the treatment of asthma and acute or chronic lung disease. However, these claims are based mostly on clinical experience[1, 8, 9] rather than research data. Although a study by Engel and Vemulpad[10] suggests that manual therapy and exercise can improve respiratory function in normal or asymptomatic individuals, there is little research demonstrating whether OM techniques, used to treat the diaphragm, produce changes in diaphragm movement in asymptomatic subjects.

Osteopathic manipulative techniques have been investigated for the treatment of asthma,[11, 12] chronic obstructive pulmonary disease,[13] and other respiratory problems. These investigations have demonstrated increases in vital capacity and rib cage mobility and improvement of diaphragm function.[14] However, there has been no investigation into whether OM treatment, which requires selection and application of specific osteopathic techniques, actually has an effect on the rate of diaphragm movement. Therefore use of techniques, as commonly employed in daily practice of manipulative therapists to alter the rate of diaphragm movement, is not supported with research but is based on anecdotal success, and clinical experience.

The aim of this study was to investigate the extent to which the application of osteopathic techniques to the diaphragm as described by various authors,[1, 15-17] have an effect on the rate of diaphragm movement.

Methods

Subjects

A convenience sample was recruited using notices posted on campus of a tertiary institution (Unitec, NZ). Subjects were recruited on the basis that they were aged between 20-45 years and were able to read and understand English language. Subjects were excluded if they (1) were pregnant; (2) were asthmatic or had chronic airflow limitations (3) had any known abdominal pathologies (for example, hiatus hernia); (4) had a history of gastroesophageal reflux of any degree; (4) had persistent hiccups within previous three months; (5) had a history of serious injury to the spine or thorax, including costal or spinal fractures or (6) had a history of diaphragm surgery.

All subjects gave written, informed consent [see Appendix A] after being briefed by the principal investigator and reading an information sheet [see Appendix B]. The study was approved by Unitec Research Ethics Committee [see Appendix C]. A structured medical screening form [see Appendix D] was completed by each subject to establish general health status and identify inclusion and exclusion criteria.

Design

A randomized, controlled, pre and post-test experimental design was used with subjects randomly allocated to one of two groups, an OM technique group or a control group (see Figure 1). Block randomization was used to balance the groups. Randomization was achieved by repeated shuffling of the envelopes. The intervention consisted of three osteopathic techniques (high velocity low amplitude (HVLA) thrust manipulation of the lower thoracic/upper lumbar vertebrae (T10-L2), costal articulation[5] (ribs 7-10) and diaphragm re-doming). The control group did not receive any OM techniques, but were required to lie quietly in a supine position for seven minutes, the same length of time it took to apply the OM techniques to the technique group. Diaphragm movement was measured using a portable real time diagnostic ultrasound machine. Respiratory function was measured using a desk top spirometer.

[5] Costal articulation is a stretching of the intercostal muscles, not articulation of the costovertebral joint; where the ribs articulate with the vertebrae.

Osteopathic manipulative techniques were delivered by a registered osteopath with 5 years clinical experience. Ultrasonography was conducted by a registered sonographer with 3 years experience. Spirometry data was collected independently by a trained assistant.

Outcome Measures

Spirometry

Spirometry is used to assess severity of individual patients' respiratory disease and their response to therapy [18] and is regarded as the 'gold standard' measure of respiratory function.[19] A Medical International Research (MIR) Spirolab II spirometer was used to collect data using Knudson[20] as the 'normal' spirometry value. Calculation and interpretation of test results were made by comparing the measured parameters with specific 'normal' spirometry values (known as predicted values) which are calculated from subject data: age, height, weight, sex and ethnic group.[21] A closed circuit technique was used.[18] Pre and post-test outcome measures for the following variables were recorded; forced vital capacity (FVC) defined as the maximal volume of air with maximally forced effort from a position of maximal inspiration; forced expiratory volume achieved in 1 second (FEV1), which is the volume of air exhaled in the first second of FVC; tidal volume (TV), which is the amount of air that moves into and out of the lungs with each breath; and peak expiratory flow (PEF) which is the largest expiratory flow achieved with a maximally forced effort from a state of maximal inspiration.[18] These variables were calculated according to the methods as defined in MIR manual.[21]

Ultrasound

The scientific method for *direct* assessment of diaphragm movement has traditionally been fluoroscopy.[22] Recent literature shows there has been an increase in the use of ultrasound, which is now the preferred method over fluoroscopy.[3, 23-25] Ultrasound has proved to be a safer and more effective form of diaphragm measurement.[26, 27] Houston et al.,[22] conducted a study on 55 subjects and found ultrasound to be a reliable and reproducible measure. This finding was further supported by inter- and intra-observer coefficients of variation ranging from 6.5 to 13%. Gerscovich et al.,[28] concluded that ultrasound not only proved feasible, but had many advantages over fluoroscopy, including portability, visualization of structures of the thoracic base and upper abdomen, and lack of ionizing radiation. Ultrasound is a well recognized and readily used form of measurement for investigating diaphragm movement.[3, 29, 30] In this study a Chison 8300 portable ultrasound machine: (Chison Medical Imaging Co., Ltd.) was used with a 3.5 mHz curvilinear transducer on abdominal preset. Diaphragm location was determined using B-mode 2-D imaging, once located the mode was changed to M-mode. M-mode was set to the slowest speed to measure all pre and post-variables of breathing rate (Br/min), inspiration (Insp), expiration (Exp) and pause (P), for treatment and control groups.

Experimental Procedure

Subjects were randomly allocated, by selection of sealed envelope, into one of two groups, an OM technique group or control group. They were allocated one of three days and given one 60 minute appointment between 8.30am and 3.00pm to attend. Appointments were staggered at 30 minute intervals. Age, height and weight were recorded for spirometry purposes. Subjects were taken to one of three adjacent rooms where the first (pre) spirometry measures were recorded. The subject was then shown to a second room where the first (pre) ultrasound measure was taken. After completion of the ultrasound measure the subject was shown to a third room where they received either the OM technique procedure or the control procedure. The control group did not receive any OM technique procedure, they were required to lie supine for seven minutes, the same length of time it took to apply the OM techniques. The subject was then taken back to the ultrasound room for the final (post) ultrasound measure and then taken back to the spirometry room for the final (post) spirometry measure. The total distance walked was less than 10 meters.

Spirometry Procedure

Spirometry procedures, as described in ‘Spirolab II instructions for use’ of MIR manual,[21] were demonstrated to each subject by the technician prior to testing. After demonstration and just prior to data collection the subject was asked to re-demonstrate the procedure to the technician to ensure understanding. Spirometry was the first and last procedure performed in data collection.

Ultrasound Procedure

The sonographer introduced herself to the subject, explained what was going to be done and gained their verbal consent. They were asked to adjust their clothing to expose their upper abdomen, and to lie supine on an examination table, with their arms resting by their sides. They were then instructed to relax and breathe normally. Warm coupling gel was applied to the abdomen, to allow efficient ultrasound transmission from the transducer face into the patient.

The transducer was applied in longitudinal section just below the xyphisternum. The liver was visualised and the scan plane adjusted until the inferior vena cava was visible. The transducer was then angled subcostally to the right, through the liver, to bring the right diaphragm into view. Depth and focus were adjusted to provide optimal image quality. M-mode was then activated, and the line of sight cursor was adjusted to cross perpendicularly over the diaphragm. An M-mode trace was then obtained. When a representative trace had been obtained, the image was captured and measurements were taken and recorded. Four M-mode tracings were obtained, with adjustments in B-mode as required. Only the right hemi-diaphragm was analysed because examination of the left hemidiaphragm is more difficult due to the limited acoustic window offered by the spleen compared with the liver window.[26, 29, 30]

Osteopathic Manipulative Techniques

Three OM techniques were selected for this study; high velocity low amplitude thrust manipulation of the lower thoracic/upper lumbar vertebrae (T10-L2), costal articulation of ribs 7-10 and abdominal diaphragm re-doming. Technique selection was based on the relevance of anatomical attachments to the diaphragm. T10-L2 is notable for its relationship to crural attachments of the diaphragm and articulation with ribs 11 and 12. Costal articulation is believed to improve diaphragm movement by stretching the inter-costal muscles of the lower six ribs, and diaphragm 're-doming' is thought to stretch the diaphragm muscle itself. The techniques were applied to each individual in a manner as described in Ward and DiGiovanna.[1, 16, 17]

For the purpose of this study the OM techniques were applied in the following order:

1. HVLA thrust manipulation of the lower thoracic/upper lumbar vertebrae (T10-L2) (see Figure 2).

   [insert Figure 2]

2. Costal Articulation (see Figure 3)

   [insert Figure 3]

3. Abdominal Diaphragm 'Re-doming' (see Figure 4)

   [insert Figure 4]

Data Extraction and Analysis

Spirometry

A MIR Spirolab II (Medical International Research, Wisconson, USA) was used to construct flow-volume (L/s) and volume-time (s) curves. To obtain this data tests were conducted for forced vital capacity (FVC), vital capacity (VC), inspiratory vital capacity (IVC) and maximum voluntary ventilation (MVV). Measurements were recorded for the variables FVC, FVC1, PEF and TV.

Ultrasound

For both pre and post-measures an image of the right diaphragm was screen captured to take measures of four variables; breaths per/min, inspiration time, expiration time and, if present, pause (see Figure 5). This process was repeated four consecutive times at an interval of 5-10 seconds. The mean was calculated from these four measures and used for data analysis.

[insert Figure 5]

Sample Size

In planning the study we assumed we would observe a similar effect size as that reported by Guiney et al.,[12] who investigated the effect of OM treatment on peak expiratory flow in asthmatics. Based on the 'small' to 'moderate' effect size achieved by Guiney (d=0.4), a sample size of 64 subjects per group would be required to achieve a power of 0.80. A sample of this size was considered logistically unachievable for this project, therefore a study using 20-30 subjects (split into two equal groups) was undertaken.

Statistical analysis

Raw data were explored for normality using the Shapiro-Wilk statistic and measures of skewness and kurtosis. Stem-and-leaf, histograms and Q-Q plots were constructed and inspected for consistency with normality. For variables that were normally distributed paired samples t-tests were undertaken, and for non-normal variables Wilcoxon signed rank tests were used. For normally distributed variables, 95% confidence intervals were constructed for the mean differences and effect sizes calculated. Effect sizes for non-parametric data were calculated using $r = z/\sqrt{n}$ where n=28.[31] Effect sizes for parametric data were calculated using the Cohen effect statistic .[32] Descriptors for magnitudes of effect were based on those described by Hopkins.[33] SPSS v17.0 (SPSS Inc., Chicago, IL.) was used for all statistical analysis.

Results

Subjects were recruited between 22nd August and the 5th October 2008. A sample of 30 subjects were enrolled in the study. There was an equal ratio of males and females with 15 subjects in the OM technique group (n=7M and n=8F) and 15 subjects in the control group (n=7M and n=8F). The characteristics of the technique and control groups are described in table 1.

[insert Table 1]

All subjects tolerated the procedure well and there were no reported reactions to the treatment techniques. There were complications encountered with ultrasound measurement of data from two subjects, one from the control group (F) because they were breath holding and one from the treatment group (M) because they had a very slow breathing pattern and were not able to be measured on the portable ultrasound equipment. Data from these two subjects were excluded from data analysis. Therefore data from 28 subjects was analysed. At baseline, treatment and control groups were comparable for all measured spirometry and ultrasound variables (see Table 2).

[insert Table 2]

Results of this study indicate that application of the OM techniques, applied to anatomical areas relating to the diaphragm showed a non-trivial increase in ultrasound and spirometry measures in the treatment group compared to the control group. Ultrasound measures in the treatment group showed a 'large' effect in breathing rate and a 'moderate' effect in pause phase. Ten to fourteen breaths per minute is considered to be a "good breathing rate"[6] and the treatment group showed a reduction in mean breathing rate from 13.6 Br/min to 11.9 Br/min. A reduction in breathing rate indicates deeper breathing at a slower rate and better achieves oxygen delivery.[4] In the treatment group Pause phase increased from 0.87s to 1.12s. The increase in pause phase indicates relaxation of the diaphragm with an exhalation pause producing a more ideal breathing pattern.[6] Spirometry measures in the treatment group showed a 'large' effect in TV and a 'moderate' effect in PEF. The increase in TV, from 1.02L to 1.21L, indicates that a larger amount of air moved into and out of the lungs with each breath.

Peak expiratory flow decreased from 114.3L/s to 109.0L/s indicating a reduction in airway obstruction. The control group did not show substantial changes in ultrasound or spirometry measures and there were only ‘small’ and ‘trivial’ effects for all other ultrasound and spirometry measures between pre and post intervention.

Discussion

The aim of this study was to investigate the effects of OM technique on diaphragm movement in asymptomatic subjects. To date, there have been no manual therapeutic intervention studies that have utilised ultrasound to visualise diaphragm movement in response to OM treatment. Pre and post-test measurements using ultrasound and spirometry were performed on both the treatment and control groups. This study demonstrated that osteopathic techniques applied to anatomical attachment areas of the diaphragm had a beneficial effect on diaphragm movement and spirometry. Subjects in the treatment group, who received HVLA thrust manipulation of the thoracolumbar junction (lower thoracic/upper lumbar vertebra T10-L2), costal articulation of ribs 7-10 and abdominal diaphragm 're-doming', demonstrated 'large' changes in breathing rate and tidal volume and 'moderate' changes to the pause phase of diaphragm movement and the peak expiratory flow of respiration. Subjects in the control group demonstrated 'trivial' to 'small' effects across all spirometry and ultrasound measures.

There are a small number of studies that have evaluated the effects of osteopathic techniques on diaphragm and respiratory function.[11-14] A few studies have shown some clinically relevant findings when investigating the effect of manual techniques on respiratory outcome measures.[11-13] Although much of the manual therapy research available focuses on respiratory pathology (e.g. COPD and asthma), when considered collectively the studies show that manual therapy appears to have a positive effect on respiratory function measures.[11-13] Engel and Vemulpad[10] did not find substantial improvements in spirometry measures after manual therapy in normal asymptomatic individuals, whereas the current study did demonstrate moderate to large effects in several clinically relevant variables. Although the current study investigated asymptomatic individuals the findings are similar to those found in studies conducted on symptomatic individuals with respiratory pathology.[12, 13, 34] A peak expiratory flow measurement provides a quick exclusion of significant respiratory restrictions such as asthma or chronic airflow limitations,[5] however, it may not detect mild respiratory restrictions that may contribute to breathing dysfunction. This study excluded subjects with asthma or chronic airflow limitations, but the protocol did not include a musculoskeletal examination at baseline to establish the presence of any musculoskeletal signs associated with asymptomatic breathing dysfunction. A recent study[35] describes common biomechanical changes, such as reduced rib movement, found on physical examination are often associated with breathing dysfunction, as is commonly observed in respiratory diseases such as asthma. Sammut and Searle-Barnes[36] outline various musculoskeletal features, based on their clinical experience, with the presence of asthma. These features include “increased muscle tension” in the diaphragm and intercostal muscles. Furthermore, DiGiovanna et al.,[1] describe physical findings associated with breathing dysfunction to include restricted rib motion, restriction to diaphragm motion and decreased range of motion in the thoracic spine. These features are considered to be clinically important and may be useful in the early detection of dysfunctional breathing or respiratory disease.[9] The results of the current study show a moderate increase in PEF after the application of OM techniques indicating there may have been asymptomatic breathing dysfunction present in the sample.

The principles outlined in osteopathic literature emphasize the importance of the musculoskeletal system as a major component in patient well-being.[1, 37, 38] The role of the diaphragm in maintaining efficient breathing patterns and the relationship between breathing and health maintenance is attracting attention in both scientific[7, 39, 40] and popular literature.[5, 6] The majority of previous studies have investigated the effects of OM treatment on respiratory function in symptomatic subjects with conditions such as asthma and COPD, however, very little has been conducted on normal asymptomatic subjects to establish whether there is any basis to the concept that osteopathic techniques influence the diaphragm.

Noll et al.,[13] reported that a single multi-technique OM treatment session produced measurable changes in pulmonary function parameters in subjects with chronic obstructive pulmonary disease. Although the findings of Noll et al.,[13] indicated possible beneficial effects, such as an increase in inspiratory capacity (IC) there were also clinically undesirable effects such as an increase in residual volume (RV). The increase in RV is not a desirable change in subjects with COPD because they already have an elevated RV due to airflow limitation caused by chronic inflammation of the airways and lung parenchyma.[41] Noll et al.,[13] speculated that one of the seven techniques used in their study, the ‘thoracic lymphatic pump technique’, resulted in a sudden rush of air into the lungs which study subjects were not able to fully exhale because of their COPD status. Although the efficacy of OM treatment is thought to be enhanced by using techniques in combination to achieve an overall effect,[15] there is also an increased likelihood that a beneficial technique may be diluted out by a technique with an adverse effect. It is difficult to establish in the investigation carried out by Noll et al.,[13] which techniques may have yielded the effects observed, as technique selection and treatment was at the discretion of the practitioner and pragmatically tailored to each individual subject. In contrast to Noll et al.,[13] a study by Bockenhauer et al.,[11] found no substantial difference between the OM procedure and the sham procedure when they investigated the effects of four OM techniques, applied in sequential order, on patients with chronic asthma. Bockenhauer et al.,[11] partially attribute this outcome to the fact that OM treatment was not individualized to treat each patient's "pattern of strain". This is in contrast to common practice in an osteopathic treatment setting where OM treatment is individualized. Although the current study used asymptomatic subjects and a standardised treatment protocol of three osteopathic techniques it did reveal some clinically important findings. However, like Noll et al.[13] and Bockenhauer et al.,[11] the current study was unable to determine the relative positive or negative contributions from individual techniques. In routine practice, OM treatment sessions are guided by the patient's condition and response to treatment, which then determine the techniques used. Therefore, future studies may benefit by applying only one or two techniques to diaphragm attachment areas matched to individual physical examination findings, thereby limiting the likelihood of a beneficial technique negating a non-beneficial technique.

Several studies acknowledge the relationship between the diaphragm and breathing dysfunction.[7, 10, 42-45] Osteopathic literature has long maintained that diaphragm function plays a key role in well-being and therefore treatment of the diaphragm may alleviate the symptoms of dysfunctional breathing and disease.[1, 2, 5, 8, 9, 15, 46, 47] However, defining dysfunctional breathing, identifying such dysfunction, and determining the cause of any dysfunction, is fraught with difficulty. For example, it is not clear whether dysfunctional breathing may be the result of altered biomechanics, or the early stages of pathology, or related to psychological factors such as anxiety, stress or mood. Regardless of the "cause" of breathing dysfunction, the aim of osteopathic treatment is to alleviate or resolve musculoskeletal dysfunction, improve or maintain breathing function by optimising diaphragm excursion, and promote beneficial changes to physiological processes that are influenced by breathing and thoracic cage function.

The changes in breathing rate, tidal volume, peak expiratory flow and pause phase in the current study suggest that OM techniques, applied to anatomical attachment areas of the diaphragm in asymptomatic subjects may improve breathing patterns. However, these changes could also be attributable to factors other than the application of OM techniques such as the spirometry procedure or the combination of the spirometry procedure and OM techniques. The 'large' effect size in tidal volume observed in the current study may be attributable to the spirometry procedure itself. For example, some authors claim that the spirometry procedure, requiring forced inhalation, may alter diaphragm motion and cause an increase in tidal volume.[29] The standard spirometry procedure requires the application of a noseclip to ensure no air is lost through the nasal passage.[21] Previous studies[29, 48-50] have demonstrated the effect of noseclips on ventilatory patterns and have shown that wearing a noseclip can positively induce measurable changes in diaphragm kinetics. The results of these studies demonstrate increases in tidal volume[48, 49] ($p = 0.05$) and inspiratory time ($p = 0.01$),[29] and a decrease in breathing rate ($p < 0.05$)[48] and resting time ($p = 0.007$).[29] Although the current study omitted to use noseclips the results were comparable to previous studies that did.[29, 48-50] On balance it is difficult to conclude whether the absence of noseclips in the present study positively or negatively affected the results. However, taking into account the 'large' increase in tidal volume without the application of noseclips, it would appear unlikely that spirometry was the contributing factor for the change in tidal volume and that the change observed was more likely as a result of the intervention. Further examination of the results in the current study support the notion that OM techniques were more likely to be the greatest contributing factor to the results as measurable changes occurred in the treatment group and not the control. Given that both groups received pre and post spirometry measures the assumption may be made that if spirometry was a contributing factor then tidal volume changes would have been observed in both groups.

The current study only assessed the right hemidiaphragm as the acoustic window through the liver allows clearer pictures to be obtained than on the left.[26, 30] Some research has found unequal excursion of right and left hemidiaphragm in normal subjects,[22, 30] however, other areas of the hemidiaphragm (i.e. anterior and posterior) have also shown different degrees of displacement.[22, 30, 51] As the left hemidiaphragm was not assessed in the current study it cannot be confidently concluded that the left hemidiaphragm behaved similarly to the right. Future studies may choose to include measurements of the left hemidiaphragm to establish a comparison – although this is technically challenging.

The costal articulation technique employed in the current study is thought to influence thoracic excursion via the intercostal muscles, thereby affecting diaphragm function via mechanical connections. Application of the technique known as 'rib raising'[1, 15,] may have been a valid alternative to costal articulation. Although both costal articulation and rib raising promote maximal excursion of the thoracic cage, rib raising, according to osteopathic literature, is claimed to lessen the effects of increased sympathetic nervous system activity.[15] Research has established that an increase in sympathetic nervous system activity affects numerous physiological processes, including heart rate and respiration.[52] Heightened activity of the sympathetic nervous system may increase breathing rate, reduce inspiration time and reduce pause phase.[6] Such a breathing pattern would be undesirable as shorter, quicker and shallower breaths without a clear pause phase are known to contribute to anxiety states,[53] unfavourably affect blood gases,[7] and have detrimental effects on the cardiovascular and lymphatic systems.[6, 7, 54] Rib raising is claimed to cause an initial increase in sympathetic activity followed by a reflex reduction which in turn leads to increased respiratory efficiency and depth, increased lymphatic return, and reduced stress.[1, 15] The current study elected to use costal articulation over rib raising in the treatment protocol, because although relatively short-lived, the initial increase in sympathetic activity following rib raising may have a negative influenced.

The current study employed a registered osteopath with five years experience and a registered sonographer with three years experience to perform OM techniques and ultrasound measures. An independently trained research assistant conducted spirometry measures for respiratory function. To ensure optimal results, a high level of training and proficiency is required as the interactions between technicians and subjects is crucial to obtain adequate spirometry.[18] A possible weakness of the current study may have been the limited experience of the spirometry assistant. Therefore more extensive training or a fully qualified technician may enhance spirometry measurement in future studies.

There are a number of technique protocols[6] that are believed to improve ventilation and respiration that indirectly influence diaphragm function.[13, 15] These techniques are applied to areas which do not relate directly to the anatomical attachments of the diaphragm but are believed to have an effect on diaphragm function via neuromusculoskeletal connections. Osteopathic literature highlights the presence of a reflex arc from the nucleus solitarius in the brainstem to the mid-cervical area (C3-4-5) which induces a contraction of the diaphragm through the phrenic nerve.[15] The focus of the current study was to examine the effect of three specific osteopathic manipulative techniques using a standardised protocol to areas which relate to the anatomical attachments diaphragm. However there is an osteopathic theory that manipulative treatment applied to the related cervical segments may ameliorate diaphragm dysfunction via somatovisceral reflex pathways.[2] A further theory is that irritation or restriction of cervical spine segments from which the phrenic nerve originates may contribute to compromised diaphragm function.[55] Therefore future research could investigate the effects of techniques applied to cervical spine segments C3-4-5 on diaphragm movement and breathing.

This research studied asymptomatic subjects. Although all subjects were required to complete a 'medical history form' to establish inclusion and exclusion criteria and their general health status, baseline physical examination to establish the presence of breathing dysfunction was not conducted. Consequently, if a subject was asymptomatic yet had an unidentified breathing dysfunction and responded to treatment, this could result in inflation of the treatment effect in favour of the finding that the techniques had a positive effect in this asymptomatic sample. Any future research investigating an asymptomatic population should include a more robust inclusion and exclusion criteria, including a musculoskeletal examination to minimise possible contamination of a homogenous group.

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[6] Thoracic lymphatic pump and thoracic myofascial release[13] and bilateral soft tissue of the paravertebral muscles in the occipitoatlantal area down to at least C5.[15]

Research has shown that compared with men, women often use their intercostal muscles more than their diaphragms during inspiration[30] and that males have a greater degree of diaphragm movement than females.[51] The results of the current study showed a 'large' change in tidal volume and breathing rate without consideration of any gender effects. Gender differences in breathing mechanics (i.e. male abdominal breathing verses female upper rib breathing)[6, 30] may lead to different responses to the intervention. Therefore further analysis to investigate if there is a gender effect would have been useful.

The present study recruited a sample of 32 subjects using convenience sampling. Although this method allowed for ease of recruitment, it may have lead to potential self selection bias as the majority of subjects selected for the study were motivated to voluntarily participate.[56] Consequently it is unclear which attributes (motivation, activity level or self interest) prompted subjects to agree to participate as opposed to those who did not. Although convenience samples are composed of subjects that agree to voluntarily participate, those who agree to be part of a convenience sample may not be representative of the population.[56] It is not clear how typical the sample may be of any specific population, limiting the extent to which the findings may be generalised. Hence the results of this study should be interpreted with caution, due to its small sample size and possible self-selection bias – two factors which limit external validity.

A recommended follow on to this study could be to undertake similar research with subjects who display respiratory disease to investigate whether OM techniques may ease symptoms or alter quality of life and sense of well-being.

Ultrasound, a direct measure; and spirometry, an indirect measure were used in the current study. Since completion of data collection and a further review of the literature it is apparent that the procedure of spirometry measures, itself, may influence diaphragm movement.[29, 48] If the outcome measure of most interest is diaphragm movement then a study excluding the use of spirometry as a measure may therefore be preferred.

Conclusion

The results of the current study suggest that OM techniques, applied to anatomical attachment areas of the diaphragm in asymptomatic subjects may lead to an improvement of in breathing rate, tidal volume, peak expiratory flow and pause phase of breathing. The reduction in breathing rate and the increase in pause phase and tidal volume indicates that the individual is taking deeper slower breaths achieving better oxygen delivery. These improvements were not observed in the control group.

Although the current study was underpowered, the observed effects demonstrate that improvements were achieved. Therefore it is fair to conclude that OM techniques that influence diaphragm movement may improve breathing (ventilation and respiration). However, due to the lack of literature in this field and supporting evidence, further investigations are required to substantiate these findings.

An interesting follow-on study would be to identify how OM techniques applied to the diaphragm may improve breathing capacity for those who have respiratory disease, with a view to improving their comfort, reducing their need for medication and helping them to gain a greater sense of well-being.

Tables

Table 1. Characteristics of subjects in the treatment and control groups

	Sample	Control	Treatment
No. of subjects	30	15	15
Age range (years)	20-43	20-41	20-43
Mean (SD) age (years)	27.7 (±4.5y)	25.6 (±4.5y)	29.7 (±4.5y)
No females	15	8	8
No males	15	7	7
Height range (cm)	156 - 187	156 - 183	158 - 187
Mean height (cm)	172.3	171.0	173.5
Weight range (kg)	49 - 86	49 - 84	57 - 86
Mean weight (kg)	71.4	71.3	71.6

Table 2. Results

Results from the paired-sample *t* test distributed Pre and Post Ultrasound and Spirometry; treatment and control group data and from wilcoxon signed ranks test for non-normal Pre and Post Ultrasound and Spirometry; treatment and control group data

		Mean Pre	Mean Pre SD	Mean Post	Mean Post SD	Mean difference	95% CI for difference		P-value	Effect Size[a]	Descriptor[b]
							Lower	Upper			
Ultrasound											
Br/min	Tx	13.60	3.29	11.98	2.91	1.62	0.37	2.88	0.01	0.51	'large'
	Control	13.18	4.02	12.41	4.14	0.76	-0.29	1.80	0.14	0.19	'small'
Insp	Txc	1.78	0.49	1.92	0.54	-0.14			0.19	0.24	'small'
	Control[c]	1.87	0.38	1.94	0.52	-0.08			0.68	0.08	'trivial'
Exp	Tx	1.81	0.40	1.82	0.40	-0.02	-0.28	0.24	0.86	0.05	'trivial'
	Control	1.99	0.53	2.06	0.68	-0.06	-0.42	0.28	0.68	0.11	'small'
Pause	Tx	0.87	0.43	1.12	0.85	-0.25	-0.68	0.18	0.23	0.37	'moderate'
	Control[c]	0.89	0.91	1.08	1.30	-0.18			0.42	0.15	'small'
Spirometry											
FVC	Tx	104.14	12.41	102.92	12.78	1.21	-2.66	5.09	0.51	0.10	'small'
	Control	109.00	16.48	108.50	16.50	0.50	-2.54	3.54	0.72	0.03	'trivial'
FEV1	Tx	105.86	12.17	104.50	13.02	1.35	-0.08	3.58	0.21	0.11	'small'
	Control	109.21	10.56	108.00	13.33	1.21	-0.96	3.39	0.24	0.10	'small'
TV	Tx	1.02	0.36	1.21	0.36	-0.18	-0.42	0.04	>0.05	0.51	'large'
	Control[c]	1.01	1.12	0.79	0.47	0.22			0.97	0.01	'trivial'
PEF	Tx	114.35	17.34	109.00	15.16	5.35	2.89	7.82	≤ 0.001	0.33	'moderate'
	Control	114.50	10.42	109.07	10.78	5.42	1.51	9.34	0.01	0.50	'small'

Notes

a. Effect sizes for non-parametric data were calculated using r = z/√ n where n=28 [31]. Effect sizes for parametric data were calculated using the Cohen statistic.[32]

b. Descriptors for magnitudes of effect are based on those described by Hopkins.[33]

c. Indicates that these variables are non-normally distributed. P-values were calculated using Wilcoxon signed rank test.

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Figures

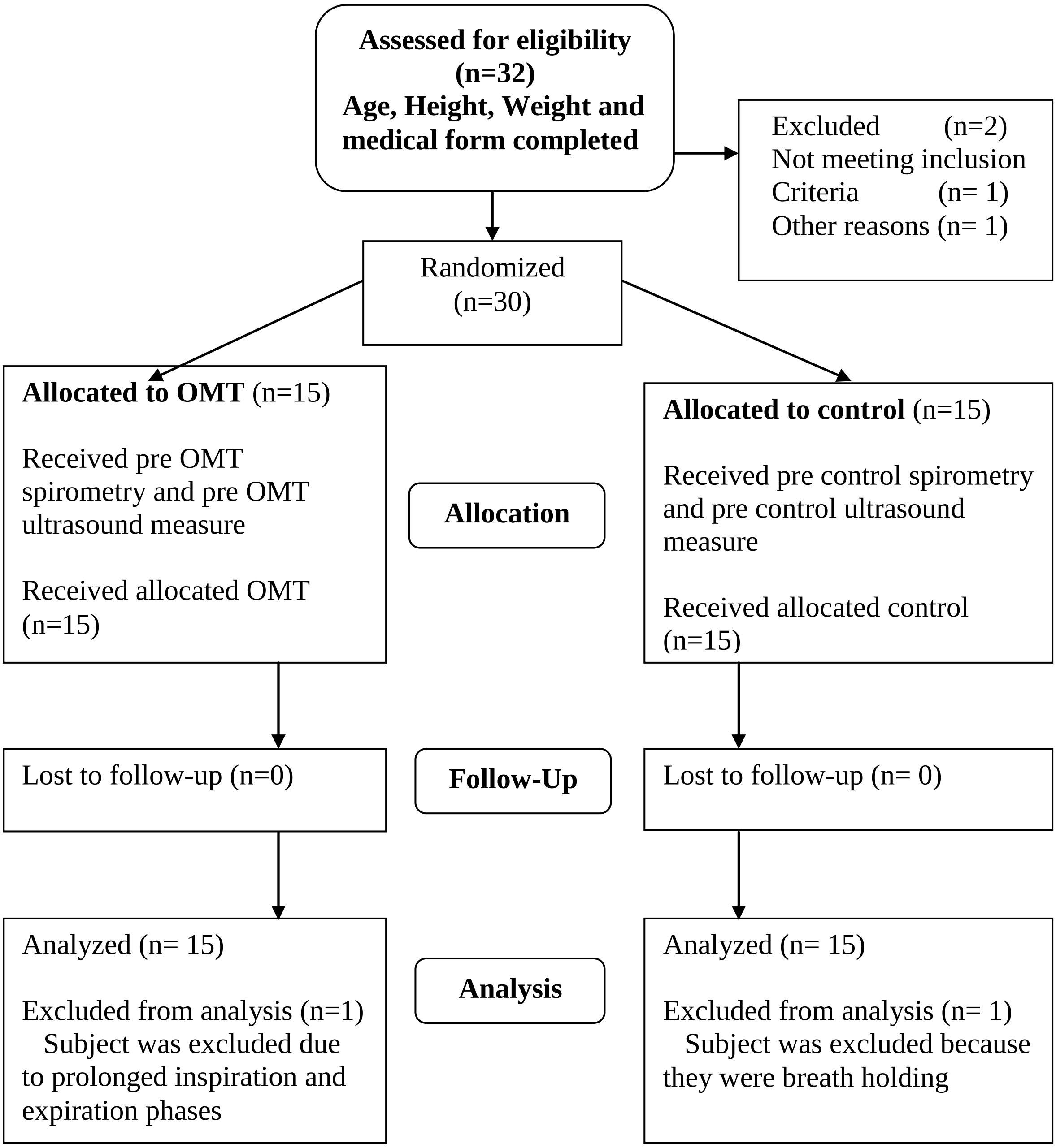

Figure 1. Modified consort flowchart

Figure 2. HVLA thrust manipulation of the lower thoracic/upper lumbar vertebrae

The subject was asked to lie on their back and the practitioner stood to the side of the subject's thoracolumbar region. Subjects were instructed to cross their arms by holding their shoulders. The practitioner then supported the subjects' head and neck, raised the subject up and places their hand, as a fulcrum, under the subject's lower thoracic/upper lumbar vertebra (T10-L2). The practitioner then positioned the subject's elbows in their epigastric area and a pillow or folded towel was placed between elbow and epigastric. The practitioner then side bent and rotated the subject's trunk towards them to increase local tension at the targeted segments by creating a cumulative barrier that closes the zygaphophyseal facet joint. The practitioner localizes fulcrum focus by transferring minimal body weight over targeted area and the subject was asked to inhale and exhale. At the end of exhalation the practitioner applied a HVLA thrust to achieve joint cavitation. Joint cavitation was achieved on the first attempt in all of the subjects.

Figure 3. Costal articulation

The subject was asked to lie on their back. The practitioner stood on the appropriate side, for example when working on ribs 7-10 on the right the practitioner stood on the right, level with the subjects mid thoracic region. The practitioner 'fixed' ribs 7-10 with the heal of their right hand and using their left hand grasps the subjects right arm and gently raises the arm in a cephalad direction inducing a stretch through the intercostal muscles. To enhance the technique the subject was asked to inhale when the arm was in cephalad position. This was repeated three times on the right side before being repeated to the subject's left side.

Figure 4. Abdominal diaphragm 're-doming'

The subject was asked to lie on their back. The practitioner stood to the side (either side) of the subject at waist level. The practitioner simultaneously placed their hands on either side of lower costal cage. The subject was then instructed to "take a deep breath in and out". The practitioner applied resistance to thoracic movement to gain a sense of bilateral movement in the thoracolumbar region. The practitioner again instructs the subject to "take a deep breath in" and at the end of the "out" breath applied resistance to the thoracolumbar region, while holding the resistance, the subject was instructed to take another breath "in". Resistance was maintained over the three or four breath cycle. With this positioning and the patient's respiratory efforts, the diaphragm re-domes itself.

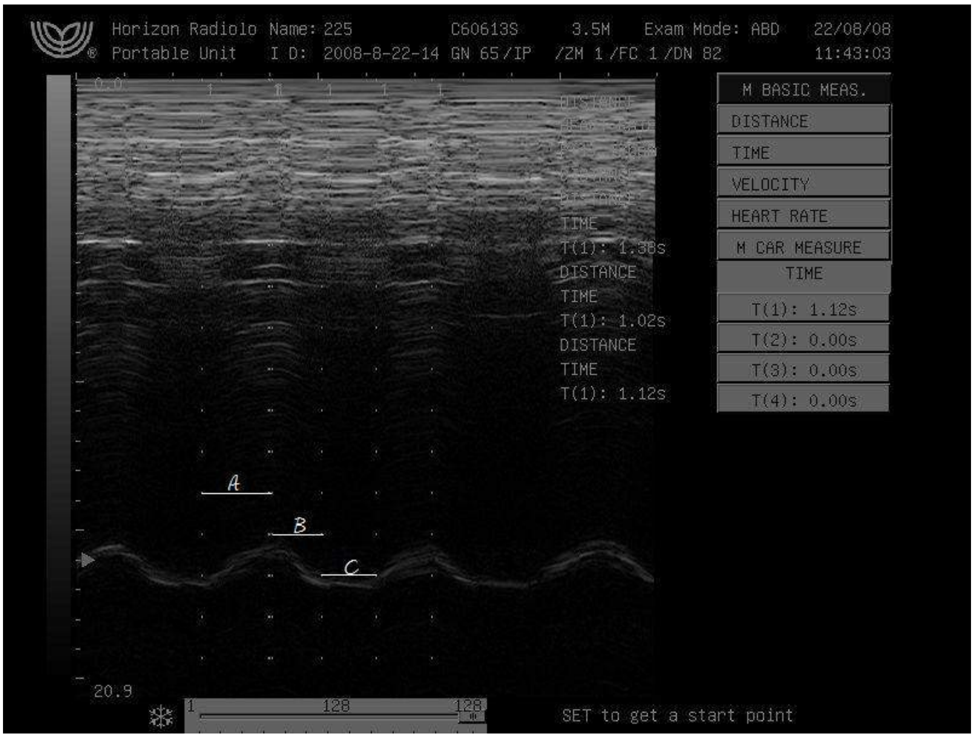

Figure 5. Typical M mode screen capture for calculation of ultrasound variables. Pre measure of right diaphragm using Chison 8300 ultrasound machine with 3.5mHz curvilinear transducer. Four measures (Breaths per/min, Inspiration time, Expiration time and Pause (if present)) were recorded four consecutive times at an interval of 5-10 seconds. A. represents the inspiration time (t=1.38s), B. Represents the expiration time (t=1.02s), C. represents the pause phase (t=1.12s). Image by Sharon Hosking

Section 3: Appendices

Appendix A: Informed Consent Form

Unitec NEW ZEALAND Te Whare Wānanga o Wairaka

Participant Consent Form

The Effect of Osteopathic Manipulative Techniques on Diaphragmatic Movement

This research project investigates whether the application of osteopathic manipulative techniques will effect diaphragm movement. This research is being undertaken by Sharon Hosking, a Master of Osteopathy student, from Unitec NZ, and will be supervised by Robert Moran and Dr Craig Hilton.

Name of Participant: ………………………………………………………………….

I have seen the Information Sheet for people taking part in the project titled "The Effect of Osteopathic Manipulative Techniques on Diaphragmatic Movement" and have had the opportunity to read the contents of the information sheet and to discuss the project with Sharon Hosking. I am satisfied with the explanations I have been given. I understand that taking part in this project is voluntary (my choice) and that I may withdraw from the project at any time (refer below) and this will in no way affect my access to the services provided by Unitec NZ, or the Unitec Osteopathic Clinic.

I understand that I can withdraw from this study if, for any reason, I want this up to 1 week after the last data collection session but no later.

I understand that my participation in this project is confidential and that no material that could personally identify me will be used in any reports on this project.

I have had enough time to consider whether I want to take part and acknowledge that any data collected during the study will be stored securely so that only the researchers may access them.

I know whom to contact if I have any questions or concerns about the project.

The principal researcher for this project is Sharon Hosking, principal supervisor is Rob Moran.
Contact Details: Sharon Hosking Phone: (09) 845 5665 Email: shosking@yahoo.com

Signature…………………………………(Participant) Date : ……………………

Project explained by Sharon Hosking

Signature………………………………… Date: ....

The participant should retain a copy of this consent form.
This study has been approved by the UNITEC Research Ethics Committee from 25th June 2008 to 30th December 2009. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the Secretary (ph: 09 815-4321 ext 8041). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

Appendix B: Information Sheet

Information for Participant

The Effect of Osteopathic Manipulative Techniques on Diaphragmatic Movement

About this research
You are invited to take part in a research project being undertaken by Sharon Hosking. Sharon is an osteopathic student who is interested in finding out if osteopathic techniques have an effect on diaphragm movement. By taking part in this research project you will be helping health care professionals to identify how osteopathic techniques may be used to influence muscles involved in breathing. This research will assist by furthering our understanding of this effect and contribute to better health care for other people.

What will happen in the research?
Should you agree to take part in this research you'll be required to attend an appointment at the Unitec Osteopathic clinic (Unitec, Entry 3, Building 41, Carrington Road, Mt. Albert, Auckland) on one occasion where:

- You'll be required to complete a short medical screening form.
- You'll be required to do a spirometry reading, used to measure lung ventilation.
- You'll have an ultrasound done on your diaphragm (refer to **description of process** below).
- You'll then receive either osteopathic techniques (refer to diaphragm re-doming, rib raising, and thoracic spine techniques below) or you'll rest quietly, lying for approximately ten minutes.
- After this you'll undergo another spirometry and ultrasound measurement.
- The total visit should take approximately 40 minutes.

Description of process
When conducting the ultrasound and osteopathic techniques we will require access to your lower rib cage, diaphragm, stomach and lower thoracic/upper lumbar spine areas. To do this you'll be requested to remove your outer layers of clothing. If you are a female participant we suggest that a singlet or sports bra would be most suitable.

What does the diaphragm re-doming technique involve?
The patient lays on their back, practitioner places their hands on either side of the subjects lower costal cage. Participant is instructed to "take deep breath in and out". Practitioner applies resistance to thoracic movement and gains a sense of bilateral movement in the thoracolumbar region. Practitioner resists movement of the thoracolumbar region and instructs the participant to take three to four deep breaths in and out allowing the diaphragm to re-domes itself.

What does lower costal articulation involve?
The patient lays on their back, practitioner holds down the lower 2-3 ribs and gently raises the arm placing a stretch through the intercostals muscles relating to the area being worked on. This will be applied independently to both sides. Breathing may be employed to enhance technique.

What does the thoracic spine technique involve?
For the thoracic spine technique we are asking you lie on your back on a treatment table (Fig.1 person in the green top). The practitioner (Fig. 1 person in the blue shirt) will then palpate your lower thoracic spine underneath you. They will cross your arms over your chest placing hands on opposite shoulders. Practitioner supports patients' head and neck, raises patient up and places hand under lower thoracic/upper lumbar spine. Practitioner positions patient's elbows in their epigastric area (a pillow or folded towel is placed between elbow and epigastric). Practitioner localizes fulcrum focus by transferring minimal body weight over targeted area. Patient is asked to inhale and exhale. Physician applies a compressive force through your lower chest towards the table. This is a safe routine procedure routinely used in osteopathic practice.

Figure. 1

Your name and any information that may identify you will be kept completely confidential. All information collected from you will be stored on a password protected computer or stored in a locked filing cabinet and only you, Sharon Hosking, and supervisors Robert Moran or Craig Hilton will have access to this information. After the conclusion of the study we can send you a copy of our report if you are interested.

You have the right to not participate, or withdraw at any time during data collection and you may remove data up to 1 week after completion of collection.

Please contact us if you need more information about the project. At any time if you have any concerns about the research project you can contact one of us:

Sharon Hosking
Monaghan Ave
Mt Albert, Auckland 1025
Tel: (09) 845 5665,
0274 931 936
shosking@yahoo.com

Rob Moran
Unitec NZ, Carrington Rd
Mt Albert, Auckland 1025
Tel: (09) 815 4321 8642
rmoran@unitec.ac.nz

Thanks for your help in completing this research. We appreciate your time.

UREC REGISTRATION NUMBER: (2008.856)
This study has been approved by the UNITEC Research Ethics Committee from 25th June 2008 to 30th December 2009. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee hrough the UREC Secretary (ph: 09 815-4321 ext 8041). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

Appendix C: Ethics Approval for this Project

Unitec NEW ZEALAND Te Whare Wānanga o Wairaka

phone +64 9 849 4180 fax +64 9 815 2901 web www.unitec.ac.nz
address Private Bag 92025, Auckland Mail Centre, Auckland 1142, New Zealand
Mt Albert campus Carrington Rd, Mt Albert, Auckland, New Zealand
Waitakere campus Ratanui St, Henderson, Auckland, New Zealand

Sharon Hosking
17 Monaghan Avenue
Mt Albert
Auckland

30 June 2008

Dear Sharon

Your file number for this application: 2008.856
Title: The effect of osteopathic manipulative techniques on diaphragmatic movement

Your application for ethics approval has been reviewed by the Unitec Research Ethics Committee (UREC) and has been **approved** for the following period:

Start date: 30 June 2008
Finish date: 30 June 2009

Please note that:

1. the above dates must be referred to on the information AND consent forms given to all participants
2. you must inform UREC, in advance, of any ethically-relevant deviation in the project. This may require additional approval.

You may now commence your research according to the protocols approved by UREC. We wish you every success with your project.

Yours sincerely

Deborah Rolland
Deputy Chair, UREC

cc: Rob Moran
Cynthia Almeida

Appendix D: Medical History Form

MEDICAL HISTORY FORM

COMPLETION OF THIS FORM IS FOR THE PURPOSE OF THIS RESEARCH PROJECT ONLY.
ALL INFORMATION OBTAINED WILL BE KEPT SECURE AND CONFIDENTIAL.

Name:..

Email Address:...

Age: .... **Sex:** ....

Please indicate the following with a tick	**Yes**	**No**
Is English your first language?	....	....
Do you have, or have you had a cold in the last 2 weeks?	....	....
Have you recently had a chest infection?	....	....
Do you suffer from asthma?	....	....
In the last week have you experience reflux, indigestion or heart burn?	....	....
Have you had persistent hiccups over the past 12 weeks?	....	....
Have you ever fractured your ribs?	....	....
Have you ever had surgery on your diaphragm?	....	....
Have you ever had abdominal surgery?	....	....
Do you have a liver condition?	....	....
Do you have any heart conditions?	....	....
Do you have hypertension (high blood pressure)?	....	....
Are you currently on any medication?	....	....
Are you a smoker?	....	....
Are you pregnant?	....	....

Appendix E: Guidelines for Submission to the International Journal of Osteopathic Medicine (IJOM)

Former title: Journal of Osteopathic Medicine

Guide for Authors

The journal Editors welcome contributions for publication from the following categories: Letters to the Editor, Reviews and Original Articles, Commentaries and Clinical Practice case studies with educational value.

Online Submission

Submission to this journal proceeds totally online.(http://ees.elsevier.com/ijom) you will be guided stepwise through the creation and uploading of the various files. The system automatically converts source files to a single Adobe Acrobat PDF version of the article, which is used in the peer-review process. Please note that even though manuscript source files are converted to PDF at submission for the review process, these source files are needed for further processing after acceptance. All correspondence, including notification of the Editor's decision and requests for revision, takes place by e-mail and via the Author's homepage, removing the need for a hard-copy paper trail.

The above represents a very brief outline of this form of submission. It can be advantageous to print this "Guide for Authors" section from the site for reference in the subsequent stages of article preparation.

Submission of an article implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, without the written consent of the Publisher.

Types of contributions

Letters to the Editor As is common in biomedical journals the editorial board welcomes critical response to any aspect of the journal. In particular, letters that point out deficiencies and that add to, or further clarify points made in a recently published work, are welcomed. The Editorial Board reserves the right to offer authors of papers the right of rebuttal, which may be published alongside the letter.

Reviews and Original Articles These should be either i) reports of new findings related to osteopathic medicine that are supported by research evidence. These should be original, previously unpublished works. The report will normally be divided into the following sections: abstract, introduction, materials and methods, results, discussion, conclusion, references. Or ii) critical or systematic review that seeks to summarise or draw conclusions from the established literature on a topic relevant to osteopathic medicine.

Short review The drawing together of present knowledge in a subject area, in order to provide a background for the reader not currently versed in the literature of a particular topic. Shorter in length than and not intended to be as comprehensive as that of the literature review paper. With more emphasis on outlining areas of deficit in the current literature that warrant further investigation.

Research Note Findings of interest arising from a larger study but not the primary aim of the research endeavour, for example short experiments aimed at establishing the reliability of new equipment used in the primary experiment or other incidental findings of interest, arising from, but not the topic of the primary research. Including further clarification of an experimental protocol after addition of further controls, or statistical reassessment of raw data.

Preliminary Findings Presentation of results from pilot studies which may establish a solid basis for further investigations. Format similar to original research report but with more emphasis in discussion of future studies and hypotheses arising from pilot study.

Commentaries Include articles that do not fit into the above criteria as original research. Includes commentary and essays especially in regards to history, philosophy, professional, educational, clinical, ethical, political and legal aspects of osteopathic medicine.

Clinical Practice Authors are encouraged to submit papers in one of the following formats: Case Report, Case Problem, and Evidence in Practice.

Case Reports usually document the management of one patient, with an emphasis on presentations that are unusual, rare or where there was an unexpected response to treatment eg. an unexpected side effect or adverse reaction. Authors may also wish to present a case series where multiple occurrences of a similar phenomenon are documented. Preference will be given to reports that are prospective in their planning and utilise Single System Designs, including objective measures.

The aim of the *Case Problem* is to provide a more thorough discussion of the differential diagnosis of a clinical problem. The emphasis is on the clinical reasoning and logic employed in the diagnostic process.

The purpose of the *Evidence in Practice* report is to provide an account of the application of the recognised Evidence Based Medicine process to a real clinical problem. The paper should be written with reference to each of the following five steps: 1. Developing an answerable clinical question. 2. The processes employed in searching the literature for evidence. 3. The appraisal of evidence for usefulness and applicability. 4. Integrating the critical appraisal with existing clinical expertise and with the patient's unique biology, values, and circumstances. 5. Reflect on the process (steps 1-4), evaluating effectiveness, and identifying deficiencies.

Presentation of Typescripts
Your article should be typed on A4 paper, double-spaced with margins of at least 3cm. Number all pages consecutively beginning with the title page.

To facilitate anonymity, the author's names and any reference to their addresses should only appear on the title page. Please check your typescript carefully before you send it off, both for correct content and typographic errors. It is not possible to change the content of accepted typescripts during production.

Papers should be set out as follows, with each section beginning on a separate page:

Title page
To facilitate the peer-review process, two title pages are required. The first should carry just the title of the paper and no information that might identify the author or institution. The second should contain the following information: title of paper; full name(s) and address(es) of author(s) clearly indicating who is the corresponding author; you should give a maximum of four degrees/qualifications for each author and the current relevant appointment only; institutional affiliation; name, address, telephone, fax and e-mail of the corresponding author; source(s) of support in the form of funding and/or equipment.

Keywords
Include three to ten keywords. These should be indexing terms that may be published with the abstract with the aim of increasing the likely accessibility of your paper to potential readers searching the literature. Therefore, ensure keywords are descriptive of the study. Refer to http://www.nlm.nih.gov/mesh/meshhome.html for the MeSH thesaurus.

Abstract
Both qualitative and quantitative research approaches should be accompanied by a structured abstract. Commentaries and Essays may continue to use text based abstracts of no more than 150 words. All original articles should include the following headings in the abstract as appropriate: *Background*, *Objective*, *Design*, *Setting*, *Methods*, *Subjects*, *Results*, and *Conclusions*. As an absolute minimum: *Objectives*, *Methods*, *Results*, and *Conclusions* must be provided for all original articles. Abstracts for reviews of the literature (in particular systematic reviews and meta-analysis) should include the following headings as appropriate: *Objectives, Data Sources, Study Selection, Data Extraction, Data Synthesis, Conclusions*. Abstracts for Case Studies should include the following headings as appropriate: *Background, Objectives, Clinical Features, Intervention and Outcomes, Conclusions*.

Text
The text of observational and experimental articles is usually, but not necessarily, divided into sections with the headings; introduction, methods, results, results and discussion. In longer articles, headings

should be used only to enhance the readability. Three categories of headings should be used:

•major ones should be typed in capital letter in the centre of the page and underlined
•secondary ones should be typed in lower case (with an initial capital letter) in the left hand margin and underlined
•minor ones typed in lower case and italicised

Do not use 'he', 'his' etc. here the sex of the person is unknown; say 'the patient' etc. Avoid inelegant alternatives such as 'he/she'. Avoid sexist language.

References
Responsibility for the accuracy of bibliographic citations lies entirely with the Authors.

Citations in the text: Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Avoid using references in the abstract. Unpublished results and personal communications are not recommended in the reference list, but may be mentioned in the text. If these references are included in the reference list they should follow the standard reference style of the journal and should include a substitution of the publication date with either "Unpublished results" or "Personal communication" Citation of a reference as "in press" implies that the item has been accepted for publication.

Text: Indicate references by superscript numbers in the text. The actual Authors can be referred to, but the reference number(s) must always be given.

List: Number the references in the list in the order in which they appear in the text.

Examples:

Reference to a journal publication:

1. Van der Geer J, Hanraads JAJ, Lupton RA. The art of writing a scientific article. *J Sci Commun* 2000;**163**:51-9.

Reference to a book:

2. Strunk Jr W, White EB. *The elements of style*. 3rd ed. New York: Macmillan; 1979.

Reference to a chapter in an edited book:

3. Mettam GR, Adams LB. How to prepare an electronic version of your article. In: Jones BS, Smith RZ, editors. *Introduction to the electronic age*. New York: E-Publishing Inc; 1999, p. 281-304

Note shortened form for last page number. e.g., 51-9, and that for more than 6 Authors the first 6 should be listed followed by "et al." For further details you are referred to "Uniform Requirements for Manuscripts submitted to Biomedical Journals" (J Am Med Assoc 1997;**277**:927-934) (see also http://www.nejm.org/general/text/requirements/1.htm)

Citing and listing of Web references. As a minimum, the full URL should be given. Any further information, if known (Author names, dates, reference to a source publication, etc.), should also be given. Web references can be listed separately (e.g., after the reference list) under a different heading if desired, or can be included in the reference list.

Tables, Illustrations and Figures
A detailed guide on electronic artwork is available on our website: http://www.elsevier.com/artworkinstructions

Preparation of supplementary data. Elsevier accepts electronic supplementary material to support and enhance your scientific research. Supplementary files offer the author additional possibilities to publish supporting applications, movies, animation sequences, high-resolution images, background datasets, sound clips and more. Supplementary files supplied will be published online alongside the electronic version of your article in Elsevier Web products, including ScienceDirect: http://www.sciencedirect.com. In order to ensure that your submitted material is directly usable, please ensure that data are provided in one of our recommended file formats. Authors should submit the material in electronic format together with the article and supply a concise and descriptive caption for each file. Video files: please supply 'stills' with your files: you can choose any frame from the video or make a separate image. These will be used instead of standard icons and will personalize the link to your supplementary information. For more detailed instructions please visit our artwork instruction pages at http://www.elsevier.com/artworkinstructions.

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The text of original research for a quantitative or qualitative study is typically subdivided into the following sections:

Introduction
State the purpose of the article. Summarise the rationale for the study or observation. Give only strictly pertinent references and do not review the subject extensively. Do not include data or conclusions from the work being reported.

Materials and Methods
Describe your selection of observational or experimental subjects (including controls). Identify the methods, apparatus (manufacturer's name and address in parenthesis) and procedures in sufficient detail to allow workers to reproduce the results. Give references and brief descriptions for methods that have been published but are not well known; describe new methods and evaluate limitations.

Indicate whether procedures followed were in accordance with the ethical standards of the institution or regional committee responsible for ethical standards. Do not use patient names or initials. Take care to mask the identity of any subjects in illustrative material.

Results
Present results in logical sequence in the text, tables and illustrations. Do not repeat in the text all the data in the tables or illustrations. Emphasise or summarise only important observations.

Discussion
Emphasise the new and important aspects of the study and the conclusions that follow from them. Do not repeat in detail data or other material given in the introduction or the results section. Include implications of the findings and their limitations, include implications for future research. Relate the observations to other relevant studies. Link the conclusion with the goals of the study, but avoid unqualified statements and conclusions not completely supported by your data. State new hypothesis when warranted, but clearly label them as such. Recommendations, when appropriate, may be included.

Acknowledgments
In the appendix one or more statements should specify (a) contributions that need acknowledging, but do not justify authorship (b) acknowledgments of technical support (c) acknowledgments of financial and material support, specifying the nature of the support. Persons named in this section must have given their permission to be named. Authors are responsible for obtaining written permission from those acknowledged by name since readers may infer their endorsement of the data and conclusions.

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All manuscripts submitted to the journal should be accompanied by an Author Contribution Statement. The purpose of the Statement is to give appropriate credit to each author for their role in the study. All persons listed as authors should have made substantive intellectual contributions to the research. To qualify for authorship each person listed should have made contributions in each of the following;
1) Contributions to conception and design; data acquisition; data analysis and interpretation;
2) Drafting of manuscript, or critical revision for important intellectual content;

3) All authors must have given approval to the final version of the manuscript submitted for consideration to publish.
Acquisition of funding; provision of resources; data collection; or general supervision, alone, is not sufficient justification for authorship. Contributors who do not meet the criteria for authorship as outlined above should be listed in the Acknowledgements section. Acknowledgements may include contributions of technical assistance, proof reading and editing, or assistance with resources and funding. The statement may be published in the paper as appropriate.
Example of suggested format. Note the use of author initials.

AB conceived the idea for the study. AB and CD contributed to the design and planning of the research. All authors were involved in data collection. AB and EF analysed the data. AB and CD wrote the first draft of the manuscript. EF coordinated funding for the project. All authors edited and approved the final version of the manuscript.

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