The development of a palpation-based clinical assessment of breathing motion: A Nominal Group Technique approach

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A thesis submitted in partial fulfilment of the requirements for the degree of Master of Osteopathy.
Unitec of Technology, 2018.
Declaration

Name of candidate: Kirstie Petch

This Thesis/Dissertation/Research Project entitled **The development of a palpation-based clinical assessment of breathing motion: A Nominal Group Technique approach** is submitted in partial fulfilment for the requirements for the Unitec degree of Master of Osteopathy

**CANDIDATE’S DECLARATION**

I confirm that:

- This thesis represents my own work;
- 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: 2017 - 1072

Candidate Signature: …………………………………………………Date: 26/03/2018

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Abbreviations

BHT – Breath Hold Time
DB – Dysfunctional Breathing
DBP – Dysfunctional Breathing Patterns
HVS – Hyperventilation Syndrome
MARM – Manual Assessment of Respiratory Motion
NGT – Nominal Group Technique
NQ – Nijmegen Questionnaire
RIP – Respiratory Inductive Plethysmography
SEBQ – Self-Evaluation of Breathing Questionnaire
Abstract

Background: Dysfunctional breathing appears to be widely prevalent within the general population, negatively impacting the health of patients. Several palpation-based assessments of breathing have been described but associated research is subject to criticism.

Aims: To develop a palpation-based assessment of breathing motion; and to develop a simple notation format for clinical recording.

Methods: A Nominal Group Technique was employed. Nine participants (6 osteopaths, 3 physiotherapists) with an established interest in breathing assessment and management were recruited, and attended two group meetings. Group discussions pivoted around key questions (hand-hold, patient position, combination of the two, and notation format). Participants individually ranked generated ideas in order of importance and the findings were collated. The generated assessment and notation was framed at the level of new graduates so the items considered most important in the palpatory-based assessment of breathing should able to be performed regardless of clinical experience.

Results: The highest ranked handhold was the Hi-Lo, the highest ranked position was seated, and the highest ranked combination of handhold and patient position was ‘Seated – Upper ribs (over the shoulder to clavicle)’. “Cueing” of the patient and their breathing was a topic that arose during the course of discussion. The notation format that was developed consisted of listed items, with the Hi-Lo considered the most important of these. Consensus on how the notation should be marked was not reached.

Conclusions: The main outcome of the study is a consensus-based description of what participants considered most important in the manual assessment of breathing, ranking ‘Hi-Lo’, ‘seated’ and ‘seated – upper ribs (over shoulder to clavicle)’ as the most important items in their respective categories.

Keywords: Breathing, dysfunctional breathing, physical examination, palpation, Nominal Group Technique, osteopathy, physiotherapy.
Introduction

Breathing, especially its associated dysfunction, has received increasing attention in the field of health care research. There is good reason for this. The respiratory system is essential in the homeostatic process through its interaction with biochemical, biomechanical and psychosocial features of the body (Chaitow, Gilbert, & Morrison, 2014; Courtney, 2009). As such, it follows that dysfunctional breathing (DB) could negatively influence a person’s health, with the potential to affect multiple systems. The concept of dysfunctional breathing is not a new one, with links between over-breathing and numbness, tingling and dizziness being described in the literature as early as the 1900s (Haldane & Poulton, 1908). However, given DB’s dynamic and multifactorial qualities, there is no precise definition or gold-standard for its identification (Barker & Everard, 2015; Courtney, Greenwood, & Cohen, 2011; Mitchell, Bacon, & Moran, 2016). This lack of clarity may have a negative impact on clinicians’ perceptual model of the condition (Barker & Everard, 2015), making diagnosis and management of the condition challenging.

Dysfunctional Breathing has been used to describe a range of chronic or intermittent signs and symptoms (Courtney, Greenwood, et al., 2011). Amongst others, common symptoms include shortness of breath, sighing, yawning and chest pain (Barker & Everard, 2015). Prevalence in the general population is estimated to be 11% and up to 83% of those with anxiety (Courtney, 2009). Clinically, DB can result in significant patient morbidity (Barker, Jones, Harvey, Marston, & O’Connell, 2013).

There are a range of tools currently used in the diagnosis of DB. These tools include instruments, self-report symptoms questionnaires, and physical examination particularly observation and palpation-based approaches. Of the palpatory based approaches described in the literature, the Manual Assessment of Respiratory Motion or “MARM” has the largest body of associated research. This, however, is still limited to a small number of studies (Courtney, Cohen, & Reece, 2009; Courtney, van Dixhoorn, & Cohen, 2008; Courtney, Cohen, & van Dixhoorn, 2011; Courtney, Greenwood, et al., 2011). While these studies suggest that the MARM is a clinically valid and reliable tool, a recent unpublished thesis showed poor rater reliability for the MARM (Ludwig, 2013). Additionally, the genesis of palpation-based assessments of breathing, including the MARM, are not clearly described in the published literature. This is problematic because it is not clear how rigorous or systematic the processes to develop these clinical tools were. This lack of development information, in conjunction with the limited rater reliability and validity, specifically of the MARM, provides an opportunity for further exploration. Furthermore, anecdotal evidence suggests that although awareness of the MARM may be reasonable, it may not be in widespread clinical use. Discussion with practitioners who routinely incorporate palpation-based assessment indicates there is an opportunity to generate a
palpation-based assessment of breathing based on drawing together the views and experiences of a number of practitioners who are routinely engaged in clinical assessment and management of DB.

This thesis aims to develop a guideline of a palpation-based assessment of breathing motion; and develop a notation format for the guideline that is simple to apply in clinic. This thesis is arranged into three sections. Section 1 consists of a literature review. This review describes the anatomy and physiology of the respiratory system, discusses dysfunctional breathing, its possible aetiology and consequences, and explains the different assessments of dysfunctional breathing with a specific focus on the palpation-based assessment options. Section 2 of the thesis contains a manuscript formatted for submission to the *International Journal of Osteopathic Medicine*. This manuscript addresses the aims of the thesis using a Nominal Group Technique (NGT) method in which a number of practitioners with a specific interest in breathing discussed different approaches to the palpation-based assessment of breathing and the notation of assessment findings. Finally, Section 3 (Appendices) contains material supplementary to this thesis including ethics documentation.
Section I: Literature review
1 Introduction

Dysfunctional breathing (DB), or Breathing Pattern Disorder (BPD), is a proposed umbrella term to encompass all dysfunction of breathing pattern, including the classical term hyperventilation syndrome (HVS). HVS is defined as a state of alveolar ventilation in excess of metabolic requirements which leads to a decrease in arterial partial pressure of carbon dioxide (PaCO₂), respiratory alkalosis (hypocapnia) (Malmberg, Tamminen, & Sovijärvi, 2000), and symptoms associated with disrupted acid-base balance (Chaitow, Gilbert, & Morrison, 2014). However, research suggests that many of the symptoms related to hyperventilation can occur independently of hypocapnia (Courtney, 2009), suggesting that an all-inclusive terminology, such as ‘DB’, would be useful (Barker & Everard, 2015). While this may be the case, difficulty also arises in terms of a definition for DB as it incorporates multiple symptoms across many different systems, the causes of which are not well understood.

Symptoms often associated with DB include dyspnoea, frequent sighing or yawning, thoracic dominant breathing, chest pain, altered breathing frequency and pattern, and inability to take a deep breath (Barker & Everard, 2015; Courtney, 2009). A practical approach to DB that has heuristic value is to define it as breathing which is unable to perform its various functions efficiently and is inappropriate for the needs of the individual at that time (Courtney, 2009). Decreased efficiency is problematic in that such a system increases its demand for energy during normal activity, thereby increasing the stress put on the homeostatic mechanisms of the body (Chaitow et al., 2014). Breathing is a complex movement involving muscular contraction and relaxation, movement of fascia along different planes and movement of multiple joints (Chaitow et al., 2014; Levangie & Norkin, 2011). Given that a person takes 21,000 breaths per day (Courtney, 2009) it is reasonable that any inappropriate change in breathing, even if small, will decrease efficiency and alter energy expenditure over the course of a day. Additionally, dysfunctional breathing patterns (DBP) affect muscle function and may lead to musculoskeletal symptoms such as low back pain (Chaitow, 2004).

People who have been diagnosed with cardiac or respiratory diseases such as chronic obstructive pulmonary disease, asthma, and ischaemic heart disease commonly experience concurrent DB (Warburton & Jack, 2006). Additionally, patients with conditions that have no clear pathophysiological link to the respiratory system such as fibromyalgia, chronic fatigue syndrome and temporomandibular syndrome are often observed to experience DB (Chaitow, 2007). While it is understandable that DB is present in those with systemic pathological changes, symptoms resultant of DB can be present in those that have no underlying condition (Courtney, van Dixhoorn, Greenwood, & Anthonissen, 2011). This suggests that DB itself may increase patient morbidity in the absence of pathology.
Dysfunctional breathing is proposed to have several features that relate to biomechanical, biochemical and psychophysiological functions of breathing (Courtney, van Dixhoorn, et al., 2011). Attempts to link only the biochemical division and symptoms associated with DB have been unsuccessful (Courtney, Greenwood, et al., 2011). Therefore, the diagnosis of DB would require a multifaceted approach to encompass all systems involved in its production. The psychological aspect of DB is most commonly assessed with self-report questionnaires. Instrumentation can be used to assess both biochemical and biomechanical aspects of the dysfunction, and palpation-based examination techniques such as the Manual Assessment of Respiratory Motion are used to clinically assess specific biomechanical dysfunction.

This review explores the respiratory system and describes the aetiology and consequences of DB. The review also describes and critically evaluates diagnostic tools for the assessment of DB, with specific focus on the tools used for palpation-based assessment.

2 The Respiratory system: structure and function

2.1 Background

The respiratory system is essential in the homeostatic process through its interaction with biochemical, biomechanical, and psychosocial features of the body (Chaitow, Gilbert, & Morrison, 2014; Courtney, 2009). It provides the oxygen required for aerobic metabolism and removes carbon dioxide, thereby assisting in the maintenance of the acid-base balance of the blood (Courtney, 2009). Furthermore, breathing assists with postural and motor control and plays a key role in autonomic nervous system regulation, efficient interaction between different body systems and cardiac oscillatory rhythms (Courtney, 2009; Courtney, Greenwood, et al., 2011). Breathing also plays a role in venous and lymphatic return to the thorax and affects motor and postural control (Gandevia, Butler, Hodges, & Taylor, 2002).

The function of the respiratory system relies on two processes: ventilation and respiration. Ventilation is the mechanical movement occurring during inhalation and exhalation of air (Tortora & Derrickson, 2009). Respiration occurs in two stages. External respiration denotes the gaseous exchange between the lung tissue and the blood, and internal respiration denotes the gaseous exchange between the blood and the cells (Marieb & Hoehn, 2013).

The skeletal muscles of breathing are supplied by both autonomic and voluntary nerves (West, 2002). The pons and medulla contain the respiratory control centres that are influenced by chemoreceptors and mechanoreceptors and autonomically regulate breathing rhythm (West, 2002). Voluntary control occurs when the cortex overrides the brain stem; for example during speaking and playing a wind instrument (Chaitow et al., 2014; West, 2002), or via impulses from the limbic system during strong emotions (Mclafferty, Johnstone, Hendry, & Farley, 2013b).
2.2 Anatomy of the respiratory system:
Structurally, the respiratory system is comprised of the upper and lower respiratory tracts (McLafferty, Johnstone, Hendry, & Farley, 2013a). The upper tract includes the nose, pharynx, larynx and trachea, while the lower consists of the right and left bronchi, bronchial tree and lungs, including the alveoli (Marieb & Hoehn, 2013; Tortora & Derrickson, 2009). Functionally the respiratory system is divided into two zones: the respiratory zone and the conducting zone. The respiratory zone is the site of gas exchange and consists of the respiratory bronchioles, alveolar ducts and alveoli (Marieb & Hoehn, 2013). The conducting zone consists of all other respiratory passageways which provide conduits for air to reach areas of gas exchange (Marieb & Hoehn, 2013). The structures in the conducting zone also act to warm and humidify incoming air.

2.3 The mechanics of breathing
Gas exchange in the body is classically considered to occur in three basic steps (Tortora & Derrickson, 2009). These are: 1) pulmonary ventilation or breathing; the process of inhalation and exhalation involving the exchange of air between the atmosphere and the alveoli of the lungs; 2) external or pulmonary respiration; the exchange of gases between the alveoli of the lungs and blood in the pulmonary capillaries across the respiratory membrane; 3) internal respiration; the exchange of gases between blood in systemic capillaries and tissue cells (Tortora & Derrickson, 2009).

A pressure gradient between the atmosphere and alveoli is responsible for air movement during pulmonary ventilation. This pressure gradient is created by the contraction and relaxation of respiratory muscles (Marieb & Hoehn, 2013). The rate of airflow and amount of energy expended during breathing is influenced by alveolar surface tension, airway resistance and lung compliance (McLafferty et al., 2013a).

2.3.1 Inhalation
Boyle’s law states that at a constant temperature, the pressure of gas varies inversely with its volume (Marieb & Hoehn, 2013). Therefore, for air to flow into the lungs, the pressure within the alveoli must be less than that of the atmosphere (P_{atm}) (Tortora & Derrickson, 2009). This is achieved by increasing the size of the lung which is facilitated by the contraction of muscles acting on the chest wall to change its shape in the vertical, transverse and anteroposterior diameters (Chaitow et al., 2014; Courtney, 2009). These muscles are often termed the ‘primary muscles’ of ventilation and include the diaphragm, the intercostal muscles, parasternal muscles, and the scalenes (Courtney, 2009; Levangie & Norkin, 2011).

1 Ventilation is the movement of air in and out of the lungs, whereas respiration is the movement of oxygen and carbon dioxide in and out of the blood. Often within the literature ventilation is referred to as respiration. This is a misnomer and is not physiologically correct. Throughout this review these terms will be used as defined here.
2 Breathing is the non-technical term for ventilation.
The diaphragm, a primary muscle of ventilation, is a dome shaped skeletal muscle that forms the floor of the thoracic cavity and accounts for approximately 75% of the air that enters the lungs during quiet breathing (Courtney, 2009; Tortora & Derrickson, 2009). During inhalation the diaphragm contracts and descends with a slight change in its contour that results in an increased vertical dimension of the thoracic cavity (Levangie & Norkin, 2011). The intercostal muscles are also considered primary muscles of ventilation and account for approximately 25% of the air that enters the lungs during quiet breathing (Tortora & Derrickson, 2009). These muscles act to increase the lateral and anteroposterior diameters of the thoracic cavity. Their function during inhalation is complex and controversial. It has long been thought that the external intercostals are active only during inhalation and the internal intercostals active only during exhalation. However, electromyography studies have shown that both sets of muscles are active during both phases of breathing (Levangie & Norkin, 2011). The recruitment of intercostals during the ventilatory cycle is in the cranial to caudal direction. This means that the recruitment of muscle fibres begins in the higher intercostal spaces and moves inferiorly as inhalation progresses (Levangie & Norkin, 2011). Parasternal muscles also account for a portion of the increase in size of the thoracic cavity during inhalation. These muscles act on the costo-sternal joints to elevate the ribs and move the sternum antero-superiorly, thereby increasing the anteroposterior diameter of the thoracic cage (Levangie & Norkin, 2011). The parasternal muscles also act to stabilise the rib cage. The scalenes are also considered as primary muscles of ventilation (Courtney, 2009), and elevate the first and second ribs, thereby acting on the sternum in the pump-handle motion of the upper rib cage.

During quiet inhalation, the pressure between the two pleural layers of the thoracic cage is always sub-atmospheric (West, 2002). As the diaphragm and intercostals contract the volume of the thoracic cavity increases. The volume of the pleural cavity also increases resulting in a decrease of the intrapleural pressure. The parietal and visceral pleural layers adhere tightly to one another. This is a result of the sub-atmospheric pressure between them and the surface tension created by their moist adjoining surfaces (McLaugherty et al., 2013a). As the thoracic cavity expands the parietal pleura lining the cavity is drawn outwards pulling both the visceral pleura and the lungs with it. This movement enlarges the lungs creating the pressure gradient required for air movement, thereby filling the lungs.

During forceful inhalation, secondary muscles\(^3\) of ventilation are recruited to further increase the volume of the thoracic cavity. This greater increase in size results in a larger pressure differential and more air is inhaled. The secondary muscles of ventilation are so named because they make little, if any contribution, during normal quiet inhalation (Chaitow et al., 2014). The secondary muscles include any muscles that attach the rib cage to the shoulder girdle, head, vertebral column, or pelvis (Levangie & Norkin, 2011).

\(^3\) Often called secondary muscles of respiration. See footnote 1.
In thoracic dominant breathing, the normal pattern of diaphragmatic breathing is replaced by a situation where the respiratory pump is largely being driven by the upper chest wall and secondary muscles of ventilation (Barker & Everard, 2015). Thoracic dominant breathing is a normal response to certain conditions, such as increased ventilatory demand during exercise, however, the length-tension relationships and co-ordination patterns of the primary ventilatory muscles that are expressed when breathing is at its most ‘efficient’ suggest that ‘optimal’ breathing results from a relatively equal contribution from the upper chest and the lower chest and abdominal compartments (Courtney, 2009; Courtney, van Dixhoorn, & Cohen, 2008). (Courtney, 2009; Courtney, van Dixhoorn, et al., 2011).

2.3.2 Exhalation

Similar to inhalation, exhalation is also the result of a pressure gradient. However, the gradient is in the opposite direction: the pressure in the lungs is higher than that of the atmosphere (Tortora & Derrickson, 2009). Quiet exhalation is a passive process and involves the elastic recoil of the chest wall and lungs. This elastic recoil is supported by two inwardly directed forces: 1) the recoil of elastic fibres that were stretched during inhalation; 2) the surface tension produced by alveolar fluid (surfactant) (Marieb & Hoehn, 2013). The process of exhalation starts when the inspiratory muscles relax. As the diaphragm and intercostals relax, the dome of the diaphragm moves superiorly, and the lower ribs are depressed. These movements decrease the vertical, lateral and anteroposterior diameters of the thoracic cage, thus decreasing its volume. As predicted by Boyle’s law, this decrease in volume increases the pressure in the alveoli causing air to flow out of the lungs (Tortora & Derrickson, 2009). As with inhalation, expiration typically becomes active during forceful exhalation, for example when sighing or playing a wind instrument. Forceful exhalation involves recruitment of the intercostals and abdominals to increase both the speed and volume of the process (Levangie & Norkin, 2011).

2.4 Physiology of breathing

2.4.1 External Respiration

The conventional standard textbook definition of external respiration is the diffusion of oxygen from air in the alveoli of the lungs to blood in the pulmonary capillaries, and the diffusion of carbon dioxide in the opposite direction (Marieb & Hoehn, 2013). Deoxygenated blood coming from the right side of the heart is converted into oxygenated blood that returns to the left side of the heart to be pumped throughout the body (Tortora & Derrickson, 2009). As blood flows through the pulmonary capillaries oxygen diffuses into it from alveolar air, and carbon dioxide is unloaded into alveolar air with each gas diffusing as a result of partial pressure differences. External respiration is influenced by three factors: (1) the thickness and surface area of the respiratory membrane; (2) partial pressure gradients and gas solubility; and (3) ventilation-perfusion coupling that matches alveolar ventilation with pulmonary blood perfusion (Marieb & Hoehn, 2013).
Fick’s law states that the rate of transfer of a gas through a sheet of tissue is proportional to the tissue area and the difference in gas partial pressure between the two sides, and inversely proportional to the tissue thickness (West, 2002). In healthy lungs, the respiratory membrane is just 0.3µm-1µm thick and the surface area is about 90m², making gas diffusion very efficient (Tortora & Derrickson, 2009; West, 2002). Any pulmonary disorder that decreases the surface area of the alveoli, for example emphysema, decreases the efficiency of external respiration (Marieb & Hoehn, 2013).

Partial pressure gradients of oxygen and carbon dioxide drive the diffusion of these gases across the respiratory membrane. At rest, the partial pressure of oxygen (PO₂) in alveolar air is 105mmHg into pulmonary capillary blood where the PO₂ is 40mmHg (Tortora & Derrickson, 2009). Diffusion continues until the PO₂ in the pulmonary capillary blood has increased to match that of the alveolar air. Carbon dioxide diffuses in the opposite direction along a shallower pressure gradient of about 5mmHg until equilibrium occurs at 40mmHg (Marieb & Hoehn, 2013). Even though the pressure gradient for oxygen diffusion is much steeper than that of carbon dioxide, equal amounts of gas are exchanged because carbon dioxide is approximately twenty times more soluble in plasma and alveolar fluid than oxygen.

For optimal gas exchange to take place there must be a close match between ventilation (the amount of gas reaching the alveoli) and perfusion (the blood flow to the pulmonary capillaries (Marieb & Hoehn, 2013). This ratio plays a key role in pulmonary gas exchange because it determines the PO₂ and PCO₂ (West, 2002). Both perfusion and ventilation are controlled by local autoregulatory mechanisms that are continuously active. PO₂ controls perfusion by changing arteriolar diameter and PCO₂ controls ventilation by changing the bronchiolar diameter (Marieb & Hoehn, 2013).

2.4.2 Internal Respiration
Unlike external respiration that occurs in the lungs, internal respiration occurs in tissues throughout the body. The left ventricle of the heart pumps blood that has been oxygenated into the aorta and through systemic arteries to systemic capillaries (Tortora & Derrickson, 2009). The oxygen from this blood then diffuses into the capillaries to tissues cells throughout the body and carbon dioxide, one of the waste products of cell metabolism, diffuses from the tissues cells into the blood of the capillaries (Mclafferty et al., 2013b). As with external respiration, internal respiration relies on a pressure gradient to drive the movement of oxygen and carbon dioxide. The PO₂ of arterial blood is 100mmHg, higher than the PO₂ of the blood in tissue cells (40mmHg) (Tortora & Derrickson, 2009). This is because the cells continuously use oxygen to produce energy. Due to this difference in partial pressure, oxygen rapidly diffuses into tissue cells. In the production of energy, carbon dioxide is produced resulting in a PCO₂ within the cells of 45mmHg (Tortora & Derrickson, 2009). This is 5mmHg higher than that of the blood in the capillaries, driving the diffusion of carbon dioxide out of
the cells and into the blood. The deoxygenated blood is then returned to the heart and the process of external and internal respiration repeats.

2.5 Control of breathing

The classical model for the control of breathing as described by West (2002), contains three basic elements. These are: (1) sensors which gather information and feed it to the; (2) central controller in the brain which coordinates the information and, in turn, sends impulses to the; and (3) effectors (respiratory muscles) which cause ventilation (West, 2002).

![Diagram of respiratory control system](image)

*Figure 1. Basic elements of the respiratory control system (Redrawn after West, 2002, p. 104).*

The nervous supply to the muscles of breathing is both autonomic and voluntary (West, 2002). Autonomic supply is derived from the respiratory centres of the pons and medulla, which are influenced by both central and peripheral chemoreceptors and mechanoreceptors (West, 2002). While breathing is under voluntary control to a considerable extent, the cortex can override the function of the brain stem within limits, for example, during voluntary hyper or hypoventilation or speaking, playing wind instruments and singing (Chaitow et al., 2014; West, 2002). Respiratory rate is also influenced by emotional state (Boiten, Frijda, & Wientjes, 1994; Courtney, 2009). The limbic centre plays an important role in this. Impulses from the limbic centre reach the respiratory centre allowing respiratory alterations associated with emotional responses such as laughing and crying (Mclafferty et al., 2013b).

2.6 Psychological aspects of breathing

Emotions and stress influence breathing rate, depth and location. A study monitoring the amount of carbon dioxide in exhaled air found that subjecting college students to brief mental stressors, such as
mental calculations, increased their breathing rate and lowered their end-tidal carbon dioxide in the
direction of hyperventilation (Ley, 1999). Dysfunctional breathing may be triggered by emotional
states such as grief, frustration, anger and anxiety, and may be maintained indefinitely without
conscious awareness of the dysfunction (Gilbert, 1998). Physical of behavioural changes often have
an impact on the emotional state as a result of the bidirectional relationship of body and mind
(Chaitow et al., 2014). This was demonstrated by Philippot, Chapelle and Blairy (2002) who found
that manipulation of participants’ breathing patterns could induce specific emotional states, including
anger, fear, joy and sadness (Philippot, Chapelle, & Blairy, 2002). There are also numerous studies
that have demonstrated the efficacy of conscious control of breathing and decreased levels of anxiety,
deression and fatigue (Chiang, Ma, Huang, Tseng, & Hsueh, 2009; Hayama & Inoue, 2012; Valenza
et al., 2014). It is, therefore, reasonable to suggest that while breathing patterns are subject to the
emotional state, they are also important in sustaining the emotional state (Philippot et al., 2002).

3 Dysfunctional Breathing

Dysfunctional breathing (DB) is a term used to describe disturbances in breathing function that
negatively impact on a person’s health (Courtney, Greenwood, et al., 2011). There are multiple
possible causes of DB including stress and anxiety, disease and musculoskeletal dysfunction
(Courtney, 2009). The pattern with which DB presents is variable and can include hyperventilation,
irregularity of depth and rate, thoracic dominant breathing and recruitment of secondary muscles of
ventilation during quiet breathing (Barker & Everard, 2015; Han et al., 1997). Dysfunctional
breathing disorders can change respiratory chemistry leading to pH changes, of which the flow on
effects include, but are not limited to; low oxygen concentration in tissues, reduced cerebral blood
flow, increased neuronal excitability and impaired cellular metabolism (Courtney, 2009). These
effects result in numerous symptoms across a range of body systems. Chaitow (2007) has attributed
the following symptoms to DBP; neck and head pain, chronic fatigue, anxiety, cardiovascular distress,
gastro-intestinal dysfunction, lowered pain threshold, spinal instability and hypertension (Chaitow,
2007). However, this is not an exhaustive list of all possible symptoms that DB can cause.

3.1 Dysfunctional Breathing Patterns

Dysfunctions of breathing co-ordination (Courtney, van Dixhoorn, et al., 2011), abnormalities of
timing and volume (Han et al., 1997) and abnormalities in the variability of breathing (Baldwin et al.,
2004) can all contribute to DBP as outlined below.

3.1.1 Dysfunctions of breathing co-ordination

Low amplitude upper chest or thoracic dominant breathing and paradoxical breathing are considered
dysfunctions of breathing co-ordination (Courtney, van Dixhoorn, et al., 2011). A thoracic dominant
breathing pattern is increasingly being used by clinicians to generate a clinical impression of
ventilatory muscle function (Gallego et al., 1997). Paradoxical breathing occurs with inward motion
of the abdominal wall during inspiration. This movement can be a normal response to increased lung volume, exercise or standing posture that maintains abdominal pressure (Courtney, 2009). However, paradoxical breathing becomes dysfunctional when it is not adequately compensated for by lateral widening of the rib cage and instead the lower rib cage narrows (Courtney, 2009).

3.1.2 Abnormalities of timing and volume
In addition to dysfunctions of breathing co-ordination, DB is also characterised by abnormalities of timing and volume of breath which may contribute to symptom production. Normal resting breathing rates are between 10 and 14 breaths per minute, moving 500ml of air with each inhalation (Chaitow et al., 2014). In normal people breathing rates and volume increase and fluctuate in response to physical or emotional demands, but will return to relaxed abdominal breathing patterns once the stimuli ceases (Chaitow et al., 2014). This is not the case in those with DB as demonstrated by Han et al. (1997) who found that when patients with hyperventilation or anxiety disorders performed a voluntary hyperventilation test the end tidal fractional concentration of carbon dioxide decreased compared to healthy subjects (Han et al., 1997). This measure also did not return to its steady state in the 5 minutes following the hyperventilation test as it had in control subjects (Han et al., 1997). Tobin et al. (1983) also found that in patients with Chronic Obstructive Pulmonary Disease (COPD), restrictive lung disease and pulmonary hypertension, mean inspiratory flow and inspiratory rate were elevated (Tobin et al., 1983). Further, it was noted that patients with chronic anxiety demonstrated higher frequency of sighing and occasionally periods of episodic apnoea (Tobin et al., 1983).

Chaitow et al. (2014) define hyperventilation as “a pattern of over-breathing where the depth and rate are in excess of the metabolic needs of the body at that time”. Recruitment of the upper chest and accessory muscles of ventilation is generally associated with mild hyperinflation, irregular rate and volume of ventilation, frequent sighing and may be accompanied by an increase in rate (Barker & Everard, 2015).

3.1.3 Abnormalities of variability of breathing
Respiratory variability is an intrinsic property of breathing and reflects the degree of freedom of the respiratory control system (Baudin et al., 2014). While essential to the breathing process, excess variability of breathing, where there is no obvious pattern, is a reliable indicator for DB suggesting that the respiratory control system is struggling to maintain homeostasis (Baldwin et al., 2004; Perna, Caldirola, & Bellodi, 2004). Contrastingly, low respiratory variability is associated with pathological conditions in adults and infants (Baudin et al., 2014).

3.2 Aetiology
Given the complexity of the respiratory system there are multiple ways that its efficacy can be compromised. These include: (1) changes to the quantity or quality of the alveolar fluid, changes to airway resistant and lung compliance (Marieb & Hoehn, 2013); (2) muscular factors such as
decreased power and efficiency (Courtney, 2009); (3) behavioural and psychological factors such as anxiety or depression (Wolf, 1994); and (4) chronic disease such as fibromyalgia and multiple sclerosis (Chaitow, 2004).

3.2.1 Surface tension of alveolar fluid, airway resistance and lung compliance

A thin layer of alveolar fluid coats the luminal surface of alveoli and exerts surface tension. This surface tension occurs at any gas-liquid boundary as the molecules of the liquid are more strongly attracted to each other than to the gas molecules (Marieb & Hoehn, 2013). The surface tension in the lungs causes the alveoli to assume the smallest possible diameter. This surface tension must be overcome to expand the lungs during inhalation (Tortora & Derrickson, 2009). The consequences of conditions that affect the quality and quantity of surfactant, such as infant respiratory distress syndrome, are decreased lung compliance, areas of atelectasis (collapsed alveoli) and alveoli filled with transudate (West, 2002).

The rate of airflow through the airways depends on both the pressure gradient and the resistance of those airways and can be expressed as in Equation 1:

\[
\text{Flow} (F) = \frac{\text{Change in pressure} (\Delta P)}{\text{Resistance} (R)}
\]

Equation 1: Relationship between gas flow \((F)\), pressure \((P)\) and resistance \((R)\) (Marieb & Hoehn, 2013).

The amount of gas flowing into and out of the alveoli is directly proportional to \(\Delta P\). Any condition that narrows or obstructs the airways increases resistance so that more pressure is required to maintain airflow (Tortora & Derrickson, 2009). This increase in required pressure makes breathing movements more strenuous which can result in altered breathing mechanics and patterns (Marieb & Hoehn, 2013).

Compliance can be expressed as a function of lung volume and transpulmonary pressure (see Equation 2):

\[
\text{Compliance} \ (C_L) = \frac{\text{Change in lung volume} (\Delta V_L)}{\text{change in transpulmonary pressure} (\Delta(P_{\text{pat}}-P_{\text{ip}}))}
\]

Equation 2: Relationship between compliance \((C_L)\), lung volume \((V_L)\) and transpulmonary pressure \((P_{\text{pat}}-P_{\text{ip}})\) (Marieb & Hoehn, 2013).

The more the lung expands for a given rise in transpulmonary pressure the greater its compliance. Two principle factors govern lung compliance, these are: (1) elasticity; and (2) surface tension (Tortora & Derrickson, 2009). Because elastic fibres in lung tissue are easily stretched and surfactant keeps alveolar tension low, health lungs tend to have high compliance. Any decrease in the natural resilience of the lungs diminishes lung compliance. This can be caused by pulmonary conditions that
(1) scar lung tissue (e.g. tuberculosis), (2) cause lung tissue to become filled with fluid (e.g. pulmonary oedema), (3) produce a deficiency of surfactant; and (4) impede lung expansion in anyway (Tortora & Derrickson, 2009). If lung compliance is decreased the body must work harder to fill the lungs to maintain homeostasis which may result in DBP and muscles over-recruitment (McLaugherty et al., 2013b).

3.2.2 Muscular factors

As with all skeletal muscles, the ability of the diaphragm to generate force effectively is related to length of the muscle fibres (Caruana, Petrie, McMurray, & MacFarlane, 2001; Finucane, Panizza, & Singh, 2005). If the diaphragm is shortened and hypertonic its power and efficiency is decreased (Courtney, 2009). This dysfunction may also cause the other respiratory muscles to alter their function, often becoming overloaded (Courtney, 2009). Diaphragm dysfunction also decreases the ability of the respiratory system to manage sudden increases in ventilatory demand (Teixeira et al., 2005). Additionally, the diaphragm provides proprioceptive input to the central nervous system via afferent mechanoreceptors that influence the perception of breathing (Caruana et al., 2001). A shortened diaphragm may alter the sensation of breathing and thereby contribute to increased respiratory drive (Frazier & Revelette, 1991). A chronically increased respiratory drive further increases the tension of accessory breathing muscles as a result of increased frequency of contraction (Rochester, 1993). Consequently, the respiratory system is less efficient and more vulnerable to fatigue. This was demonstrated by Finucane et al. (2005) who found that diaphragm efficiency is decreased with hyperinflation (Finucane et al., 2005). The study of 5 healthy non-smoking males assessed oesophageal, gastric and mouth pressures and diaphragm electromyography with hyperinflation. Multiple regression analysis showed efficiency was highly correlated with diaphragm length-efficiency decreasing ~34% for every 10% decrease in diaphragm length (Finucane et al., 2005).

Diaphragm function is also affected by abdominal muscle dysfunction and therefore breathing function (Hruska, 1997). Hypertonic4 abdominals limit diaphragmatic shortening during expiration. The opposite is also true - diaphragm dysfunction is aggravated by abdominal muscle weakness (Courtney, 2009). In this case the abdominal muscles are not effective in assisting full diaphragmatic relaxation in expiration which can lead to breathlessness and changes in breathing pattern (Cahalin, Braga, Matsuo, & Hernandez, 2002; Sharp, Goldberg, Druz, & Danon, 1975).

Increase in the end-expiratory lung volume (hyperinflation) can alter the mechanical function of the muscles of inspiration and may affect the pattern of thoracoabdominal movement (Wolfson, Strohl, Dimarco, & Altose, 1983). When the system is in a state of hyperinflation the inspiratory muscles are

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4 Hypertonicity is defined in osteopathy as: “A condition of excessive resting tone of skeletal muscles characterised by increased resistance of the muscle to passive stretching” (American Association of Colleges of Osteopathic Medicine, 2011).
shortened. At 30% of the lungs inspiratory capacity the diaphragm no longer expands the rib cage. Above this capacity the diaphragm has a rib cage deflating action (Courtney, 2009). Enlarged thoracic volumes increases the tendency for paradoxical breathing to occur which contributes to the inefficiency of the respiratory system (Wolfson et al., 1983).

Neck pain has been linked to DB. A study by Perri and Halford (2004) found that 83% of patients with neck pain in a population of different chronic musculoskeletal pain syndromes experienced a changed breathing pattern. Neck pain patients also demonstrated a significant decrease in their maximum voluntary ventilation (p<0.05), maximum inspiratory pressure (P_{\text{max}}) (p<0.01) and maximum expiratory pressure (P_{\text{emax}}) (p<0.05) (Kapreli, Vourazanis, Billis, Oldham, & Strimpakos, 2009). Additionally, regression analysis for P_{\text{max}} and P_{\text{emax}} showed significant negative correlation with forward head posture, indicating that forward head posture may be associated with these lung function parameters in neck pain patients (Kapreli et al., 2009). Forward head posture can lead to functional alterations that cause biomechanical modifications in the thoracic spine which affect respiratory muscle function.

3.2.3 Behavioural and psychological factors
Chronic emotional stress and increased mental load can disrupt normal breathing patterns, independent of chemoreceptor and mechanoreceptor input (Courtney, 2009; Jack, Rossiter, Warburton, & Whipp, 2003). Higher neural centres are activated during anticipatory anxiety, which suggests that psychological factors or emotional states might have a profound effect on respiratory control mechanisms (Jack et al., 2003). This is supported by the absence of evidence of pulmonary or chemoreceptor dysfunction or hypersensitivity in those that display hyperventilation, which suggests that it is the behavioural factors that result in the increased respiratory rate (Jack et al., 2003). If breathing changes in response to feelings and thoughts rather than metabolic signal from chemoreceptors, then it may not align with the actual physical requirements of the body or its metabolism (Courtney, 2009). Wolf (1994) has demonstrated the link between emotional stress and respiratory distress. Seventeen individuals with a history of respiratory distress were examined fluoroscopically while engaged in a known area of emotional sensitivity (Wolf, 1994). The results showed that the ensuing emotional stress caused hyperventilation with increased lung volume (hyperinflation) and increased tension and flattening of the diaphragm. Although no statistical analysis was provided in this study – a notable weakness – the study does provide some useful insight into the effects of emotion on breathing patterns.

3.2.4 Chronic disease
Impaired breathing biomechanics and function are a feature of many multi-symptom syndromes including fibromyalgia, irritable bowel syndrome (IBS), chronic obstructive pulmonary disease (COPD), anxiety, multiple sclerosis (MS) and chronic fatigue syndrome (CFS) (Chaitow, 2007).
3.2.4.1 Multiple Sclerosis

The three most common respiratory problems in MS are: (1) respiratory muscles weakness, (2) bulbar function impairment; and (3) abnormal breathing control. A study by Mutluay, Gürses and Saip (2005) investigated the effect of MS on respiratory function in 38 patients with a definite diagnosis of MS. Spirometry and maximal inspiratory and expiratory pressures were used to assess the patients. The values of those assessed were compared with expected values from the healthy general population to determine the effect of MS on respiratory function. Significant reductions in respiratory functions were found by both measurements. However, the reductions in spirometry measures (6-9%) were lower than those of maximal inspiratory pressure and maximal expiratory pressure (-23% and -40% respectively). These results agree with earlier reports that suggest MS patient have more pronounced expiratory muscle weakness (Smeltzer et al., 1992) and that MS does impair respiratory function. It is thought that the severity of MS (as measured by MS induced disability level) rather than duration is the principal cause of respiratory weakness (Mutluay, Gürses, & Saip, 2005). The results also showed that patients with MS tended to have a faster rate and more superficial pattern of breathing.

3.2.4.2 Cardiorespiratory diseases

Cardiorespiratory conditions may be associated with DB as they place higher demands on the respiratory system that must then adapt to maintain homeostasis. Adaptations include changes in respiratory drive, rate and pattern. To illustrate these changes, the example of chronic heart failure is informative. Caruana, Petrie et al. (2001) found that chronic heart failure led to changes in the composition of muscles fibres, decreasing their activity (Caruana et al., 2001). This decrease in function of primary muscles of ventilation leads to increased recruitment of the secondary muscles of ventilation and a thoracic dominant breathing pattern (Caruana et al., 2001; Weitzenblum, 2003).

3.2.4.3 Asthma

Several studies have investigated the link between asthma and DB, finding that functional breathing disorders have been described in people with asthma and asthma-like symptoms (Thomas et al., 2003). A total of 227 patients with diagnosed asthma completed the Nijmegen Questionnaire (NQ) with 63 of those participants scoring ≥23 (a threshold suggestive of DB) (Morgan, 2002; Thomas et al., 2003). Females and those of younger age were more likely to score higher on the NQ. A follow-on study in the same group of participants identified that breathing retraining improved scores with the Asthma Quality of Life Questionnaire (AQLQ) and NQ scores in the six months following breathing retraining intervention (Thomas et al., 2003). Another study of 206 outpatient children attending an asthma clinic found that in those with poor asthma control their NQ score was likely to be ≥23 (90.9%) (de Groot, Duiverman, & Brand, 2013). While there was a low prevalence of DB within the sample, the survey still showed a significant and clinically relevant negative association between DB and asthma control (de Groot et al., 2013).
3.2.4.4 *Chronic Obstructive Pulmonary Disease*

Similar links have been made between COPD and DB. A study of breathing patterns in 49 people diagnosed with the disease found that of 28 patients with COPD, 14 with restrictive lung disease and 7 with pulmonary hypertension, all had an increased respiratory rate and mean inspiratory flow (Tobin et al., 1983). Tobin et al., (1983) also found that patients with COPD often had major fluctuations in their expiratory timing and end-expiratory level as well as asynchronous movements between the rib cage and abdominal movements (Tobin et al., 1983).

The body is in a constant state of trying to maintain its homeostatic balance. This can be difficult given the adaptations that occur with chronic disease. It is likely that these changes contribute to symptom presentation and, therefore, the diagnosis and treatment of DB may be of benefit to the management of the underlying condition.

3.3 Consequences

Several consequences of DB have been suggested including dyspnoea, adverse fluid dynamics, impaired postural and motor control and musculoskeletal pain.

3.3.1 Dyspnoea

Dyspnoea has been described as a sensation experienced by individuals of unpleasant or uncomfortable breathing of which breathlessness is the most common symptom (Scano & Ambrosino, 2002). These respiratory sensations may vary in their quality and intensity depending on the underlying pathophysiological mechanisms (Simon et al., 1990; Von Leupoldt et al., 2007). It is thought that dyspnoea results from a central perception of an overall increase in central respiratory motor output that is directed preferentially at the secondary muscles of ventilation resulting in an thoracic dominant breathing pattern (Scano & Ambrosino, 2002; Simon et al., 1990). This increase in central respiratory motor output may be different from the ‘condition’ expected by the brain and this deviation of breathing pattern may either cause or intensify the sensation of dyspnoea (Manning & Schwartzstein, 1995).

3.3.2 Adverse fluid dynamics

The cyclical changes in the pressure gradients of the abdomen and thorax during inhalation and exhalation aid the movement of blood between the two compartments. The increase in intra-abdominal pressure and decrease in intra-thoracic pressure generated by inhalation encourages the movement of venous blood superiorly into the thorax (Dornhorst, Howard, & Leathart, 1952; Tortora & Derrickson, 2009). Dysfunctional breathing patterns, including paradoxical and thoracic dominant patterns affect the amplitude of the rhythmic pressure changes and therefore the volume of blood moved with each breath (Courtney, 2009). This in turn activates homeostatic reflexes responsible for maximizing optimal cardiopulmonary interaction and regulating blood pressure (Bernardi, Porta, Gabutti, Spicuzza, & Sleight, 2001). A study of the relationship between inferior vena cava (IVC)
collapsibility and abdominal breathing found that IVC collapsibility index was significantly higher in the abdominally breathing group when compared to the control group (Byeon et al., 2012). This is important, because amplitude of IVC collapsibility is indicative of efficient venous return (Byeon et al., 2012).

3.3.3 Impaired posture and motor control

The function of trunk muscles that are active during breathing is not limited to ventilation. These muscles play an important part in many other movements including swallowing, speech production, Valsalva movements, spinal stabilisation and movement of the trunk and limbs (Courtney, 2009). For example, the diaphragm, pelvic floor and transversus abdominus are integral in regulating intra-abdominal pressure and providing anterior lumbopelvic postural stability (Frank, Kobesova, & Kolar, 2013). This need for integration of often unrelated functions places considerable demand on the mechanisms of motor control (Courtney, 2009). In situations where the respiratory drive is increased, such as stress, disease or exercise, the ability of the ventilatory muscles to perform postural tasks is decreased. Using a 10% carbon dioxide gas mix to elevate breathing, McGill, Sharratt and Seguin (1995) noted that a decrease in support offered to the spine by the muscles of the trunk may occur if there is both a load challenge to the low back in conjunction with a breathing challenge (McGill, Sharratt, & Seguin, 1995). Additionally, Hodges demonstrated that after ~60 seconds of hypercapnia the postural and phasic functions of both the diaphragm and transversus abdominus are decreased or absent suggesting that an increase in central respiratory drive may attenuate the postural commands reaching the motor neurons (Hodges, Heijnen, & Gandevia, 2001). This is supported by Janssens et al. (2013) who found a group of 20 individuals with COPD, especially those with inspiratory muscles weakness, had an increased reliance on ankle muscles proprioceptive signals and decreased reliance on back muscle proprioceptive signals during balance control (Janssens et al., 2013). This led to a decrease in postural stability and an increased risk of falls when compared to healthy controls (Janssens et al., 2013). Kolar et al. (2012) conducted a study examining postural diaphragm function in 18 patients with chronic low back pain due to chronic overloading and 29 healthy controls. They noted that those with chronic low back pain appear to have both abnormal position and a steeper slope of the diaphragm, suggesting that this could be a contributing aetiological factor in low back pain (Kolář et al., 2012).

Forward head posture, commonly associated with DBP, especially oral breathing (Cuccia, Lotti, & Caradonna, 2008), can have considerable adverse effects on the biomechanics of the head, neck and jaw (Hruska, 1997). Additionally, oral breathing can affect the morphology of the craniofacial structures and result in neck pain, temporomandibular disorders, headaches and craniofacial pain (Cuccia et al., 2008; Goodarzi, Rahnama, Karimi, Baghi, & Jaberzadeh, 2017; Hruska, 1997).
3.3.4 Musculoskeletal pain
Various regions of musculoskeletal pain have been associated with DB. These include the neck and shoulder region (Kapreli et al., 2009; Perri & Halford, 2004), chest wall (Wolf, 1994), and the low back (Chaitow, 2004). A study of 38,050 women from three age-cohorts found that prevalence of back pain was higher in those who experienced disorders of continence and ventilation (Smith, Russell, & Hodges, 2006). The same study also demonstrated that the relationship between back pain and disorders of continence and respiration was more consistent than that between back pain and BMI and activity level (Smith et al., 2006).

3.4 Clinical importance of dysfunctional breathing
The lack of clarity surrounding the aetiology, diagnosis and management of DB is considered to negatively impact on clinicians' perceptual model of the condition (Barker & Everard, 2015). This makes diagnosis and management of the condition difficult and as such diagnosis may not occur, or may take a long time, with the patient undergoing multiple inconclusive investigations under many different specialisations (Barker et al., 2013). The ambiguity around DB deprives the patient of effective treatment and also places them at risk of adverse effects of misdiagnosis and accompanying treatment (Barker & Everard, 2015).

Estimates of the prevalence of DB in the general population range from 5% to 11% (Chaitow et al., 2014; Thomas et al., 2005). This prevalence may be increased in adults who also suffer from diagnosed asthma with some studies reporting prevalence of 20% and up to 83% of those with anxiety (Cowley & Roy-Byrne, 1987; Thomas, McKinley, Freeman, & Foy, 2001). Clinically, DB can result in elevated patient morbidity and is considered an important factor in the presentation of many conditions, for example Chronic Obstructive Pulmonary Disease and asthma (Barker et al., 2013). However, there is debate as to whether DB exacerbates the patient's symptoms, or is a result of the condition (Mitchell et al., 2016).

4 Assessment of breathing dysfunction
There are a wide variety of breathing assessment techniques that explore the psychological, biochemical and biomechanical aspects of breathing (Courtney, 2009). This wide range of techniques help to provide a more complete picture of DB. Psychological aspects of breathing and breathing symptoms are assessed using questionnaires including the Nijmegen Questionnaire (van Dixhoorn & Duivenvoorden, 1985), and the Self-Evaluation of Breathing Questionnaire (SEBQ) (Courtney & Greenwood, 2009). Biochemical and physiological aspects are generally assessed using instrument-based assessments which and include capnography (Johnson, Schweitzer, & Ahrens, 2011), spirometry (Paraskeva, Borg, & Naughton, 2011), and breath hold time (BHT) (Courtney & Cohen, 2008). Finally, the biomechanical aspects of breathing can be assessed in two ways. These are either instrument-based assessment, for example Respiratory Inductive Plethysmography (RIP) (Heyde,
Leutheuser, Eskofier, Roecker, & Gollhofer, 2014), or palpation-based assessment using either the Manual Assessment of Respiratory Motion (MARM) (Courtney et al., 2008), or the Hi-Lo (Courtney et al., 2009).

While the range of approaches to breathing assessment will be reviewed in this next section, the specific focus will be on the palpation-based assessment approaches of MARM and Hi-Lo.

4.1 Questionnaire based

4.1.1 Nijmegen Questionnaire

The Nijmegen questionnaire (NQ) is the most commonly used questionnaire to identify DB (Courtney, Greenwood, et al., 2011). The 16-item questionnaire seeks to evaluate the likelihood that certain symptoms indicate a hyper-ventilatory pattern (Chaitow, 2004). It was first developed by van Doorn and colleagues who demonstrated that the test-retest reliability was good in a sample of 20 chronic hyperventilation syndrome patients ($r=0.87$) (van Doorn, Folgering, & Colla, 1982). The 16 items relate to possible symptoms experienced in a range of body systems: (1) cardiovascular, for example palpitations, (2) neurological, for example dizziness, tingling fingers, (3) respiratory, for example shortness of breath, (4) gastrointestinal, for example bloated abdominal sensation; and (5) mental, for example tension (Ristiniemi, Perski, Lyskov, & Emtner, 2014). As a clinical tool the Nijmegen questionnaire is non-invasive in nature and is scored on a five-point ordinal scale (0: never, 4: very often) (Li Ogilvie & Kersten, 2015). An advantage of the NQ is that it is responsive to treatment effect and, given its short length, can be repeatedly administered over the course of a series of treatment sessions to assess treatment response (Chaitow et al., 2014).

4.1.2 Self-Evaluation of Breathing Questionnaire

The Self-Evaluation of Breathing Questionnaire (SEBQ) was developed in 2009 by Courtney and Greenwood. It contains items drawn from the various descriptions in scientific and popular literature of respiratory symptoms and breathing behaviours proposed to be associated with breathing dysfunction (Chaitow et al., 2014). The most current version of the SEBQ (see Appendix B) contains 25 items that are answered on a four-point ordinal scale (0: never, 3: very frequently/ very true) (Courtney & Greenwood, 2009). The SEBQ is useful as a means of evaluating the quality and quantity of uncomfortable respiratory sensations and the person’s perception of their own breathing (Chaitow et al., 2014). Factor analysis has identified two distinct categories of breathing discomfort: Factor 1; “lack of air” which is predominantly about feeling or sensing and Factor 2; “perception of inappropriate or restricted breathing” which is predominantly about observing or noticing (Courtney & Greenwood, 2009). Recently, a reliability study conducted by Mitchell and colleagues aimed to determine the test-retest reliability of the SEBQ as a measure of DB (Mitchell et al., 2016). The analysis of the collected data showed very high test-retest reliability (ICC = 0.89) and internal consistency (Cronbach’s $\alpha = 0.93$) for the 25-item SEBQ, as well as a shortened version of the
questionnaire with as few as six items (Mitchell et al., 2016). This may suggest that a shortened form is clinically appropriate; however, the inclusion of a greater range of symptoms may increase the sensitivity of the SEBQ to forms of DB not associated to hyperventilation or not detectable by other breathing dysfunction questionnaires (Mitchell et al., 2016).

4.2 Instrument based (biochemical and physiological)

4.2.1 Capnography
Capnography is the measurement of the amount of carbon dioxide exhaled with each breath (Johnson et al., 2011). The examination is performed during spontaneous breathing and breath-to-breath measurements are collected, including tidal volume, minute volume and end tidal carbon dioxide (Modena et al., 2018). The data collected can provide critical information about cardiac and pulmonary function (Riley, 2017). This technique is additionally useful in the clinical setting as it obtains accurate and time sensitive measures of arterial carbon dioxide and is non-invasive (Chaitow et al., 2014; McLaughlin, Goldsmith, & Coleman, 2011).

4.2.2 Spirometry
Spirometry is used to measure the flow and volume of air entering and leaving the lungs (Paraskeva et al., 2011). It is useful in the assessment of ventilatory function and differentiates between healthy lung volumes and diseases causing obstructive or restrictive changes (Paraskeva et al., 2011). Measurements gained from the use of spirometry include forced vital capacity, total lung capacity and residual volume (Tiller & Simpson, 2018).

4.2.3 Breath Hold Time
Breath hold time can be used as an indicator of a person’s ventilatory response to biochemical, biomechanical and psychologic factors. An abnormally shortened BHT is indicative of abnormalities in respiratory control that can result in DB (Courtney & Cohen, 2008). Breath hold time in patients with chronic idiopathic hyperventilation has been reported to be only 20 seconds, when held at the end of inhalation, when compared to normal individuals whose BHT is around 60 seconds (Courtney, Greenwood, et al., 2011). There are two different approaches to assessing BHT. These are breath holding until first difficulty or first desire to breath or breath holding until the first involuntary movement of the respiratory muscles (Courtney & Cohen, 2008). Interestingly, breathing pure oxygen does not alter BHT in individuals with chronic idiopathic hyperventilation which therefore suggests that BHT offers a simple test for chronic idiopathic hyperventilation that only requires a timepiece (Warburton & Jack, 2006).
4.3 Instrument based (biomechanical and palpation based)

4.3.1 Respiratory Inductive Plethysmography

Respiratory Inductive Plethysmography (RIP) is a validated method of evaluating tidal ventilation during quiet breathing using measurements derived from chest wall motion (Heyde et al., 2014; Retory, Niedzialkowski, de Picciotto, Bonay, & Petitjean, 2016). It is a non-invasive method that relies on the measurement of the current induced by an alternating magnetic field in coils, which is a function of the surface encircled by the coil (Retory et al., 2016). Measurements derived from assessment using RIP include; tidal volume (Vt), inspiratory (Ti) and expiratory (Te) times and their subsequent ratios (Ti/Ttot, Vt/Ti) (Retory et al., 2016). The advantage of using RIP in contrast to methods requiring mouthpieces, nose clips or facemasks is that it is less likely to interfere with natural breathing patterns, which is a well-known and documented phenomenon (Heyde et al., 2014).

4.3.2 Osteopathic approach to assessment

Chaitow, et al. (2014), outlines an osteopathic approach to the assessment of ventilatory function based on four key elements: (1) category- does breathing involve the lower rib cage and/or the diaphragm?; (2) locus of abdominal motion- does abdominal movement occur as far as the pubic bone?; (3) rate; and (4) duration of cycle- are the inhalation and exhalation phases equal or is one longer than the other? (Chaitow et al., 2014). The authors also describe a series of observations and palpation methods that can be combined into a sequence. This series includes palpation and observation of a patient’s breathing in seated, supine, side-lying and prone positions, in addition to a standard evaluation of posture in which head position, shoulder ‘rounding’ (forward appearance of the shoulder) and upper and lower crossed syndromes are noted (Chaitow et al., 2014). The assessment process provided appears to be a thorough and considered approach to assessing the ventilatory system, but it is also a lengthy process. Additionally, there appear to have been no investigations of reproducibility of validity of this approach.

4.3.3 The Manual Assessment of Respiratory Motion and Hi-Lo

MARM

The Manual Assessment of Respiratory Motion (MARM) is an assessment technique that utilises palpation to assess biomechanical aspects of breathing and its pattern. According to Courtney et al. (2008), the MARM is particularly useful for assessing breathing pattern and the relative distribution of breathing motion between the upper and lower rib cage and the abdomen (balance). Other aspects of breathing that can be assessed during application of the MARM include manual counting of breathing rate and regularity, and palpation-based assessment of flexion and extension of the spinal column (Courtney et al., 2008). The MARM was first developed and applied in a study of breathing and relaxation therapy with cardiac patients in the 1980s (van Dixhoorn, 1994). As a clinical test requiring no special technology, the MARM is a minimally invasive, cost-effective technique. Three
studies (Courtney et al., 2009, 2008; Ludwig, 2013) assessed the MARM’s inter-rater reliability. Two were in support, indicating its potential as a clinical and research tool for the assessment of breathing patterns and related dysfunction and one demonstrating less favourable inter-rater reliability (Courtney et al., 2008).

The MARM technique is performed by placing the hands lightly on the lower lateral rib cage with fingers spread so that the little finger approaches horizontal and the thumbs are parallel to the spine (Courtney et al., 2009). The examiner then assesses the patient’s breathing and records the findings using the MARM graphic notation (Courtney et al., 2009). The graphic notation uses a circle which is dissected into quarters with the horizontal line representing the middle. The practitioner then draws two lines in one half of the circle with the upper line representing the motion occurring in the upper rib cage and the extent of vertical motion. The lower line represents the motion of the lower rib cage combined with the extent of movement in the lateral rib cage and abdomen (Chaitow et al., 2014) [see Appendix C]. Various aspects of the assessment are not specified, such as patient posture, or the depth of the breath taken during palpation. The graphic notation of the MARM allows the examiner to generate a numerical value which corresponds to the degree of expansion, location and balance of the patient’s breathing (Courtney, Greenwood, et al., 2011). These numerical values represent one of four variables: (1) area of breath, (2) MARM average, (3) MARM balance and (4) percentage of rib cage motion (Chaitow et al., 2014) [see Appendix C]. One difficulty that practitioners face using the MARM is in providing a simplified way to describe the global process of inhalation (Courtney et al., 2008). Practitioners must convert a three-dimensional process into a two-dimensional representation. There is also a perceptual difficulty in estimating the degree of “upper chest” and “lower chest” expansion.

Hi-Lo

The Hi-Lo is a palpatory assessment that is used to distinguish between abdominal and upper rib cage breathing. It is particularly useful for identifying paradoxical breathing, if present (Courtney et al., 2009). Similarly to the MARM, the Hi-Lo is a non-invasive and cost-effective technique for the palpation-based assessment of breathing.

In a study completed by Courtney et al. (2008), the MARM technique was compared to an instrumental assessment of breathing, Respiratory Induction Plethysmography (RIP). The aim of the study was to investigate the utility of the MARM in the clinical setting and to determine the inter-rater reliability of the MARM. Twelve participants who were designated as “experienced” breathers consciously altered their breathing and posture to achieve 9 conditions arising from the combination of 3 breathing and 3 postural instructions while being assessed by 3 experienced osteopaths (Table 1). The participants wore an instrumented garment with sensors that detected motion around the circumference of the thorax and abdomen (Life Shirt) throughout the examination process.
Table 1: Breathing postures and instructions used in Courtney et al. (2008).

- 1. Breathe normally – sit in your normal posture
- 2. Breathe thoracically – sit in your normal posture
- 3. Breathe abdominally – sit in your normal posture
- 4. Breathe normally – sit in slumped posture
- 5. Breathe normally – sit in erect posture
- 6. Breathe thoracically – sit in slumped posture
- 7. Breathe abdominally – sit in slumped posture
- 8. Breathe thoracically – sit in erect posture
- 9. Breathe abdominally – sit in erect posture

The MARM measurements taken by Courtney et al. (2008) were ‘volume/area’ ((upper) ribcage and abdominal excursion), ‘balance’ (difference between (upper) ribcage and abdominal excursion) and ‘percentage rib cage (%RC)’ (the percentage of relative ribcage contribution). [Appendix C].

The RIP measurements used were percentage rib cage motion (RIP%RC) (the percentage of relative rib cage contribution), ‘mean phase relation of total breath’ (the percentage of direction in which the ribcage and abdomen move in opposite directions during the respiratory cycle) and ‘peak inspiratory flow’ (reflects respiratory drive in the thoracic compartment).

The results demonstrate strong inter-rater reliability for MARM balance ($r = 0.851, p = .01$) and MARM %RC ($r = 0.844, p = .01$) indicating substantial agreement between three clinically experienced osteopaths who fulfilled the role of examiners. The strongest correlations were demonstrated between measures of upper rib cage involvement i.e. RIP%RC and MARM%RC ($r = 0.597, p = .01$) and MARM balance ($r = 0.591, p = .01$). Other correlations identified were positive but weak. The authors concluded from the correlation of the MARM measures with the RIP%RC that the MARM may be a reliable tool for the measurement of a thoracically dominant breathing pattern. Despite the strong correlations between MARM and RIP measures, the results and resulting conclusions may have been limited by the relatively small number of participants and examiners, and by the analytical method. Firstly, it appears that the correlational analyses reported in

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5 The term thoracically was not clearly defined by Courtney et al. (2008). It is a colloquial description likely derived from clinical experience indicating a tendency to breathe with the upper ribs and chest.
this study arose from pooling measurements taken for all the different breathing and posture combinations, creating heterogeneous test-retest variables, from which nonsensical correlations can arise (Hassler & Thadewald, 2003). Because of the large range of scores that are likely to arise from various “simulated” DB conditions, the correlation coefficients here were very likely to have been artifactually inflated due to score clustering at high and low extremes for particular conditions. It is also important to note that in this study the order of the posture and breathing changes were not randomised and examiners may have been aware of the subsequent next change after performing numerous examinations. Additionally, Courtney’s data (Courtney et al., 2008) were used to compare with the instrumented garment and the other examiners, rather than all examiners data being compared to each other and the instrumented garment. This generates an inter-rater reliability between practitioners and the instrumented garment that is not representative of the sample.

Instructions to breathe normally resulted in decreased rib cage involvement and vice versa for all three positions. A within-subject analysis of variance using the three factors (breathing, posture and measurement method) (dependent variable) showed significant differences between the three postures (independent variable) across all 9 combinations. This suggests that each measurement was able to detect voluntary changes in breathing. The MARM%RC \( (2.22) = 191.2, p = 0.0001, \text{partial eta-squared} = 0.946 \) and balance \( (2.22) = 189.4, p = 0.0001, \text{partial eta-squared} = 0.945 \) measures displayed a higher ability to differentiate between the three breathing patterns than the RIP%RC \( (2.16) = 12.89, p = 0.0001, \text{partial eta-squared} = 0.617 \) measure. A possible explanation for this is that the Life Shirt only measures horizontal rib cage expansion, whereas the MARM measures both horizontal and vertical expansion, and may therefore be better suited to specifically assessing vertical ribcage motion than RIP.

While it may be that the MARM is better suited to assessing vertical ribcage expansion, it can be argued, as acknowledged by Courtney et al. (2008), that observer bias may affect the results gained in terms of the visual information gathered by the examiner seeing the participant’s chest movement. In contrast, as RIP is collected electronically this bias is not present. Additionally, the inclusion criteria for the “experienced” breathers was not clear and their ability to accurately reproduce the different breathing patterns can be questioned. Whilst the small amount of variation between participants for all parameters in each condition might suggest that participants could accurately reproduce the breathing patterns being assessed, few data exist to compare these simulated conditions with the range of breathing pattern disorders exhibited clinically.

In another study by Courtney, Cohen et al. (2009), the MARM was compared to the Hi-Lo, which is another manual breathing assessment technique. The aim of this study was to examine the relationship between practitioner’s performance in the use of MARM and Hi-Lo. A secondary aim was to
establish the relationship between experience and ability. This was done by comparing the ability of students and practitioners to perform the assessments.

A total of 56 osteopaths (n = 29) and osteopathic students (n = 27) were involved in this study in which they performed both assessments on each other. All participants attended a two-hour training session in which they were how to perform both the MARM and Hi-Lo assessments and how to simulate abnormal breathing patterns. Participants were individually assigned random combinations of thoracic, abdominal or paradoxical breathing (Hi-Lo only) which were then assessed by their partner and vice versa. All participants were also surveyed on their confidence, perceived ease of use and intended future use of each technique.

No significant difference was found in assessment performance across the three simulated breathing styles, thoracic, abdominal or paradoxical, using MARM either for the sample as a whole, or for practitioners or students separately (Table 2). This was not the case for the Hi-Lo. Across the three breathing styles, performance on paradoxical breathing (66% correct) was inferior to both abdominal breathing (94% correct) and thoracic breathing (96% correct). There was no significant difference between students’ performance of both the MARM and Hi-Lo. However, there was a modest difference for practitioners, where their performance of the Hi-Lo was superior to that of the MARM. Both techniques were able to identify thoracic breathing with agreement in scores not being moderated by experience. Performance using the MARM was significantly correlated with perceived ease of use ($r_t = .31, p = .018$), confidence in use of the technique ($r_t = .28, p = .028$), and intention to use the technique in future ($r_t = .43, p = .001$).

Table 2: Performance on specific MARM and Hi-Lo measures (Courtney et al., 2009).

<table>
<thead>
<tr>
<th>Measure</th>
<th>Students</th>
<th>Practitioners</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% correct</td>
<td>% correct</td>
<td>% correct</td>
</tr>
<tr>
<td>MARM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thoracic</td>
<td>82 (31/38)</td>
<td>88 (36/41)</td>
<td>85 (67/79)</td>
</tr>
<tr>
<td>Abdominal</td>
<td>87 (40/46)</td>
<td>78 (29/37)</td>
<td>83 (69/83)</td>
</tr>
<tr>
<td>Hi-Lo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thoracic</td>
<td>94 (32/34)</td>
<td>97 (32/33)</td>
<td>96 (64/67)</td>
</tr>
<tr>
<td>Abdominal</td>
<td>93 (26/28)</td>
<td>96 (26/27)</td>
<td>95 (52/55)</td>
</tr>
<tr>
<td>Paradoxical</td>
<td>68 (13/19)</td>
<td>78 (14/18)</td>
<td>73 (27/37)</td>
</tr>
</tbody>
</table>

While examiners were able to distinguish between simulated thoracic and abdominal breathing, but not paradoxical breathing using the MARM, it is difficult to evaluate the clinical applicability of these
results. The lack of a reference measure makes establishing how meaningful a correlation between these two measures demanding.

In general, it is difficult to know the validity of the MARM in the clinical context given that breathing patterns in both reviewed studies employed simulated breathing (Courtney et al., 2009, 2008). The measures of reliability may have been inflated by inadvertent cues presented to the “practitioner” by the “patient”. The information provided by a simulated dysfunctional breathing pattern may differ from a dysfunctional breathing pattern in the clinical setting. For example, trunk or upper rib cage involvement may be more exaggerated in a simulated pattern. Another notable limitation arising from the use of simulated breathing in these studies was the lack of assessment to determine whether breathing styles were being consistently performed according to instruction. Thus, it is possible that some of the issues surrounding the perceived accuracy or inaccuracy of the assessments may be due to the breather rather than the examiner. Courtney et al., (2009), asked participants to exclude themselves if they were unable to modify their breathing pattern, but did not report if participant’s ability to judge their own performance was assessed.

In contrast to the good degree of reliability claimed by authors of previous studies of MARM measures, a recent unpublished study by Ludwig (2013) showed poor reliability for all measures of MARM, worse for inter-rater (ICC range = -0.18 to 0.36) than intra-rater (ICC range = -.051 to 0.92) (Ludwig, 2013). The main differences in this study, compared to the two Courtney et al. studies, (2008; 2009) were that the “patients” for this study had been recruited from multiple clinical settings and were not simulating their breathing patterns. Additionally, Ludwig (2013) calculated reliability of the individual MARM measures with each patient as an independent observation, rather than by pooling multiple measures in the same patients undertaken in different situations. This methodology examines the reliability of MARM based variables (i.e. Area of breathing, balance and percentage rib cage motion), rather than intra-examiner agreement in detecting simulated breathing styles, or examiner accuracy in relation to the intended breathing style of the patient.

5 Conclusion and research question
This literature review has revealed that DB is insufficiently characterised and there is a need for a clinically useful tool for its diagnosis, especially given the number of symptoms that can be attributed to it. At present diagnosis is made using a variety of diagnostic tools. However, it can be argued that their use in isolation may not provide sufficient information to diagnose DB (Courtney, Greenwood, et al., 2011). Accuracy of diagnosis would be improved with specific characterisation of DB and an associated guideline for examination that would inform assessment, identification, treatment and management of the condition (Courtney et al., 2009). It is possible that the multi-systemic presentation of DB has hindered the development of a standardised diagnostic approach. While this may all be true, it is important to consider the clinical utility of the diagnostic tools developed. Given
the apparent lack of information around what palpation-based assessment techniques are being applied clinically, involving practitioners in a dialogue about their assessment techniques is an important developmental step. Therefore, the aims of the investigation reported in the next section of the thesis were to (1) develop a guideline of a palpation-based assessment of breathing motion; (2) and develop a notation format for the guideline that is more clinically reliable and valid.
References


Physiology, (29), 118-121. https://doi.org/10.1046/j.1440-1681.2002.03611.x


Section II: Manuscript

The manuscript presented in this section follows the Instruction to Authors for the *International Journal of Osteopathic Medicine* [see https://goo.gl/heDbRn]. The manuscript is presented using the journal’s “Your Paper Your Way” policy in which referencing, and formatting is at the authors’ discretion. Also, for the purposes of the thesis, the thesis Appendices are referenced within the manuscript in square brackets.
1 Introduction

Dysfunctional breathing (DB) is a frequently used term to describe disturbances in breathing function that impact on a person's health (1–3). Dysfunctional breathing is an umbrella term encompassing all breathing pattern disorders, including hyperventilation syndrome (HVS). Due to the dynamic and multifactorial qualities of DB, a precise definition is difficult, and moreover, there is no gold-standard for its identification (1,4,5). However, Barker and Everard's recent definition (5) of DB as “an alteration in the normal biomechanical patterns of breathing that result in intermittent or chronic symptoms which may be respiratory and/or non-respiratory” appears to be the most comprehensive and coherent definition to date. DB has been used to describe a range of chronic or intermittent signs and symptoms arising from abnormal biomechanical, biochemical or psychological origins that result in inappropriately altered breathing patterns (1,5,6). Symptoms associated with DB include, but are not limited to, dyspnoea, deep sighing, chest pain and tightness, frequent yawning, breathlessness during exercise, dizziness, tremor, fatigue and paraesthesia (7–9). Estimates of the prevalence of DB in the general population range from 5% to 11% (3,6), but may be higher in adults who also suffer from diagnosed asthma (20%) and up to 83% of those with anxiety (10,11). Clinically, DB can result in significant patient morbidity and is considered an important factor in the presentation of many acute and chronic systemic conditions (8).

The lack of consensus surrounding definition of DB, and the lack of clarity relating to aetiology and diagnosis may be a result of the apparent multisystemic characteristics of DB (5). This lack of clarity may negative impact on clinicians’ perceptual model of the condition (5), making diagnosis and management of the condition challenging. As such, diagnosis may not occur or may take a long time, with the patient undergoing multiple inconclusive investigations under different specialisations (8). Ambiguity surrounding the diagnosis of DB may delay access to appropriate treatment and also places them at risk of adverse effects of misdiagnosis and inappropriate treatment (5).

There are a wide variety of breathing assessment techniques that explore the psychological, biochemical and biomechanical aspects of breathing (12). Psychological aspects of breathing and breathing symptoms are assessed using questionnaires (1). Biochemical and physiological aspects are generally assessed using instrument-based measures (13). Finally, the biomechanical aspects of breathing can be assessed in two ways; either instrument-based assessment (14), or palpatory assessment. The two main palpatory assessments described to date are the Manual Assessment of Respiratory Motion (MARM) and the Hi-Lo.

The MARM procedure can be used to clinically estimate breathing rate, regularity, and the relative distribution of motion between the upper rib cage, and the lower rib cage and abdomen (14). The notation format of the MARM allows the practitioner to derive a numerical value that corresponds to
the degree of expansion, location and balance of a patient’s breathing (1), as well as creating a two-dimensional interpretation of a three-dimensional process (14).

A reliability study completed by Courtney et al. (15) suggested that the MARM is a reliable and valid tool to assess breathing, as well as being user friendly and cost effective. Additionally, a good level of inter-rater agreement for the MARM has been demonstrated by a study evaluating its utility (14). However, both of these studies utilised simulated breathing patterns which may provide the examiner with information, visual or palpatory, that is markedly different to those with a dysfunctional breathing pattern. Moreover, it appears that the correlational analyses reported by Courtney et al (14) arose from pooling measurements taken for all the different breathing and posture combinations, creating heterogeneous test-retest variables, from which spurious correlations can arise (16). A study by Ludwig (17) contrasts with the reliability findings of previous studies (14,13,15). Ludwig assessed the reliability of the MARM in a sample of people with known breathing dysfunction. The interrater and intra-rater reliability was below the level of clinically accepted reliability; however, raters were more consistent within themselves (intra-rater) than with others (inter-rater). Additionally, it was not clear if the poor reliability was attributable to the raters or to changes in the breathing patterns of the participants. Anecdotal evidence from this study suggested that practitioners had difficulty notating and interpreting the notation format of the MARM.

In addition to the MARM, the Hi-Lo can be used to manually assess breathing by examining the dominance and co-ordination of upper chest to lower chest and abdominal motion during the ventilatory cycle (15). The Hi-Lo is also useful for noting paradoxical breathing (1). Two previous studies have investigated the utility of the Hi-Lo (13,15), with one of these also investigating its validity using simulated breathing patterns (15). While moderated by experience (students vs. practitioners), the Hi-Lo appears to be reasonably accurate in detecting paradoxical breathing and would be most useful for the assessment of gross asynchrony of motion of thoracic and abdominal compartments during breathing (13,15).

At present there is no standardised clinical assessment for breathing and any associated dysfunction. This makes it difficult for practitioners to ensure that they have sufficiently assessed the palpable motion features of breathing to ensure dysfunction would be identified if present. As an assessment tool, palpation of the motion of breathing in the clinical setting offers an efficient and cost-effective option when compared to instrumented sensors more appropriate for laboratory research. Palpation offers osteopaths and other manual and manipulative practitioners a minimally invasive assessment approach and provides the examiner with a large range of information to inform treatment and management. As such, it would be useful to have a set of guidelines as to what constitutes sufficient palpatory motion assessment of breathing for clinicians in the identification and treatment of dysfunctional breathing. To date, there are no published reports describing what might constitute
appropriate palpation-based assessment of breathing. Therefore, the aims of this study were to: 1) develop a guideline of a manual assessment of breathing motion; and 2) develop a notation format for the guideline that is more clinically reliable and valid, and easier to use and interpret.

2 Methods
2.1 Design and Ethics
A modified Nominal Group Technique (NGT) process was employed for two 2-hour focus groups to guide discussion around the manual assessment of breathing and subsequent notation in clinical records. Established NGT designs consist of 5 main components: Introduction and explanation; Silent generation of ideas; Sharing ideas; Group discussion; and Ranking (18). The NGT was an appropriate method as it is designed as a structured procedure for gathering information from groups of people who have insight into a particular area of interest (19). Additionally, a strength of NGT design compared to other forms of focus group is avoidance of problems associated with interacting groups such as dominant personalities and the ‘focusing effect’ (19). Here, the NGT was modified from standard NGT design by not completing the second ranking round. Both meetings were conducted in a large room with participants arranged in a large semi-circular configuration to facilitate communication. This study is reported according to the COREQ guidelines (20) [Appendix E]. The study was approved by the Unitec Research Ethics Committee (Approval number: 2016-1072) [Appendix F].

2.2 Participants and Recruitment
Participants were osteopaths and physiotherapy practitioners with an established interest in breathing assessment and management. Potential participants were initially identified from existing networks of the authors, including registration at past seminars and workshops on the topic of breathing convened by our research group. Snowball sampling, a method that uses sample members to provide names of other potential sample members, was used to identify additional participants (21). An effort was made to recruit a diverse group of participants including those who performed manual and/or non-manual methods of breathing assessment.

For inclusion, participants were required to 1) have at least 5 years clinical work experience or, less than 5 years clinical work experience coupled with specialist research in manual breathing assessment practices; 2) hold a current annual practicing certificate from the appropriate regulatory authority; and 3) express a special interest in dysfunctional breathing and its associated assessment and management. There were no exclusion criteria. The aim was to recruit at least 9 participants, the minimum number suggested for information gathering in this context (22). Participants who expressed an interest in the study and met the eligibility criteria were provided with a participant information sheet and gave written informed consent.
2.3 The Nominal Group Technique Procedure

Researchers facilitated each meeting, with Meeting 1 facilitated by RM and KP, and Meeting 2 by CB and KP. Only participants and researchers were present at the meetings. At the time of data collection, RM was a registered osteopath and health science researcher, CB was a health science researcher, and KP was a post-graduate student of osteopathy. In line with established NGT protocol (18,19), the facilitators initially introduced themselves and outlined their interests in the topic and the aims for the meeting. Approximately 10 minutes were assigned to generate ideas in response to each of several key guiding questions posed by the researchers. Idea generation was undertaken individually with no communication between participants (18). After 10 minutes, each participant was invited to share their ideas in a brief verbal presentation, and researchers facilitated the group to ensure every participant had the opportunity to speak. The expressed ideas were recorded and labelled as ‘items’ by facilitators using both audio recording and field-notes until no new items were generated (19). Transcripts of the voice recordings were not made given the large volume of quantitative data that was gathered. Group discussion followed, during which the items were clarified and expanded as necessary. Facilitators were mindful of ensuring equitable participation throughout all discussion and avoided voicing judgement or negative criticism of any item (23). The final stages of individual ranking were completed for selected questions that related to the assessment and notation of assessment findings to identify the items considered most important by the group (19). For each of the ranked questions, each participant assigned a rank order to each individual item proposed in order of importance, giving the highest number to the item they considered the most important. Items that were given the same score were scored using the mean for positions taken (e.g. if two items were ranked as a ‘2’ and no item was ranked as ‘3’, the equal scores were calculated as 2.5). Ranking score was calculated as a total for each item from all participants. The voting stage of the NGT process was deemed unnecessary for this research project because all bar one question, which had 12 items, had less than 10 items generated and the ranking process itself produced clear consensus on the item(s) considered most important for all questions.

The appropriate number of NGT meetings is dependent on the nature of the question (18). Given that the questions posed covered both the manual assessment of breathing and notation of manual breathing assessment, two meetings were required to provide participants with sufficient time to fully discuss both topics. One question was posed and ranked during Meeting 1; “What observations and/or palpations do you make/use or consider important when assessing breathing in the clinical setting?” The items generated in response to this question were collated, and ranking scores calculated following the conclusion of Meeting 1. Subsequently, an email was sent to participants following the collation of scores from Meeting 1 asking them to evaluate the highest ranking three combinations of positions and handholds used during palpation in their practice, and to evaluate different instructional ‘cues’ and notation formats for their findings over the next three weeks. The format, questions and
focus of Meeting 2 were planned following an evaluation of the implementation and results from the first meeting. Evaluation and planning for Meeting 2 was completed independently by two researchers (KP and CB) and then discussed at several points over a three-week period until agreement about the protocol and questions for Meeting 2 was reached. Copies of the questions intended to be discussed during Meeting 1 were emailed to participants. Similarly, copies of the questions intended to be discussed at Meeting 2, as well as a summary of the results from Meeting 1 were emailed to participants. Both emails were sent a day prior to each meeting to allow preparation.

2.2 Meeting Plans

2.2.1 Pilot test

Prior to commencing data collection, draft questions for Meeting 1 were pilot tested on a convenience sample of 5 postgraduate osteopathy students. Results from the pilot test were used to further refine the question syntax.

2.2.2 Meeting 1

The aim of Meeting 1 was to identify what manual assessments of breathing participants routinely use in practice. Participants were asked to describe how they currently assessed breathing and were provided with the following question to guide item generation: “What observations and/or palpations do you make/use or consider important, when assessing breathing in the clinical setting?” All responses were then ranked by participants to find which individual position and handhold used during palpation was collectively considered most important.

All researchers (KP, CB, RM) agreed that a selection of a few handholds and positions could be identified from the results of Meeting 1. The combinations of these, [shown in Appendix G], were emailed to participants for them to trial over the following 3 weeks. Participants were also asked to experiment with using both “cued” and “un-cued” palpation in their clinical practice and to make notes on their palpatory impression with respect to the given positions and handholds.

2.2.3 Meeting 2

Meeting 2 addressed 4 key questions intended to guide the generation of a notation format for the manual assessment of breathing and the findings of this assessment. The first question posed was: “What combinations of positions and handholds did you find most effective? Are there any others you feel are essential and should be included?”. Secondly, participants were asked: “What, if any, cues did you give to your patient?” and asked to reflect on the previous 3 weeks. ‘Cues’ were any instruction or condition given to a patient with respect to their breathing, e.g. ‘Take a deep breath’ or ‘breathe gently’. The items relating to the first two questions were ranked by participants in terms of importance. Thirdly, participants were asked: “What were the key findings of your assessment?” and to make note of what findings they assessed during manual assessment of breathing. The final
question was: “How did you record/ notate these findings?” Although discussion and collation of items related to this question took place during Meeting 2, ranking forms were emailed to participants after the meeting due to insufficient time during the session to complete a ranking.

3 Results
Of the 9 participants (5 females, 4 males) recruited, 3 were physiotherapists specialising in breathing therapy and 6 were osteopaths. With the exception of one participant who was unable to attend the second meeting, all others attended both NGT meetings. Therefore, the second meeting fell below the recommended number of 9 participants as outlined in the methods.

3.1 Meeting 1

3.1.1 Question 1: “What observations and/or palpations do you make/use or consider important when assessing breathing in the clinical setting?”
Responses to this question initially led to a wide-ranging discussion around both palpation based and instrumented assessment (e.g. capnography). Subsequently, the scope of discussion was narrowed by the facilitator (RM) to consider only manual assessment and participants were asked to consider what handhold(s) and in what position(s) they would consider essential for a new graduate to complete to ensure that they had sufficiently assessed structure and mechanics relevant to breathing. The participants were asked to consider the question from “the perspective of new graduates” because their wide expertise and differing approaches and techniques made it difficult to generalise their processes in the clinical setting. The items given and discussed were then ranked individually.

3.1.1.1 Practitioner Hand Holds
Table 1 shows the favoured hand holds for manual assessment of breathing were (in order): Hi-Lo; Upper ribs/Shoulder Girdle/Clavicle/Clavipectoral fascia; Lower Ribs (lateral). Given the ranked importance and similarity between Hi-Lo and both Abdomen (ranked 4th) and Upper Chest (ranked 5th=), the latter were considered to be redundant. Lower Ribs – lateral (ranked 3rd) and Mid Thoracic – lateral (ranked 5th=) were considered to be sufficiently similar that only the higher ranked of the two was necessary. A substantial difference in score from the 5th to the 7th position was noted.
Table 1: Ranked importance of hand positions

<table>
<thead>
<tr>
<th>GLOBAL - Hand Position</th>
<th>Total</th>
<th>Final Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hi-Lo</td>
<td>70</td>
<td>1</td>
</tr>
<tr>
<td>Upper ribs/shoulder girdle/clavicle/clavipectoral fascia</td>
<td>63</td>
<td>2</td>
</tr>
<tr>
<td>Lower ribs - lateral</td>
<td>53</td>
<td>3</td>
</tr>
<tr>
<td>Abdomen</td>
<td>52</td>
<td>4</td>
</tr>
<tr>
<td>Upper chest</td>
<td>49</td>
<td>5=</td>
</tr>
<tr>
<td>Mid thoracic - lateral</td>
<td>49</td>
<td>5=</td>
</tr>
<tr>
<td>T spine</td>
<td>33</td>
<td>7</td>
</tr>
<tr>
<td>C spine</td>
<td>22</td>
<td>8</td>
</tr>
<tr>
<td>L spine</td>
<td>14</td>
<td>9</td>
</tr>
</tbody>
</table>

Notes: C = Cervical; T = Thoracic; L = Lumbar

3.1.1.2 Patient Position

Table 2 shows the highest ranked patient position was Seated. This was followed by Standing (ranked 2nd) and Supine (ranked 3rd). The other ranked items were considered less important with a substantial drop in the total importance score between 3rd and 4th position.

Table 2: Ranked importance of patient position

<table>
<thead>
<tr>
<th>PATIENT POSITION</th>
<th>Total</th>
<th>Final Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seated</td>
<td>69</td>
<td>1</td>
</tr>
<tr>
<td>Standing</td>
<td>56</td>
<td>2</td>
</tr>
<tr>
<td>Supine</td>
<td>52</td>
<td>3</td>
</tr>
<tr>
<td>Patient’s Sleeping position</td>
<td>42</td>
<td>4</td>
</tr>
<tr>
<td>Knees bent supine</td>
<td>32</td>
<td>5</td>
</tr>
<tr>
<td>Semi-reclined</td>
<td>27</td>
<td>6=</td>
</tr>
<tr>
<td>Side-lying</td>
<td>27</td>
<td>6=</td>
</tr>
<tr>
<td>Prone</td>
<td>19</td>
<td>8</td>
</tr>
</tbody>
</table>

During Meeting 1 there was considerable discussion about “cueing”, (the verbal instructions given, or condition (e.g. patient position or depth of breath) applied to the patient prior to assessment). This
concept had not been considered *a priori* by the researchers. Cues might relate to the depth of breath or state of breathing (e.g. relaxed or stressed). It was noted that some of the best assessment techniques may be applied without patient awareness that their breathing is being assessed. This item was acknowledged to be more challenging in a physical assessment, especially if breathing was the principal reason for consultation. This topic was not ranked during Meeting 1. However, participants were asked to trial both “cued” and “un-cued” palpation in their clinical practice.

There was a small portion of time allocated to listing the different findings or presentations that could arise from a manual assessment. However, there was insufficient time to focus on this specific aspect of manual breathing assessment. Two researchers (CJB and KP) acknowledged that this was an important discussion that would need to be addressed during Meeting 2. However, because assessment findings are patient and situation specific, following Meeting 1 and prior to Meeting 2 they had discussed the ranking of these findings and concluded that it would not add value to the study to rank these. It was decided instead to group the findings discussed in Meeting 2 and to generate a list that could be considered by participants during manual breathing assessment.

3.2 Meeting 2

3.2.1 Question 1: “What combinations of positions and handholds did you find most effective? Are there any others you feel are essential and should be included?”

Table 3 shows the rankings for the combinations of patient position and handholds. These arose from Meeting 1 rankings of participant handhold and patient position. The combinations were closely grouped for the first 9 combinations with the 10th-12th positions being considered less important. *Seated Upper ribs- over shoulder to clavicle* was the highest ranked handhold and patient position combination. This was followed by *Supine* and *Seated Hi-Lo* which were separated by 0.5 points in total ranking score. There was not as great a difference between 3rd and 4th position as seen in some of the earlier results with 4th position only being 2 points below that of 3rd.
3.2.2 Question 2: “What, if any, cues did you give to your patients?”

“Un-cued” breathing could not be further sub-divided, however, there were multiple items for “cued” breathing. Following individual idea generation and group discussion, 9 items were identified and ranked for “cued” and “un-cued” assessment. The results displayed in Table 4 show that *Unaware* (*patient distracted*) was considered the most important cue followed by *Gentle/Calming/Tidal 2nd* and *Deep/Big/Full 3rd*. Paced breathing and self-awareness of breathing were considered least important.

Though grouped together, it was noted that an instruction to produce a normal breath may result in a deeper breath or other non-normal state. Similarly, a gentle/calming state may not be the same thing as normal tidal breathing.

<table>
<thead>
<tr>
<th>POSITION/HAND HOLD COMBINATIONS</th>
<th>Total</th>
<th>Final Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seated-Upper ribs-over shoulder to clavicle</td>
<td>74</td>
<td>1</td>
</tr>
<tr>
<td>Supine-Hi-Lo</td>
<td>67.5</td>
<td>2</td>
</tr>
<tr>
<td>Seated-Hi-Lo</td>
<td>67</td>
<td>3</td>
</tr>
<tr>
<td>Standing-Hi-Lo</td>
<td>65</td>
<td>4</td>
</tr>
<tr>
<td>Standing Upper ribs-over shoulder to clavicle</td>
<td>59.5</td>
<td>5</td>
</tr>
<tr>
<td>Seated-Lower ribs lateral</td>
<td>58.5</td>
<td>6</td>
</tr>
<tr>
<td>Standing-Lower ribs lateral</td>
<td>57</td>
<td>7</td>
</tr>
<tr>
<td>Supine-Upper ribs-over shoulder to clavicle</td>
<td>55</td>
<td>8</td>
</tr>
<tr>
<td>Supine-Lower ribs lateral</td>
<td>52.5</td>
<td>9</td>
</tr>
<tr>
<td>Side-lying-Hi-Lo</td>
<td>24</td>
<td>10</td>
</tr>
<tr>
<td>Side-lying-Upper ribs-over shoulder to clavicle</td>
<td>23</td>
<td>11</td>
</tr>
<tr>
<td>Side-lying-Lower ribs lateral</td>
<td>21</td>
<td>12</td>
</tr>
</tbody>
</table>
### Table 4: Ranked importance of “cues”

<table>
<thead>
<tr>
<th>CUEING</th>
<th>Total</th>
<th>Final Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unaware (distracting patient with talking)</td>
<td>51.5</td>
<td>1</td>
</tr>
<tr>
<td>Gentle/Calming/Tidal</td>
<td>51</td>
<td>2</td>
</tr>
<tr>
<td>Deep/Full/Big</td>
<td>47.5</td>
<td>3</td>
</tr>
<tr>
<td>Breath into body part or into my hands</td>
<td>44.5</td>
<td>4</td>
</tr>
<tr>
<td>Un-cued</td>
<td>43</td>
<td>5</td>
</tr>
<tr>
<td>Nose versus mouth breathing</td>
<td>39</td>
<td>6</td>
</tr>
<tr>
<td>Default state</td>
<td>33</td>
<td>7</td>
</tr>
<tr>
<td>Paced breathing</td>
<td>26</td>
<td>8</td>
</tr>
<tr>
<td>Self-awareness: How does it feel if…?</td>
<td>24.5</td>
<td>9</td>
</tr>
</tbody>
</table>

#### 3.2.3 Question 3: “What were the key findings of your assessment?”

Many ideas were generated in response to this question. It was deemed that observations of any of these could be important if positive in a patient and were patient and situation specific. As previously decided by two facilitators (CB and KP), these findings were not subject to voting but were listed and later grouped into four broad categories as shown in Table 5.
### Table 5: Grouped list of findings of manual breathing assessment

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilation - Movement</td>
<td>Balance: Side to side/ Symmetry-Asymmetry</td>
</tr>
<tr>
<td></td>
<td>Balance: Upper to Lower</td>
</tr>
<tr>
<td></td>
<td>Coherence/ Flow/ Rhythm/ Inspiratory-Expiratory Ratio</td>
</tr>
<tr>
<td></td>
<td>Paradoxical Breathing</td>
</tr>
<tr>
<td></td>
<td>Effort Required (effortful vs lack of)</td>
</tr>
<tr>
<td></td>
<td>Degree of Movement</td>
</tr>
<tr>
<td>Palpation</td>
<td>Uniformity</td>
</tr>
<tr>
<td></td>
<td>Compliance/ Resistance</td>
</tr>
<tr>
<td></td>
<td>Tenderness/ Hypertonicity</td>
</tr>
<tr>
<td></td>
<td>Individual Joint Findings/ Rib Movements</td>
</tr>
<tr>
<td>Signs and Symptoms</td>
<td>Pain</td>
</tr>
<tr>
<td></td>
<td>Pallor</td>
</tr>
<tr>
<td>Behavioural</td>
<td>Hyperresponsiveness/ Hypervigilance/ Hypersensitivity</td>
</tr>
<tr>
<td></td>
<td>Guardedness/ Defensiveness/ Protectiveness</td>
</tr>
<tr>
<td></td>
<td>Fighting Breathing/ Strained Breath/ Withdrawal/ Traumatic - Fear -</td>
</tr>
<tr>
<td></td>
<td>Avoidance of breath</td>
</tr>
</tbody>
</table>

#### 3.2.4 Question 4: “How did you record/ notate these findings?”

Items were collated to form a notation format which encompassed the participants’ responses to the questions posed during Meeting 2 and the positions and handholds that were deemed most important by the group in Meeting 1. This question generated many items. The items converged towards a series of dichotomous observations that could be scaled along a continuum (like a VAS scale).

Results shown in table six highlighted one clear favourite notation aid, which was the Hi-Lo scale. Six of the eight respondents ranked this as the most important and one of the other two ranked it highly. Two other scales: effortful versus no effort and marking inspiration versus expiration time scored next highest, but the former had one and the latter two participants who deemed it of low importance. Most of the other notation elements had at least one protagonist who ranked it highly. Of the non-scale notation elements, the breathing trace (spirometer or “ECG” like sketch) was the most popular.
An additional question about interpretation of markings placed on the scale showed very mixed results. There was sufficient disagreement about what a mark to one end of the scale meant to suggest that this system could be very likely to cause confusion. One participant noted, as a reminder of discussion at the meeting, that using greater than “>” or less than “<” signs on the scales, instead of a mark, might help to clarify meaning.

Table 6: Ranked importance notation format components

<table>
<thead>
<tr>
<th>NOTATIONS</th>
<th>Total</th>
<th>Final Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hi / Lo</td>
<td>84</td>
<td>1</td>
</tr>
<tr>
<td>Effortful / No Effort</td>
<td>64</td>
<td>2</td>
</tr>
<tr>
<td>Inspiration / Expiration</td>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td>Left / Right</td>
<td>53</td>
<td>4</td>
</tr>
<tr>
<td>Breathing trace (like spirometry or &quot;ECG&quot; trace)</td>
<td>51</td>
<td>5</td>
</tr>
<tr>
<td>Nose / Mouth</td>
<td>50</td>
<td>6</td>
</tr>
<tr>
<td>2º Tight / 2º Not Tight</td>
<td>48.5</td>
<td>7</td>
</tr>
<tr>
<td>1º Tight / 1º Not Tight</td>
<td>48</td>
<td>8</td>
</tr>
<tr>
<td>Quiet / Noisy</td>
<td>45</td>
<td>9</td>
</tr>
<tr>
<td>Additional comments (e.g. specific joints/muscles)</td>
<td>42.5</td>
<td>10</td>
</tr>
<tr>
<td>Stick figures of patient positions for comments/notes</td>
<td>41.5</td>
<td>11</td>
</tr>
<tr>
<td>Lung stick diagram for comments/notes/arrows/shading</td>
<td>39.5</td>
<td>12</td>
</tr>
</tbody>
</table>

Notes: 1º = Primary respiratory muscles; 2º = Secondary respiratory muscles
Table 7: Marking of scale for manual assessment of breathing notation format

<table>
<thead>
<tr>
<th>Additional Question (on how scale is marked):</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Looking at the marked scale to the left, this means…</td>
<td></td>
</tr>
</tbody>
</table>

Indicate your preference below:

- a high degree of **upper chest** relative to lower chest/abdominal breathing 5
- a high degree of **lower chest/abdominal** relative to upper chest breathing 4

4 Discussion
The aim of this study was to investigate what manual assessments of breathing were being employed (if any) by a sample of clinicians with a special interest in DB, how important these are perceived to be, and how the findings of these assessments are notated. The main finding of this study was that participants reported using a range of manual palpatory techniques to manually assess breathing, with some being considered more important than others. There were two clear preferences for hand position, three clear preferences for patient position, and three clear preferences for the combination of hand position and patient position. A notation format involving scaled comparative descriptors was the most popular for recording the findings of the manual assessment of breathing; however, disagreement was present as to how this scale should be marked.

Although a range of techniques have been described for the manual assessment of breathing (6,15), the MARM has the largest body of associated research. However, this is still limited to a few studies (1,14,13,15). While these studies suggest that the MARM is a clinically valid and reliable tool, these have originated from a small number of authors. It is difficult to determine the clinical validity and reliability of the MARM from these results, as independent replication has not taken place (24). Interestingly, anecdotal feedback from participants in this study suggests the MARM may not be in widespread clinical use. For example, although there was a reasonable level of awareness about the MARM amongst the assembled participants, none were routinely using the MARM or its notation in the clinical setting. This limited clinical use suggests that development around other approaches to the manual assessment of breathing in the clinical setting would be useful.

The findings related to practitioner handhold were considered in two groups. The first group contained handholds that assessed the thoracic cage, with the only exception to this being ‘Abdomen’.
This is unsurprising given that the thoracic cage is the primary location in which breathing motion occurs. We had anticipated that the thoracic spine would be ranked more highly. It is possible the handhold rankings reflect simplicity or ease for both the practitioner and the patient.

Perhaps unsurprisingly, the top ranked patient positions were, in order, ‘Seated’, ‘Standing’ and ‘Supine’. These reflect standard positions in routine clinical and physical examination (6), and also reflect positions of daily living. ‘Sleeping position’, however, was not expected to be ranked so highly (4th place) and was considered more important than ‘Knees bent supine’ (5th place), (Table 2). The authors are unaware of any previous mention of manual assessment of breathing in the patient’s sleeping position. It is possible this ranking reflects recent growing awareness of sleep and its impact on health (25) and may not be particularly generalisable to the clinical setting. Additionally, given that involuntary shifts of body position occur approximately every 20 minutes during deep sleep (26), the position the patient falls asleep in is highly unlikely to reflect their actual sleeping position and thus breathing assessment in ‘sleep position’ may be of limited value.

The results of the ranking of importance of the handhold and patient position combinations can be divided into three groups. Within the first group the most highly ranked item was ‘Seated-Upper ribs (over shoulder to clavicle)’. The three items were all combinations of patient position with the Hi-Lo and were closely ranked. The next group consisted primarily of combinations in which handholds were assessing the ‘Upper ribs (over the shoulder to clavicle)’ or the ‘Lower ribs lateral’. There was a notable difference in ranked importance scores between groups two and three (see Table 3) in which the position aspect of the combination was side-lying. This is unsurprising, as humans do not spend a lot of time in this position, so to assess breathing manually in this position may reflect practitioner convenience for palpation than being representative of common body position. Of note is that the individual rankings of patient position and practitioner handholds appear to be represented in the most popular combinations.

“Cueing” was, through discussion, loosely defined as the verbal instructions given, or condition (e.g. patient position or depth of breath) applied to the patient prior to manually assessing their breathing. This was a concept that emerged during the course of Meeting 1 and was an unanticipated topic of discussion that had not been considered a priori by the researchers. There was a lot of discussion as to the benefit of assessing the patient’s breathing when they were unaware as the practitioners recognised that if a patient’s awareness was brought to their breathing, their breathing itself would change. While not specifically named during the meetings, this is recognisable as the Hawthorne effect in which the mere awareness of being under observation can alter the way in which a person behaves (27). The widespread social psychological explanations for the mechanism of the Hawthorne effect are twofold: (i) awareness of being observed engenders beliefs about observer expectations; and (ii) conformity and social desirability considerations then lead to behaviour change in line with these
expectations (28). The Hawthorne effect is distinct from an incentive effect in which behaviour alters because of an expected penalty or reward for the altered behaviour (29). While the change associated with the Hawthorne effect is only temporary and return to normal behaviour will eventually occur (30), it is interesting that practitioners appear to inherently try and avoid or minimise this clinical phenomenon altogether.

Given that the aim of the study was to establish, *de novo*, a manual assessment of breathing there are no directly comparable studies. However, the popularity of the Hi-Lo as an assessment technique by the assembled practitioners, contrasts with the results of Courtney et al. (15). They found in a group of students and professionals questioned about intended future use of both the MARM and the Hi-Lo, the more positive impressions were in favour of the MARM (15). This more positive view of the MARM and higher intended future use when compared to the Hi-Lo contrasts with the results of the current study in which the assembled practitioners ranked the Hi-Lo as the most important hand position with which to manually assess breathing. Additionally, anecdotal feedback received during the background review at Meeting 1 was that although there was awareness of the MARM there was limited to no use amongst participants.

Participants demonstrated a clear preference for the Hi-Lo notation format and also assigned lower rankings of importance for the other notation forms. As there was no clear majority in preference for marking the scale of the developed notation format, it is reasonable to assume that if used as currently designed there may be variation in recording and interpretation between practitioners. One possible solution would be to provide anchoring labels, similar to the approach taken by the developers of the VAS for pain intensity (31). The VAS is a horizontal or vertical line with two anchor points, one at each extreme (32). As a clinical tool in the context of breathing assessment, diagnosis and treatment efficacy the VAS has been found to be a valid and reliable (32–34), and its further adoption as a form of notation for clinical notes should be further considered.

To the authors’ knowledge this study is the first to take a consensus-based approach in a group of practitioners with a specific interest in breathing to investigate what they consider important in the manual assessment of breathing in the clinical setting. It was important that participants were clinical practitioners in order to generate findings that could be generalised to the clinical setting and were useful in that setting. Framing the key question from the perspective of new graduates emerged during Meeting 1 and was aimed at getting all participants to approach the question from a similar angle and to generalise the responses beyond their own high-level expertise. Any practitioner of manual therapy should be able to use the items considered most important in their manual assessment of breathing regardless of the level of their clinical expertise. It is well recognised that novice and experts use different approaches to clinical reasoning (35). It was therefore important to ask participants to
express themselves and elucidate ideas or processes in a systematic way that could be readily shared with novice practitioners (36).

There are a number of limitations inherent within this study. Firstly, while 9 participants were recruited, a sample size suggested by Jones and Hunter (22) to be the minimum number of participants required for an NGT study, a larger sample may have provided a broader range of items. Having a broader range of items would have allowed closer compliance with the conventional process of NGT in which a second round of ranking occurs (19). This second ranking employs a 0 to 100 scale, with a score of 100 representing the most important item and a value between 0 and 100 on the remaining 9 (19). This is useful as it allows participants to better quantify the importance they give to each item. Here, because the majority of questions in the NGT process yielded 10 items or less, the second ranking would not have provided any further novel or important information.

Secondly, a common limitation of focus groups in general is that they can be derailed by strong personalities (19). One of the key advantages of the NGT process is that this effect is minimised. However, it is not removed completely since the individual rounds generate personal observations that are then ‘owned’ during the discussion (37). It is possible for this to create power imbalances within the group. This did not appear to be an issue in this study, but nevertheless considerable care was taken by the researchers in the conduct of the data collection to mitigate this potential limitation.

Thirdly, the lack of consensus about the marking of the scale of the developed notation format is a limitation. A third meeting would have been beneficial as it would have allowed more time for items such as an anchored VAS to be discussed and consensus to be reached. Unfortunately, it was not possible for a third meeting to be conducted as it was beyond the scope of what was proposed and consented to and was not included in the initial ethics approval.

Finally, while the results of this study identify what the participants considered to be the most important handholds, patient positions and combinations of the two for manual breathing assessment, there was no discussion about what was considered the minimum manual assessment to ensure that dysfunctional breathing would be identified if present. It would be useful for this to be assessed in future research.

Future research could also examine the reliability and validity of the highest-ranking combinations of hand-hold and position combinations in the manual assessment of breathing. Additionally, it would be useful to examine the reliability and validity of the use of a VAS scale in recording findings of manual assessment of breathing. Another possible research project could investigate the clinical implementation of both, following the establishment and validity of the developed notation and assessment techniques.
5 Conclusion
This research sought to gain insight into what manual assessments of breathing were being employed (if any) by a sample of clinicians with a special interest in DB, how important these are perceived to be, and how the findings of these assessments are notated. The main outcome of the study is a consensus-based description of what participants considered most important in the manual assessment of breathing, ranking ‘Hi-Lo’, ‘seated’ and ‘seated – upper ribs (over shoulder to clavicle)’ as the most important items in their respective categories.
6 References


Section III: Appendices
**Appendix A: The Nijmegen Questionnaire**

**Nijmegen Questionnaire**

A score of over 23 out of 64 suggest a positive diagnosis of hyperventilation syndrome.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Never</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very Often</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest pain</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Feeling tense</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blurred vision</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dizzy spells</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeling confused</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faster or deeper breathing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short of breath</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tight feelings in chest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bloated feeling in stomach</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tingling fingers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unable to breathe deeply</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stiff fingers or arms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tight feelings round mouth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold hands or feet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palpitations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeling of anxiety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Reference:

Appendix B: The Self-Evaluation of Breathing Questionnaire (SEBQ)

The Self Evaluation of Breathing Questionnaire (SEBQ): Version 2
Scoring this questionnaire: (0) never/not true at all; (1) occasionally/a bit true; (2) frequently/mostly true; and, (3) very frequently/very true
1. I get easily breathless out of proportion to my fitness
2. I notice myself breathing shallowly
3. I get short of breath reading and talking
4. I notice myself sighing
5. I notice myself yawning
6. I feel I cannot get a deep or satisfying breath
7. I notice that I am breathing irregularly
8. My breathing feels stuck or restricted
9. My rib cage feels tight and can’t expand
10. I notice that I am breathing quickly
11. I get breathless when I am anxious
12. I find myself holding my breath
13. I feel breathless in association with other physical symptoms
14. I have trouble coordinating my breathing when I am speaking
15. I can’t catch my breath
16. I feel that the air is stuffy, as if not enough air in the room
17. I get breathless even when I am resting
18. My breath feels like it does not go in all the way
19. My breath feels like it does not go out all the way
20. My breathing is heavy
21. I feel that I am breathing more

22. My breathing requires work

23. My breathing requires effort

24. I find myself breathing through my mouth during the day

25. I breathe through my mouth at night while I sleep

Reference:

Appendix C: The Manual Assessment of Respiratory Motion (MARM)

Figure 1: The MARM graphic notation

Variables Calculated From MARM Graphic Notation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of Breathing</td>
<td>Angle formed between upper line and lower line</td>
<td>Angle A B</td>
</tr>
<tr>
<td>Balance</td>
<td>Difference between angle made by horizontal axis (C) and upper line (A) and horizontal line (C) and lower line (B)</td>
<td>AC-CB</td>
</tr>
<tr>
<td>Percent rib cage motion</td>
<td>area above horizontal / total area between upper line and lower line x 100</td>
<td>AC/AB x 100</td>
</tr>
</tbody>
</table>

Reference:


Instructions from Chaitow et al. (2014)

“In performing the MARM the examiner sits behind the subject and places their hands at the posterior and lateral aspect of their rib cage. The whole hand rests firmly and comfortable so as not to restrict breathing motion. The examiner’s thumbs are approximately parallel to the spine, pointing vertically, and the hands are comfortably open with fingers spread so that the little
fingers of both hands approach a horizontal orientation. The 4th and 5th fingers reach below the lower ribs so that they can feel abdominal expansion. With this particular hand position the examiner brings their attention to the breathing motion of the whole rib cage and abdomen in the lateral, vertical and anterior/posterior directions. An assessment is then made of the extent of overall vertical motion, relative to the overall lateral motion, in order to determine whether the motion is predominantly upper rib cage, lower rib cage/abdomen or relatively balanced.” (p. 141).

Reference:

Appendix D: Consolidated criteria for reporting qualitative studies (COREQ)

Guidelines

<table>
<thead>
<tr>
<th>No.</th>
<th>Item</th>
<th>Guide questions/description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Domain 1: Research team and reflexivity</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Personal Characteristics</strong></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Interviewer/facilitator</td>
<td>Which author/s conducted the interview or focus group?</td>
</tr>
<tr>
<td>2.</td>
<td>Credentials</td>
<td>What were the researcher’s credentials? E.g. PhD, MD</td>
</tr>
<tr>
<td>3.</td>
<td>Occupation</td>
<td>What was their occupation at the time of the study?</td>
</tr>
<tr>
<td>4.</td>
<td>Gender</td>
<td>Was the researcher male or female?</td>
</tr>
<tr>
<td>5.</td>
<td>Experience and training</td>
<td>What experience or training did the researcher have?</td>
</tr>
<tr>
<td></td>
<td><strong>Relationship with participants</strong></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Relationship established</td>
<td>Was a relationship established prior to study commencement?</td>
</tr>
<tr>
<td>7.</td>
<td>Participant knowledge of the interviewer</td>
<td>What did the participants know about the researcher? E.g. personal goals, reasons for doing the research</td>
</tr>
<tr>
<td>8.</td>
<td>Interviewer characteristics</td>
<td>What characteristics were reported about the interviewer/facilitator? E.g. Bias, assumptions, reasons and interests in the research topic</td>
</tr>
<tr>
<td></td>
<td><strong>Domain 2: study design</strong></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Theoretical framework</td>
<td>What methodological orientation was stated to underpin the study? E.g. grounded theory, discourse analysis, ethnography, phenomenology, content analysis</td>
</tr>
<tr>
<td>10.</td>
<td>Methodological orientation and Theory</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Participant selection</td>
<td>How were participants selected? E.g. purposive, convenience, consecutive, snowball</td>
</tr>
<tr>
<td>12.</td>
<td>Sampling</td>
<td>How were participants approached? E.g. face-to-face, telephone, mail, email</td>
</tr>
<tr>
<td>13.</td>
<td>Sample size</td>
<td>How many participants were in the study?</td>
</tr>
<tr>
<td>14.</td>
<td>Non-participation</td>
<td>How many people refused to participate or dropped out? Reasons?</td>
</tr>
<tr>
<td></td>
<td><strong>Setting</strong></td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>Setting of data collection</td>
<td>Where was the data collected? E.g. home, clinic, workplace</td>
</tr>
<tr>
<td>16.</td>
<td>Presence of non-participants</td>
<td>Was anyone else present besides the participants and researchers?</td>
</tr>
<tr>
<td>17.</td>
<td>Data collection</td>
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Reference:
Appendix E: Consolidated criteria for reporting qualitative studies (COREQ) guidelines completed with relation to current study.

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<td><strong>Domain 2: Study design</strong></td>
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<td>How were participants approached?</td>
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<td>Sample size</td>
<td>How many participants were in the study?</td>
<td>Page 6 of manuscript, Section 3</td>
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<td>Non-participation</td>
<td>How many people refused to participate or dropped out? Reasons?</td>
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**Domain 3: Analysis and findings**

**Data analysis**

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**Reporting**

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Reference:

Appendix F: Ethics approval

Kriste Petch
51 Bluegrey Ave
Stonefields
Auckland 1072

17.11.16

Kia ora Kirstie,

Your file number for this application: 2016-1072
Title: Development of a Clinically Applicable Tool for the Manual Assessment of Breathing Biomechanics.

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: 17.11.16
Finish date: 17.11.17

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,

[Nigel Adams]
Deputy Chair, UREC

cc: Rob Moran
Cynthia Almeida
Appendix G: Email correspondence with participants prior to Meeting 2

Hi everyone,

Thank you again for coming last Wednesday’s session. We’re looking forward to the next meeting. Before then, we’d like to invite you to undertake some basic palpation during the course of your clinical work using a couple of the approaches that were discussed last week.

1. With the patient in a variety of positions including standing, sitting, and supine, please palpate for breathing-related motion using:
   a) one hand on upper chest, one hand on the abdomen (sometimes called ‘Hi-Lo’)
   b) hands over the upper shoulders and onto the clavicle

Please experiment with using both ‘cued’ and ‘uncued’ palpation. ‘Cued’ meaning you give a specific instruction to the patient about breathing – so that the patient is made conscious of their breathing, and ‘uncued’ meaning you are palpating without giving any specific instruction.

2. Make some written notes about your palpatory impressions with respect to these positions and hand holds. Please bring your notes to the next group meeting to inform discussion about what characteristics might be useful to consider when palpating for breathing motion.

Thanks,

Kirstie

Hi everyone,

Can you please also add hands on the lower rib cage (laterally) to the hand positions you try? It was missed from the previous email.

I hope you all enjoy your weekend.

Thanks,

Kirstie
Full name of author: Kirstie Ann Petch

ORCID number (Optional): ..................................................

Full title of thesis/dissertation/research project ('the work'):
The development of a palpation-based clinical assessment of breathing: A non-invasive approach

Practice Pathway: Community Development

Degree: MOst

Year of presentation: 2018

Principal Supervisor: Robert Mann

Associate Supervisor: Catherine Bacon

Permission to make open access
I agree to a digital copy of my final thesis/work being uploaded to the Unitec institutional repository and being made viewable worldwide.

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Copyright Compliance:
I confirm that I either used no substantial portions of third party copyright material, including charts, diagrams, graphs, photographs or maps in my thesis/work or I have obtained permission for such material to be made accessible worldwide via the Internet.

Signature of author: ..................................................

Date: 26/3/18