The immediate effect of osteopathic ‘rib raising’ technique on heart rate variability: A randomised sham controlled experiment

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2012

A research thesis submitted in partial fulfilment of the requirements for the degree of Master of Osteopathy.

UNITEC Institute of Technology

Declaration

Name of Candidate: Nicholas White

This Thesis entitled: "**The immediate effect of an osteopathic 'rib raising' technique on heart rate variability: A randomised sham controlled experiment"** is submitted in partial fulfilment of the requirements for the Unitec degree of: Master of Osteopathy.

Candidate's declaration

I confirm that:

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

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Abstract

The immediate effect of osteopathic 'rib raising' technique on heart rate variability: A randomised sham controlled experiment

Objective: To investigate application of an Osteopathic Manipulative Treatment (OMT) known as Rib Raising Technique (RRT) and measure its effects on the autonomic nervous system (ANS) by detecting changes in Heart Rate Variability (HRV) parameters. This thesis includes a literature review to provide the basis for an experimental investigation reported as a journal manuscript.

Design: A randomised, participant blinded, sham controlled experimental design.

Participants: Eighteen healthy asymptomatic volunteers (n=18; 9 males, 9 females; mean ± SD age = 23.9 ± 2.3 years) were recruited from a university population.

Methods: Participants were randomly allocated to sham or 'genuine' intervention groups. Participants in the genuine intervention group received a RRT applied to the upper five ribs within a single session. Those in the sham intervention group received a sham intervention designed to mimic the RRT intervention in a single session. Pre-test and post-test measures of the low frequency (LF), high frequency (HF), and low frequency: high frequency ratio (LF:HF) of the power spectra components of HRV analysis were recorded, immediately post-intervention, 24 hours post-intervention, and 7 days post-intervention.

Results: No significant difference was detected in either the RRT or sham groups between mean pre-intervention compared with immediate post-intervention; or between mean pre-intervention compared with post-intervention at 24-hour or 7-day follow up measures for any of the calculated HRV indices (LF, HF, LF:HF ratio).

Conclusion: The findings of this study indicate that RRT was not accompanied by statistically significant changes in the power spectra parameters of HRV in healthy participants.

MeSH Keywords: Therapeutics; Physical Therapy Modalities; Musculoskeletal Manipulations; Manipulation, Osteopathic

Acknowledgments

I would like to thank the following people for all their support throughout the process of completing this thesis:

To all the participants who generously dedicated their time to be part of this study.

To my supervisors Rob Moran and Jamie Mannion.

I especially would like to thank my family: Steve, Karen, Hayden and Vanessa. Thank you for your continued support; financial and emotional, and continued encouragement and motivation when times were tough. I couldn’t have completed this without you.

And a special thanks and much love to Maj Helen, who has had to continually fight with this thesis for my attention.

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Abbreviations

ANS	Autonomic Nervous System
CMA	Chiropractic Manipulative Adjustment
CTJ	Costotransverse Joint
CVJ	Costovertebral Joint
ECG	Electrocardiogram
HF	High Frequency
HRV	Heart Rate Variability
HVLAT	High Velocity Low Amplitude Thrust
LF	Low Frequency
LF:HF	Low Frequency : High Frequency Ratio
OMT	Osteopathic Manipulative Treatment
PSNS	Parasympathetic Nervous System
RR	Rib Raising
RRT	Rib Raising Technique
SNS	Sympathetic Nervous System
SV	Somato-Visceral
VLF	Very Low Frequency
VS	Viscero-Somatic

Section 1

Literature Review

Introduction

The following is a summary of literature that addresses the application of osteopathic, physiotherapeutic and chiropractic manipulative treatment techniques and their effects on the autonomic nervous system (ANS). The literature reviewed is primarily focused on two types of manual therapy techniques: i) osteopathic technique described as 'Rib Raising Technique' (RRT); and ii) a manipulative technique employed by a wide range of manual medicine practitioners called High Velocity Low Amplitude Thrust (HVLAT). Currently there is limited evidence to validate many of the techniques that osteopaths and other manual therapists use. The evidence that does exists on the effects of osteopathic manipulative treatment (OMT) technique is largely observational and based on patient outcomes such as improvement in pain scales, range of motion, and other empirical measures (Anderson & Seniscal, 2006; Burns & Wells, 2006).

The osteopathic profession has long recognized a relationship between the autonomic nervous system and the function of the body in health and disease (Waitley, 2000), although there are few examples of quantitative data evaluating the relationship between OMT and the ANS (Celander, Koenig, & Celander, 1968; Sergueef, Nelson, & Glonek, 2002). One of the underlying theoretical approaches by which OMT exerts its effects is based upon OMT causing autonomic activation resulting in vasodilatation, smooth muscle relaxation and increased blood flow, resulting in improved range of motion, decrease in pain perception, and change in tissue quality (Ward, 2003). Until recently this association remained largely a theoretical consideration due to technical challenges in accurately measuring autonomic activity directly.

Over the past two decades indirect methods have been developed and refined to provide non-invasive markers of autonomic activity (Kautzner & Camm, 1997; Sztajzel, 2004) with heart rate variability (HRV) being most commonly used (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Heart rate variability is based on the inherent variation of the R to R intervals of a standard electrocardiogram (ECG), with these variations largely due to changes in autonomic balance at the sinus node (Nakamura, Yamamoto, & Muraoka, 1993; Sztajzel, 2004)

Numerous studies (Budgell & Hirano, 2001; Budgell & Polus, 2006; Igarashii & Budgell, 2000; Sillevis, Cleland, Hellman, & Beekhuizen, 2010; Welch & Boone, 2008) have investigated the effect of a HVLAT (or other manual therapy modality equivalent) applied to the thoracic or cervical spine on autonomic function. Some studies have demonstrated a statistically significant effect including increases (Budgell & Hirano, 2001; Budgell & Polus, 2006; Mc Guiness, Vicenzino,

& Wright, 1994) or decreases (Henderson et al., 2010; Henley, Ivins, Mills, Wen, & Benjamin, 2008; Welch & Boone, 2008) in sympathetic or parasympathetic activity. To date clinically relevant changes in autonomic function or HRV have yet to be defined (Maestri et al., 2009; Pinna et al., 2007). As a consequence studies which investigate manual therapy technique aimed at influencing autonomic activity lack the ability to determine if any changes observed are clinically relevant. Additionally, other studies have found little correlation (Buchmueller, 2007; Driscoll & Hall, 2000; Roy, Boucher, & Comtois, 2009; Sillevis et al., 2010; Welch & Boone, 2008) between manual therapy and its effects on autonomic function. Due to the large amount of studies (Buchmueller, 2007; Budgell & Hirano, 2001; Budgell & Polus, 2006; Driscoll & Hall, 2000; Henderson et al., 2010; Henley et al., 2008; Mc Guiness et al., 1994; Roy et al., 2009; Sillevis et al., 2010; Welch & Boone, 2008) producing differing results regarding manual therapy influencing autonomic function; further research is needed to clarify whether there are increases, decreases or no change in autonomic function as a result of manual therapy. Additionally the mechanisms by which manual techniques exert their supposed effects on ANS function should be investigated.

Currently few studies have demonstrated significant changes in autonomic response in specific relation to RRT (Farthing, Gosling, Williams, & Vaughan, 2006; Henderson et al., 2010). After application of a RRT, it has been claimed that there will be a prolonged decrease in activity of the sympathetic nervous system from the sympathetic ganglia under the thoracic segment on which the RRT is applied (Kuchera & Kuchera, 1994a). Rib raising technique is claimed to be the ‘primary means’ of manual techniques that osteopaths use to influence the ANS (Kuchera & Kuchera, 1994a) and since it is the ‘primary means’ then it must be justified with sound evidence. Unfortunately this is not the case and many osteopathic textbooks (Gibbons & Tehan, 2006; Greenman, 2003; Kuchera & Kuchera, 1994a, 1994b; Nelson & Glonek, 2007; Nicholas & Nicholas, 2008; Parsons & Marcer, 2005; Ward, 2003) continue to make this claim relying upon conflicting evidence and anecdotal reports to validate it. In the context of evidence based healthcare; within learning texts it is imperative that the claim of the use of RRT to modify ANS function is acknowledged as hypothetical until demonstrated otherwise.

In the wider health context, the ANS is believed to play a role in causation and progression of diseases such as type 2 diabetes (M. R. Carnethon et al., 2006), hypertension (Flaa, Mundal, Eide, Kjeldsen, & Rostrup, 2006) and cardiac arrhythmias (Singh et al., 2004). These pathologies are currently treated by pharmaceutical and lifestyle interventions. If RRT can therapeutically influence ANS function then it may open further opportunities for the prevention and treatment of autonomically contributed or caused disease.

Outline

The aim of the study accompanying this literature review is to investigate if RRT has an effect on the ANS as measured by changes in HRV parameters. The study further aims to quantify the duration of the observed changes, if any, of HRV in response to RRT. The purpose of this literature review is to provide a theoretical basis on which to base the experimental investigation. It will explore the literature pertaining to manual therapy technique and its influence on autonomic function, predominantly using changes in HRV parameters as measures of autonomic function. Firstly the literature review introduces the basic anatomy of the nervous system and the costal joints. Next it describes the common manual therapy techniques of HVLAT and RRT. The plausibility of RRT is also discussed. This is followed by a discussion of the osteopathic concept of 'somatic dysfunction', and reflexes that exist between the ANS and viscera (a theorised mechanism by which RRT exerts is effects). Next HRV is reviewed including common measurement methods, frequency band parameters, factors influencing HRV, the reliability of HRV measurements, clinically relevant changes of HRV and what is considered 'normal' HRV. The final section of the literature review critically appraises and reviews studies which investigate manual therapy techniques and their influence on the ANS. The first part of this section deals with studies that have shown no effect on autonomic activity after manual therapy intervention. The second part discusses studies that have shown an increase in sympathetic activity after manual therapy intervention. The third part discusses studies that have shown a decrease in sympathetic activity.

Literature Reviewed

The databases that were searched include: MEDLINE, SCOPUS, Science Direct, SPORT Discuss, EBSCO, AMED, and PubMed. The search results found a wide range of literature from across many different healthcare fields. The search terms used to refine the results included words such as: "Spinal, thoracic, cervical, costovertebral and rib, OMT, manipulation or HVLAT effects and influence on HRV, autonomic, sympathetic parasympathetic output, outflow, regulation or modulation.” To further refine the search criteria various synonyms of the above listed words were used to generate search queries. In addition to the osteopathic literature, other journals of manual therapy such as physiotherapy and chiropractic were searched in an attempt to locate additional literature. Here the search terms were changed slightly to suite the terminology of the profession, such as the use of words ‘subluxation’ or ‘mechanical mobilization/stimulation’ as synonyms to HVLAT. A large number of osteopathic textbooks were hand searched to identify further literature.

Anatomy

The purpose of this section is to provide a brief overview of the anatomy of the nervous system and the costal joints, as these are the major structures that RRT will theoretically influence.

The Nervous System

The human nervous system has been traditionally described as having two basic components: The central nervous system, made up of the brain and the spinal cord; and the peripheral nervous system, which is comprised of peripheral nerves and their ganglia that lie outside the brain and spinal cord (Patestas & Gartner, 2006). Although anatomically separate, the two systems are functionally interconnected.

The peripheral nervous system is further divided into somatic and autonomic divisions (Drake, Vogl, & Mitchell, 2009). The somatic division is principally concerned with sensory information about the environment outside the body as well as voluntary muscle and limb movement and position (Haines, 2011). The autonomic nervous system is for involuntary control of the motor system for the viscera, the smooth muscles of the body (especially those of the vasculature) and the exocrine glands (Marieb & Hoehn, 2007). The autonomic system is vital to the maintenance of internal homeostasis and achieves this by mechanisms that regulate blood pressure, fluid and electrolyte balance and body temperature (Snell, 2006).

The ANS is composed of three distinct parts: The sympathetic, parasympathetic and enteric nervous systems (Benarroch & Low, 2008). The sympathetic nervous system (SNS) helps control the reaction of the body to stress, while the parasympathetic nervous system (PSNS) works to conserve the body's resources and to restore equilibrium to the resting state (Marieb & Hoehn, 2007). The enteric nervous system regulates the motility and secretion of gastro-intestinal organs (Kenneth, 2002). This literature review deals with the sympathetic and parasympathetic divisions.

The Thoracic Sympathetic Trunk

Rib raising technique exerts its effects on the autonomic nervous system via the sympathetic ganglia (Kuchera & Kuchera, 1994a). All fibres of the SNS arise from cell bodies of preganglionic neurons in spinal cord segments T_1 to L_2 (Haines, 2011). The sympathetic trunk contains 11 or 12 pairs of ganglia. After leaving the spinal cord via the ventral root, preganglionic sympathetic fibres pass through white rami communicantes to enter an adjoining sympathetic ganglion chain (Haines, 2011). These ganglia are also called paravertebral ganglia, named for their location. From here the postganglionic fibres go on to innervate their associated viscera (Haines, 2011).

In the thoracic part of the sympathetic trunk, these ganglia lie anterior and adjacent to the rib heads (Snell, 2006). Therefore due to their close proximity to the costovertebral and costotransverse joints, dysfunction of these joints and their surrounding musculature could potentially influence the thoracic ganglia (Kuchera & Kuchera, 1994a).

Anatomy and Biomechanics of the Costal Joints

The anatomy and biomechanics of the costal joints is essential in understating how RRT is applied, as RRT involves the practitioner inducing movement at the participant's costovertebral and costotransverse joints bilaterally (Kuchera & Kuchera, 1994a).

All ribs articulate with the thoracic vertebral column. 'Typical' ribs (ribs 3-9) are attached to the vertebrae by means of two joints (Drake et al., 2009): See Figure 1.

1. The costovertebral joint (CVJ) between the head of the rib and the intervertebral disc and the vertebral bodies.
2. The costotransverse joint (CTJ) between the rib tubercle and the transverse process of the inferior underlying vertebra.

Only the costal cartilages of the upper 7 ribs, known as 'true ribs', anteriorly articulate directly with the sternum. The remaining lower five pairs of ribs (ribs 8-12) are known as 'false ribs'. Ribs

8 to 10 are attached indirectly to the sternum through the seventh costal cartilage. The 11th and 12th rib do not attach anteriorly to any structure (Drake et al., 2009).

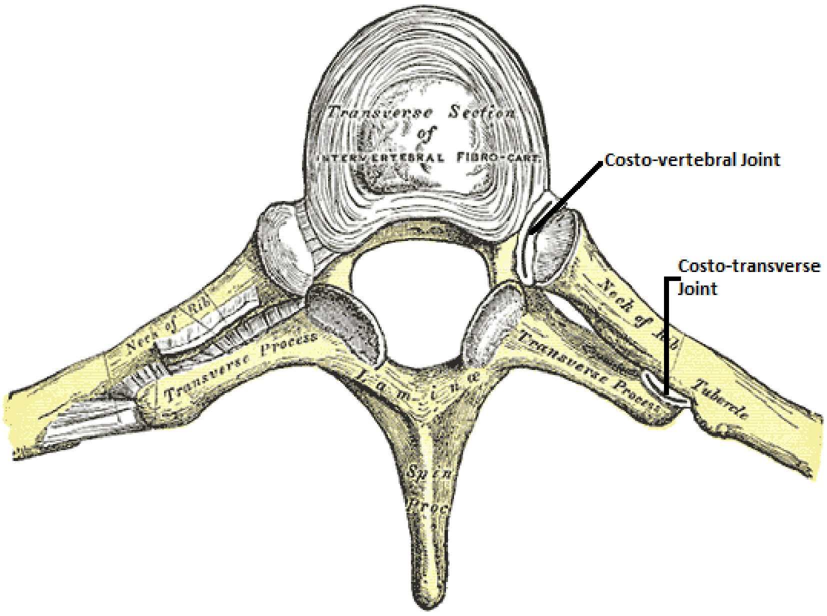

Figure 1 – Costovertebral and Costotransverse Joints

A transverse view of a thoracic vertebra and its associated ribs. Marked on the diagram are the costovertebral and costotransverse joints. Source: Gray (1918).

In the upper six ribs the main movement is one of rotation around their long axis's and the 'angle' of the rib (Drake et al., 2009). See Figure 2 for reference.

- Rotation superiorly at the angle of the rib with elevation of the anterior end of the rib and its costal cartilage occurs on inhalation.
- Rotation inferiorly at the angle of the rib with depression of the anterior end of the rib and its costal cartilage occurs on exhalation.
- This is commonly referred to as the 'pump-handle' movement and modifies the anterior-posterior diameter of the thorax.

In the seventh, eighth, ninth and tenth ribs the main movement occurs around the 'neck' of the rib (Drake et al., 2009).

- The neck of the rib moves superiorly, backwards and medially on inhalation.
- The neck of the rib moves inferiorly, forwards and laterally on exhalation.

- This is commonly referred to as the ‘bucket-handle’ movement and modifies the transverse diameter of the thorax.

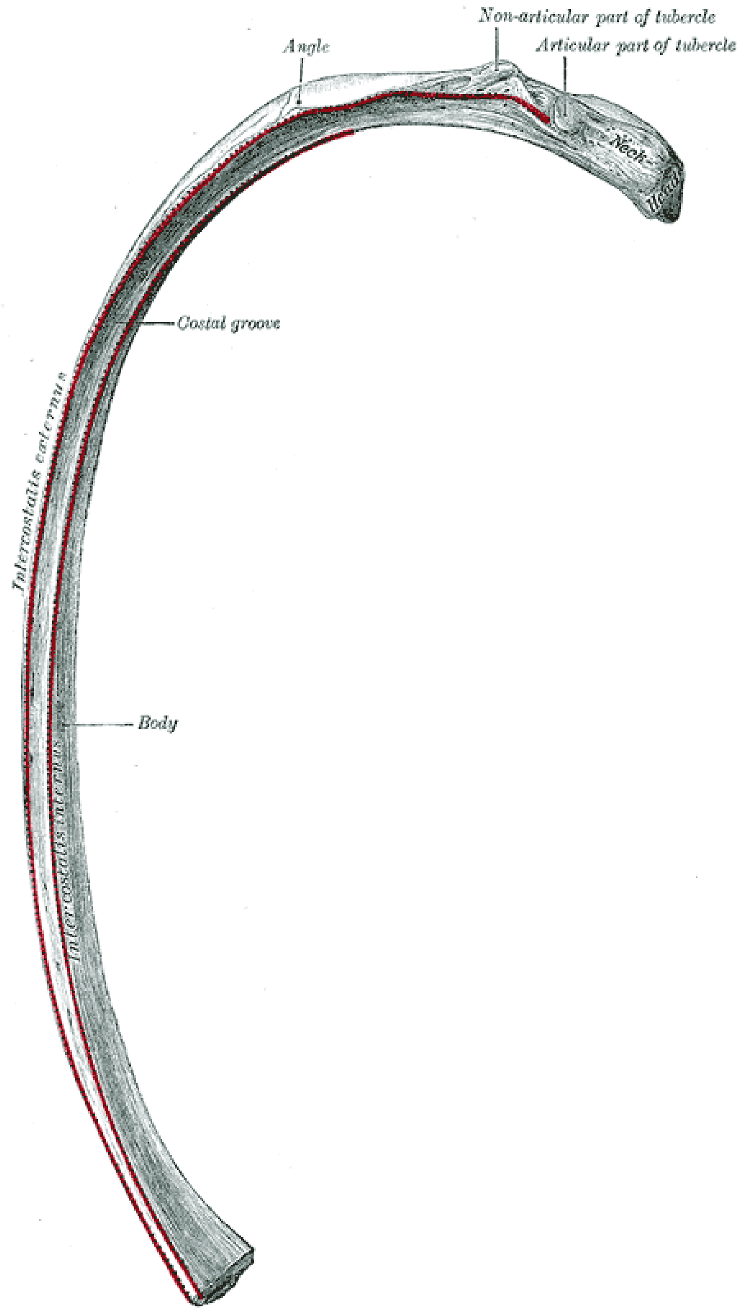

Figure 2 – A Typical Rib

A typical central rib of the left side. Inferior aspect. The ‘angle’ of the rib can be observed on the upper central aspect of the diagram and the ‘neck’ of the rib can be observed on the upper right aspect of the diagram Source: Gray (1918).

High Velocity Low Amplitude Thrust

High velocity low amplitude thrust and other modalities of manual therapy equivalents have been used in many studies to investigate inducing changes in autonomic nervous system function (Buchmueller, 2007; Budgell & Polus, 2006; Mc Guiness et al., 1994; Sillevis et al., 2010; Welch & Boone, 2008). High velocity low amplitude thrust of the human spine is one of the oldest treatment methods of manual medicine and one of the most frequently used techniques amongst osteopaths, chiropractors and physiotherapists (Greenman, 2003). This technique can be described as a direct manipulative treatment whereby “the physician must combine a rapid acceleration force with only minimal movement of the articular landmark (segment) that is being treated” (Nicholas & Nicholas, 2008), consequently forcing the joint through its restrictive barrier (Herzog, 2000). The objective of the technique is to direct forces to a specific point, area or structure. By combining many movement vectors, a barrier is formed which is at a physiological end-of-range rather than at an anatomical end of range (Gibbons & Tehan, 2006). When an HVLAT technique is performed, the applied force separates the articular surfaces of a fully encapsulated synovial joint (Greenman, 2003). This deforms the joint capsule and intra-articular tissues, which in turn creates a reduction in pressure within the joint cavity (Parsons & Marcer, 2005). As a result, ‘cavitation’, the term used to describe this vacuum phenomenon, occurs (Brodeur, 1995; Greenman, 2003). The cavitation phenomenon suggests that the synovial fluid changes from a liquid to a gaseous state (Greenman, 2003). Cavitation generally produces a noise, commonly described as a ‘click’ or ‘popping’. Some authors consider this sound as an indicator of a successful delivery of an HVLAT technique (Gibbons & Tehan, 2006; Herzog, 2000). However, there is debate about the necessity of sound production for a successful HVLAT application, as the sound has yet to be linked to clinical effects by objective findings (Flynn, Fritz, Wainner, & Whitman, 2003; Naysmith, 2009).

Rib Raising

Claims About Rib Raising Technique

Rib raising technique has been claimed to be the ‘primary means’ by which osteopaths influence ANS function (Kuchera & Kuchera, 1994a) and since it is the ‘primary means’ then this claim must be justified with sound evidence. Unfortunately this is not the case as there are few studies which have investigated RRT and its effects on the ANS (Farthing et al., 2006; Henderson et al., 2010). Many authors of osteopathic textbooks claim that raising the RRT initially stimulates regional sympathetic efferent activity to the organs related to that spinal level of sympathetic innervation, but the long-term effect is a prolonged reduction in sympathetic outflow from the area treated (Greenman, 2003; Kuchera & Kuchera, 1994a; Nelson & Glonek, 2007; Nicholas & Nicholas, 2008; Ward, 2003). These authors continue to make this claim relying upon contradictory evidence and anecdotal reports to validate it. If the relationship between RRT and autonomic function is to be considered causal, then consistency of this effect must be demonstrated in different studies and among different populations. A lack of consistency of evidence exists regarding OMT influencing autonomic function. This is because many studies have found conflicting evidence, with some showing increases in sympathetic activity (Budgell & Hirano, 2001; Budgell & Polus, 2006; Mc Guiness et al., 1994), others studies showing decreases in sympathetic activity (Henderson et al., 2010; Henley et al., 2008) and some showing no effect (Buchmueller, 2007; Sillevis et al., 2010).

Anatomical Basis for Rib Raising Technique

Anatomically it is known that the upper sympathetic ganglia lie lateral to the thoracic vertebral body and anteriorly against the costal heads (Drake et al., 2009). Based upon this anatomical relationship, Buchmueller (2007), notes a plausibility issue regarding HVLAT influencing autonomic function. Buchmueller (2007), suggests that cavitation of thoracic zygapophyseal joints during HVLAT applied to the thoracic spine is unlikely to be capable of eliciting an autonomic response on a mechanical or anatomical basis in sympathetic ganglia due to their positioning relative to the thoracic vertebrae. Therefore presumably an application of a RRT or an HVLAT to the costovertebral joint has a better chance of eliciting an autonomic response from sympathetic ganglia due to their anatomic proximity to the costal head.

Proposed Mechanism of Rib Raising Technique

A proposed mechanism of action of RRT has been hypothesised (Kuchera & Kuchera, 1994a). It is claimed that an effective RRT "lifts and rotates the rib heads; they, in turn, pull on the surrounding fascias that are common to a rib head and its sympathetic chain ganglion" (Kuchera & Kuchera, 1994a). Theoretically this causes a mechanical deformation of the sympathetic ganglia, which supposedly causes 'initial' stimulation of fast and very fast efferent sympathetic fibres, but this response is fairly localized and short lived. Shortly afterwards the RRT supposedly additionally stimulates slow and very slow efferent sympathetic fibres in the same ganglia and these fibres reflex as high as the medullary centres. These latter reflexes are reported to be inhibitory to the sympathetic system and are also 'long acting'. Kuchera & Kuchera (1994a), provides parameters to the above mentioned time frames of 'initial' and 'long acting'. The 'initial' sympathetic response occurs rapidly; 30 seconds after application, followed by the 'long acting' prolonged decrease in sympathetic activity observed up to 16 hours later. It should be noted that this is the only literature to give a quantitative timeframe of the initial increase followed by prolonged decrease in sympathetic activity. Kuchera & Kuchera (1994a), offer a rather vague description of the mechanism by which RRT exerts its supposed effects and it should be noted that no research within Kuchera & Kuchera (1994a), was referenced for this explanation or quantification of the supposed effects duration.

The theoretical mechanism by which RRT works on the ANS might be considered as a form of somato-visceral reflex, as RRT theoretically induces a therapeutic reflex between the somatic system and the viscera resulting in a reduction of sympathetic efferent signal output (King, Janig, & Patterson, 2010). The appeal of the supposed somato-visceral reflex mechanism is largely due to the clear segmental organisation of the sympathetic ganglia. This anatomic feature may be one feature to support a rationale for the clinical observation of topographical relationships between sites of somatic dysfunction and visceral disorders. Rib raising technique which innocuously mechanically stimulates the costovertebral and costotransverse joints and the surrounding paraspinal tissues would be unlikely to be able to physiologically elicit an autonomic response. This is because studies have shown that when innocuous mechanical stimulation is applied to the spine, it has been ineffective at eliciting somato-visceral reflexes in animal models (Bolton, Budgell, & Kimpton, 2006; Kang, Kenney, Spratt, & Pickar, 2003).

Somatic Dysfunction and Reliability of Identification

Kuchera & Kuchera (1994a), suggest that practitioners could decide which segment of the thoracic spine to apply a RRT based upon the identification of segments of somatic dysfunction. Somatic dysfunction has been defined as “impaired or altered function of related components of the somatic (body framework) system: skeletal, arthrodial, and myofascial structures, and related vascular, lymphatic, and neural elements” (Ward, 2003). Accompanying this altered function there are palpable tissue texture changes, asymmetries of functional position, restriction of motion and tenderness (Kuchera & Kuchera, 1994a; Nelson & Glonek, 2007; Ward, 2003). Osteopathic technique aims to remove somatic dysfunction through the use of OMT such as RRT. However, although this approach is widely taught in osteopathy, the intra-practitioner and inter-practitioner reliability of static and motion palpation procedures used to identify somatic dysfunction has been shown to be poor (Fjellner, Bexander, Faleij, & Strender, 1999; Seffinger et al., 2003). Despite this apparent inconsistency between research evidence and clinical practice, manual therapy instructional texts (Nicholas & Nicholas, 2008; Porter, 2003; Ward, 2003) maintain that motion palpation is the assessment of choice in identifying somatic dysfunction and in selecting the most suitable manipulative procedure to correct the identified segments of somatic dysfunction.

Somato-Visceral and Viscero-Somatic Reflex Physiological Mechanism

Within osteopathic medicine, one classic explanation for the relationship between somatic dysfunction findings and visceral disease is that an interrelationship exists between the somatic musculature and visceral organs, mediated by segmental-specific sympathetic reflex connections (Nelson & Glonek, 2007). The underlying principle is that reflex stimulation alters the somatic musculature in response to visceral disease or dysfunction via a viscerosomatic (VS) reflex arc (Kuchera & Kuchera, 1994a; Nelson & Glonek, 2007).

Additionally a reflex occurring in the opposite direction is theorised to occur (Kuchera & Kuchera, 1994a; Nelson & Glonek, 2007) known as a somato-visceral (SV) reflex. This is where somatic stimulation affects visceral function via a sympathetically mediated reflex arc. The theoretical mechanism by which RRT works on the ANS has been referred to as a somato-visceral (SV) reflex, as RRT theoretically induces a therapeutic reflex between the somatic system and the viscera resulting in a reduction of sympathetic efferent signal firing (Kuchera & Kuchera, 1994b) to the associated viscera. This reflex provides a convenient explanation for the mechanism of OMT and other manual therapy techniques aimed at influencing ANS function, despite there being a lack of evidence for the existence of the theorised SV reflex (Bolton et al., 2006; Kang et al., 2003; Pollard, 2004).

The theorised explanation within educational osteopathic texts (Nelson & Glonek, 2007) for the physiological mechanism of these reflexes involves:

1. A peripheral focus of irritation –
    i. In the case of a VS reflex – arising from the inflammation associated with visceral pathology, which activates general visceral afferent neurons.
    ii. In the case of a SV reflex, primary somatic dysfunction results in the activation of afferent somatosensory nociceptive neurons.
2. These primary afferent neurons enter the spinal cord and synapse in the dorsal horn with internuncial neurons.
3. On-going afferent stimulation from the focus of irritation, be it visceral or somatic, results in establishment of a state of irritability (facilitation) of the internuncial neurons of that spinal segment.
4. Additional afferent activity from any source results in a spinal segmental response to less stimulus than would be normally required (sensitisation).

    i. In the case of a VS reflex, this results in tenderness that is proportional to the degree of visceral pathology, when the area of the associated dermatome or myotome is palpated. If the amount of afferent activity from the affected organ is sufficient to cause spontaneous internuncial firing with the activation of ascending spinal pathways, referred pain results.

5. Such activity from internuncial neurons, which synapse with ventral horn motor neurons, results in segmentally related myospasticity, as seen in somatic dysfunction and viscerosomatic reflexes.
    i. Activity from internuncial neurons that synapse with neurons in the intermediolateral cell column of the thoracic and upper lumbar cord results in segmentally related somatosomatic, somatovisceral and viscerovisceral reflex sympathicotonia.
    ii. Similar physiology is thought to occur in the parasympathetically mediated reflexes, although in this instance it is less clearly identified.

A Review of the Somato-Visceral Reflex

Somato-visceral reflexes are claimed by manual therapy texts to be caused by the stimulation of somatic tissues which then manifest as alterations of visceral organ function (King et al., 2010; Nelson & Glonek, 2007). This claim is premature to make as it appears to be based upon limited evidence from a few studies (Bolton et al., 2006; Budgell, Sato, Suzuki, & Uchida, 1997; Kang et al., 2003; A. Kimura, Ohsawa, Sato, & Sato, 1995). Additionally, since most of the studies investigating SV use animals as subjects, the claim for the existence of SV reflexes (King et al., 2010; Nelson & Glonek, 2007) makes the assumption that the reflexes observed in research involving animals will be the same as the reflexes observed in humans despite humans and animals having differing neurological anatomy and physiology. One study investigating SV reflexes (A. Kimura et al., 1995) reported that noxious cutaneous mechanical stimulation resulted in changes in sympathetic motor neuron activity which corresponded to increases in cardiac sympathetic nerve activity, with proportional increases in blood pressure and heart rate (HR). Another study (Budgell et al., 1997) aimed to observe induced noxious chemosensory stimulation to the paraspinal tissues and its effects on the sympathetic nervous system. Capsaicin was injected into lumbar and thoracic interspinous tissues and resulted in increases in adrenal nerve activity and catecholamine secretion. Injection of normal saline into the lower lumbar or lower thoracic interspinous tissues produced no changes in adrenal sympathetic nerve activity or catecholamine secretion. It is therefore considered possible to induce SV reflexes by noxious chemical and noxious mechanical cutaneous stimulation in animals.

In a manual therapy treatment context, the experimentally induced visceral changes observed in response to noxious stimulation in the above studies (Budgell et al., 1997; A. Kimura et al., 1995), should not be considered the same as the changes observed in visceral function due to OMT, as OMT techniques are non-noxious when applied (Ward, 2003).

Forceful but innocuous (non-noxious) mechanical loading of the spine has been found to be ineffective at eliciting somato-visceral reflexes. A study (Kang et al., 2003) determined that mechanosensory input to the lumbar L2-4 multifidus muscles did not alter reflex sympathetic outflow to the spleen or kidney. Another study (Bolton et al., 2006) sought to determine if innocuous mechanosensory input to the deep tissues surrounding the cervical vertebrae would influence the sympathetic outflow to the adrenal gland. Rotational mechanical force was applied to the second cervical vertebrae and no significant change in sympathetic nerve activity to the adrenal gland was observed.

Rib raising technique and most manual therapy treatment techniques could be considered a form of non-noxious mechanical tissue stimulation. Additionally, if studies (Bolton et al., 2006; Kang et al., 2003) investigating SV reflexes in relation to non-noxious mechanical stimulation showed no effect in animal models, then it is unlikely that manual therapy technique could cause a reduction in somatic efferent firing and result in a reduction in dysfunction of the associated viscera in humans as theorised in osteopathic texts (Kuchera & Kuchera, 1994a; Ward, 2003). To date, studies (Bolton et al., 2006; Budgell et al., 1997; Kang et al., 2003; T. Kimura et al., 2006) have all used animal models to investigate SV reflexes therefore the physiological responses observed may not be applicable to humans. Currently no studies have demonstrated the generation of disease states from somatic dysfunction, nor has research demonstrated the restoration of normal visceral function in diseased states by normalisation of somatic structures by OMT or any other manual therapy method (Nansel & Szlazak, 1995; Pollard, 2004). Much research would be required to investigate the existence and the nature of relationships between the treatment of somatic structures of the spine and normalisation of pathological visceral tissues via SV or VS reflexes.

Quantification of Autonomic Nervous System Activity

A variety of methods have been used for the measurement of autonomic activity after the application of manual therapy technique. These include the assessment of distant skin temperature and conductance (Sterling, Jull, & Wright, 2001; Vicenzino, Collins, Benson, & Wright, 1998), pupillary reflex diameter (Sillevis et al., 2010), levels of salivary cortisol (Whelan, Dishman, Burke, Levine, & Sciotti, 2002) and α amylase (Henderson et al., 2010), HR and blood pressure (Fujimoto, Budgell, Uchiada, Suzuki, & Meguro, 1990) and HRV (Budgell, 2000; Budgell

& Hirano, 2001; Budgell & Polus, 2006). Power spectral analysis of HRV data is commonly used and considered the most convenient method of ANS activity measurement (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996).

Heart Rate Variability

Heart rate variability can be defined as "the variation over time of the period between consecutive heartbeats" (Rajendra Acharya, Paul Joseph, Kannathal, Lim, & Suri, 2006). Heart rate variability is a useful and popular non-invasive measure for assessing the status of the ANS. Since HR is influenced by parasympathetic and sympathetic divisions of the ANS, HRV analysis provides a means of observing the interplay between the sympathetic and parasympathetic nervous systems (Rajendra Acharya et al., 2006). The degree of variability in the HR provides information about the functioning of the nervous control on the HR and the heart's ability to respond to changing stimuli. There are several methods of measurement (Rajendra Acharya et al., 2006), however, there are two that are used predominantly: the time domain measurement and the frequency domain (power spectral density analysis) measurement.

Methods of Measurement and Analysis of HRV

Time Domain Method

According to the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996), the time domain method involves measuring the time between two normal QRS complexes produced by an ECG recording known as "normal to normal intervals" or between two R-R peaks of the QRS complex. The differences in intervals can be described as "either differences in heart rate or cycle length". A reduced timespan between intervals would indicate an increased sympathetic or decreased parasympathetic response. However, while time domain methods are computationally simple, they lack the ability to discriminate between sympathetic and parasympathetic contributions of HRV (Rajendra Acharya et al., 2006).

According to Acharya (2006), the separate rhythmic contributions to sympathetic and parasympathetic autonomic activity modulate the HR (R-R) intervals of the QRS complex in the ECG, at distinct frequencies. The frequency domain method of analysis enables the researcher to observe how much the SNS or PSNS is contributing towards HRV generation.

Frequency Domain Method

Frequency-domain analysis of HRV determines how power spectral density (PSD) or variance of the R-R intervals distributes as a function of frequency (King et al., 2010). Traditional spectral analysis requires at least 5 minutes of continuous ECG data (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). This method uses power spectral analysis to separate the recorded ECG signal into its frequency bands. Power spectral analysis uses Fast Fourier Transform (FFT) or autoregressive (AR) techniques to obtain the discrete frequency bands (King et al., 2010). These computational algorithms are now available as relatively user-friendly software applications for experimental use of HRV analysis (ADI Instruments, 2010; Tarvainen & Niskanen, 2012). Therefore, the HR signal is decomposed and quantified in terms of the relative intensities (power) of these frequency components (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996).

Frequency Bands

Power spectral density analysis generates three main frequency parameters. These include the high frequency band (HF) (0.4-0.15 Hz), low frequency band (LF) (0.15-0.04 Hz) and very low frequency band (VLF) (0.04-0.003 Hz) (Task force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Of these three, two are more relevant than the others when measuring autonomic activity. These are the high and low frequency band (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Sympathetic activity is associated with the low frequency range while parasympathetic activity is associated with the higher frequency range (Rajendra Acharya et al., 2006), therefore the ratio of LF:HF serves as useful indicator of sympathetic and parasympathetic autonomic balance (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996).

Very Low Frequency

Authorities consider that the VLF band (<0.04Hz) to be the least understood frequency band (Berntson et al., 1997; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). This is because meaningful determinations of the VLF power can be problematic since low level frequencies are associated with increased error in recordings (Ori, Monir, Weiss, Sayhouni, & Singer, 1992). Additionally the VLF band can only be assessed accurately over long periods of recording time (hours to days) due to the unstable and non-harmonic expression of the VLF power. This is because the VLF band is believed to be related to non-neural factors, such as temperature and thermoregulation, hormones and circadian rhythms and fluctuation in the renin and angiotensin systems (Bianchi, Mainardi, Meloni, Chierchia, & Cerutti, 1997).

High Frequency

The HF band (0.15-0.4 Hz) has been identified to be predominantly mediated by parasympathetic activity (Malliani, Pagani, Lombardi, & Cerutti, 1991; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). The vagus nerve is a parasympathetic nerve and it has been shown that the HF band can be abolished by vagal nerve block and/or vagotomy (Malliani et al., 1991). This suggests that the vagal nerve and therefore the parasympathetic nervous system modulates the HF component of HRV power spectra analysis (Malik & Camm, 1995; Randall, Brown, Raisch, Yingling, & Randall, 1991; Stein & Kleiger, 1999).

Low Frequency

The low frequency band (0.04-0.15Hz) is considered a marker of sympathetic modulation for HRV (Kamath & Fallen, 1993; Rajendra Acharya et al., 2006). However the interpretation of the LF band as an indicator of sympathetic activity is somewhat controversial (Berntson et al., 1997; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). This controversy arises because the underlying control of the LF power has yet to be fully elucidated. A relationship between LF spectrum of HRV and sympathetic activity was shown when the LF band was significantly reduced after the application of a pharmacological blockade of cardiac sympathetic synapses (Akselrod, Gordon, Ubel, Shannon, & Cohen, 1981). Additionally after stellectomy (resection of the sympathetic stellate ganglion) the LF band was found to be abolished (Pagani et al., 1986). However, other investigators using experimental means to increase the sympathetic activity, such as exercise or the addition of an adrenergic agonist, failed to see a significant increase in the LF power (Ahmed, Kadish, Parker, & Goldberger, 1995; Arai et al., 1989; Skyschally, Breuer, & Heusch, 1996; Yamamoto, Hughson, & Peterson, 1991). In some cases the LF power appeared to be solely reflecting the actions of the parasympathetic nervous system (Pomeranz et al., 1985; Randall et al., 1991; Skyschally et al., 1996). This claim is disputed by Akselrod et al. (1981), who theorises that changes in the LF band represent oscillations in both the sympathetic and parasympathetic autonomic divisions. Therefore the LF band should not be thought of as solely generated by sympathetic activity.

Low Frequency : High Frequency Ratio

Despite the difference in interpretation (Ahmed et al., 1995; Akselrod et al., 1981; Arai et al., 1989; Pomeranz et al., 1985; Randall et al., 1991; Skyschally et al., 1996; Yamamoto et al., 1991) of how much and what divisions of the ANS are contributing to the LF power spectra generation, it has been demonstrated that the ratio between LF and HF power components expressed in normal units likely reflects the balance in activity between the SNS and PSNS (Kamath & Fallen, 1993; Malliani, Pagani, Montano, & Mela, 1998; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). The LF, HF and VLF components are usually measured in absolute values of power (milliseconds squared [ms^2]). The LF and HF bands can also be measured in normalised units (nu). Normalised units represent the relative value of each power component in proportion to the total power minus the VLF band component (Malliani et al., 1991; Pagani et al., 1986). To calculate normalised units the absolute power needs to be multiplied by 100 and then divided by the (total power – VLF) (Rautaharju & Rautaharju, 2007). Therefore, expressing the LF band and HF band as a ratio in normalised units represents the controlled and balanced effects SNS and PSNS on the heart (Malliani et al., 1991; Pagani et al., 1986).

This ratio of LF:HF has been used in several osteopathic and associated manual therapy studies (Buchmueller, 2007; Budgell & Hirano, 2001; Budgell & Polus, 2006; Henley et al., 2008; Roy et al., 2009) as a means to quantify which division of the ANS is active whilst OMT or another manual therapy equivalent intervention is being applied to a participant.

Power spectral analysis has been used as a reliable tool to assess HRV in many fields of research and healthcare (Inoue, Miyake, Kumashiro, Ogata, & Yoshimura, 1990; Lombardi, Sandrome, & Mortara, 1992; Troegera, Schauba, Bernasconib, Höslia, & Holzgrevea, 2003). Heart rate variability has been successfully used in the early diagnosis of clinical conditions such as hypertension (Matveev & Prokopova, 2002), arthrosclerosis (M. Carnethon et al., 2002) and cardiac tachycardia (Osaka et al., 1996; Zimmerman, 2005). However measures of HRV are often misinterpreted as a measure of autonomic activity and it is important to recognise that HRV parameters obtained are a function of the effect of oscillations of autonomic modulation on HR and are not a direct measure of autonomic nervous system activity itself (King et al., 2010).

Factors Influencing Heart Rate Variability

A number of factors have been shown to influence HRV parameters. These factors must be considered when creating a research method that uses HRV as a measure of autonomic activity.

Some of these factors include smoking (Barutcu et al., 2005; Karakaya, 2007), caffeine consumption (Sondermeijer, van Marle, Kamen, & Krum, 2002; Sudano et al., 2005) illumination (Schäfer & Kratky, 2006), room temperature (Bruce-Low, Cotterrell, & Jones, 2006; Fox, O'Regan, & Matthews, 1991) ambient noise (Tzaneva, Danev, & Nikolova, 2001; van Amelsvoort, Schouten, Maan, Swenne, & Kok, 2000), age and gender (Fluckinger, Boivin, Quilliot, Jeandel, & Zannad, 1999; Zhang, 2007), exercise and fitness levels (Buchheit, Platat, Oujaa, & Simon, 2007; Hedelin, Bjerle, & Henriksson-Larsén, 2001; Tulppo et al., 2003), mental stress and emotions (Carney, Freedland, & Stein, 2000; Dishman et al., 2000; Sakuragi, Sugiyama, & Takeuchi, 2002) and obesity (Friederich et al., 2006; T. Kimura et al., 2006; Quilliot, Zannad, & Ziegler, 2005). Due to the number of factors influencing HRV, it is recommended that lifestyle and environmental factors be considered when recording HRV in a research setting (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996).

Body Position and Heart Rate Variability

It is known that body position can influence the LF and HF components of HRV. Numerous studies (Fagard, Pardaens, & Staessen, 2001; Lee, Buchanan, Flatau, & Franke, 2004; Malliani et al., 1997; Stauss, 2002) have demonstrated that body position can influence HRV with an increase in sympathetic activity in the standing position compared with the supine position (Jáuregui-Renaud et al., 2001) and the supine position showing an increase in sympathetic activity compared to the prone position (Jean-Louis et al., 2004). Although being positioned supine supposedly creates a sympathetic response, contrary to this notion; one study demonstrated that the seated position is associated with a greater LF and LF:HF ratio, compared with prone and supine positions (Watanabe, Reece, & Polus, 2007). Nevertheless, these studies suggest that changes in body positioning can lead to significant changes in the power spectra components of HRV. Consequently manual therapy studies must take participant position into consideration as it could bias the results toward detecting the predominant HRV parameter of the position of which the intervention technique is being applied.

Additionally head tilt (10° of cervical spine flexion or greater) whilst in a supine position has been shown to increase sympathetic activity with increases in the LF component of HRV as well as in the LF:HF ratio (Henley et al., 2008; Malliani et al., 1991; Sharma, Paudel, Singh, & Limbu, 2009). Head tilt can be induced upon the research participants as a result of the manual therapy practitioner applying the manual therapy intervention or due to the participants resting their head on a pillow during the intervention such that their neck is in flexion. Therefore post-intervention related changes in sympathetic modulation of the heart would be easier to detect in the studies where the participants were supine and head tilt could have unintentionally been induced (Budgell & Hirano, 2001; Budgell & Polus, 2006; Henderson et al., 2010).

Ventilation Rate and Respiratory Sinus Arrhythmia and Heart Rate Variability

Another factor which influences HRV is ventilation rate. This has been shown to have a large effect on HRV and HR (Berntson et al., 1997; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). This is because respiration creates a phenomenon known as respiratory sinus arrhythmia (RSA). This is where intrathoracic pressure changes that occur during ventilation cause the “heart rate variability to be in synchrony with respiration, by which the R-R interval on an ECG is shortened during inspiration and prolonged during expiration” (Yasuma & Hayano, 2004). It has been suggested by various authors (Berntson, Cacioppo, & Quigley, 1993; Guyton & Hall, 2006) that RSA is a consequence of a ‘spillover’ effect of signals within the medulla-oblongata from the medullary respiratory centre into the adjacent vasomotor centre during respiration. The ‘spillover’ of signals causes an alternate increase during inspiration and decrease during expiration in the number of impulses transmitted through the sympathetic and vagus nerves respectively to the heart.

Respiratory sinus arrhythmia is mostly facilitated by vagal nerve impulses to the heart and tends therefore to be expressed as a contribution to the HF band of the HRV power spectrum (Akselrod et al., 1981; Berntson et al., 1997; Malik & Camm, 1995). Respiratory sinus arrhythmia is nearly abolished by cholinergic blockage or functional vagotomy, but is not generally reduced by beta-adrenergic blockade (Akselrod et al., 1981; Coker, Koziell, C., & Smith, 1989; Pagani et al., 1986). In addition the LF power spectrum of HRV has also been shown to be influenced by ventilation. Some individuals show peak respiratory frequencies at lower frequencies of the power spectrum as opposed to the majority that express it in the HF power spectrum band (Berntson et al., 1997). Respiratory sinus arrhythmia tends to contaminate LF HRV power spectrum at low respiratory rates of about 10 breaths per minute (Berntson et al., 1997). Additionally, the LF power spectrum appears also to reflect a baroreflex resonance frequency (deBoer, Karemaker, & Strackee, 1987; Sleight et al., 1995). These findings suggest that RSA is mostly a function of the parasympathetic nervous system, with some sympathetic contribution. Therefore if one uses traditional HRV analysis and ignores the effects of respiration on the components of HRV power spectra, a problem arises of calculating the extent to which the SNS and PSNS contribute towards the LF and HF components of HRV power spectra analysis.

It has been recommended that researchers using HRV power spectral analysis in their studies should attempt to control the ventilation rate of the participants (Brown, Beightol, Koh, & Eckberg, 1993). When conducting research, respiratory rate may be synchronised to a metronome set at a desired frequency. Researchers have previously used a rate of 15 breaths per minute; a frequency of 0.25Hz to control RSA (Igarashii & Budgell, 2000; Song & Lehrer, 2003). Controlling breathing rate will permit the frequency peak of the spectrum relating to breathing rate to be located centrally within the HF band of the power spectrum (Berntson et al., 1997). This will ensure that parasympathetic activity be contained within the HF band and reduces the chance of RSA influencing LF values (Aysin & Aysin, 2006). However, it has been proposed that the mental exertion necessary to concentrate on maintaining a desired ventilation rate may prevent the participants from adequately relaxing (Berntson et al., 1997) and therefore bias the results towards sympathetic predominance.

Role of Ectopy Influencing Heart Rate Variability

Another factor which is known to influence the results of HRV power spectral analysis is the presence of ectopic heart beats (Mateo & Laguna, 2003). Ectopic beats are premature contractions of the heart, before a normal contraction (Malik & Camm, 1995). The majority of ectopic beats arise from ectopic foci in the heart. These discharge irregular impulses at abnormal times during the cardiac cycle. Sometimes these are associated with electrolyte imbalances in the blood (Hollifield, 1989) and regularly occur in patients with diseased myocardium (Blumenthal et al., 2007; Smith et al., 2009). Ectopic beats may be caused or aggravated by excessive smoking, alcohol consumption, caffeine, certain medications such as stimulants and some illicit drugs (Topol, 2002). It has been observed that if 1% of beats within an ECG recording are ectopic then this is sufficient to contaminate the HRV signal to noticeably affect analysis (Storck, Ericson, Lindblad, & Jensen-Urstad, 2001). It has therefore been advised that short term ECG recordings intended for HRV analysis should be removed of ectopic beats and signal noise and interpolated where necessary (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996).

Reliability of Heart Rate Variability Measurements

Short-term (5-15 minutes) HRV recordings have shown highly variable reliability coefficients in several investigations (Sandercock, Bromley, & Brodie, 2005; Tarkiainen et al., 2005). It has been suggested (Tarkiainen et al., 2005) that HRV recordings of 40 minutes or greater demonstrate significantly less variation than short-term recordings and therefore recordings of this duration should be used in preference of short-term recordings. It has been shown (Tarkiainen et al.,

2005) that the coefficient of variation varied between 5.1-16.7% for the 40-minute and 6.0-37.1% for the 5-minute time domain and 4.4-11.0 % for the 40-minute and 7.2-16.5 % for the 5-minute frequency domain measurements. Even day to day changes in HRV parameters with no intervention demonstrate large variability. It was shown that (Maestri et al., 2009) measurements of HRV parameters can be 2–4 times larger or 0.5–0.25 times smaller than the measurements taken 24 hours earlier. These results indicate that large random changes in HRV indices are to be expected in the same subject from day to day measurement. Due to this, in response to a manual therapy intervention, it is difficult to ascertain what a minimum clinically significant change in HRV is as this would need to be greater than normal individual day to day variation.

Clinically Relevant Change in Heart Rate Variability

Although changes have been observed in HRV in response to manual therapy in previous studies (Budgell & Hirano, 2001; Budgell & Polus, 2006; Henderson et al., 2010), it remains uncertain if these changes are clinically relevant as currently there is no criterion as to what constitutes a clinically relevant change in HRV or autonomic activity in response to manual therapy (Maestri et al., 2009; Pinna et al., 2007). However one study (Pinna et al., 2007) has attempted to create criterion for what they define as a clinically relevant change in HRV indices. They define this as a change greater than or equal to 30% of between-subject standard deviation. This choice was based on the rationale that the larger the spread of values in a population, the greater the effect of a treatment should be in order to be clinically relevant. Despite this, HRV changes in response to factors of everyday life, demonstrate similar magnitudes of change to the changes observed in studies in response to manual therapy intervention (Budgell & Hirano, 2001; Budgell & Polus, 2006; Henderson et al., 2010). These activities include smoking (Karakaya, 2007; Nabors-Oberg, Niaura, Sollers, & Hayer, 2002), body position (Jáuregui-Renaud et al., 2001; Lee et al., 2004), caffeinated beverage consumption (Quinlan et al., 2000; Rauh, Burkert, Siepmann, & Mueck-Weymann, 2006; Sondermeijer et al., 2002), mental stress (Bernardi et al., 2000) massage (Buttagat, Eungpinichpong, Chatchawan, & Kharmwan, 2011; Takamoto et al., 2009), diurnal rhythm (Boudreau, Yeh, Dumont, & Boivin, 2012; Roeser et al., 2012), and menstrual cycle (Bai, Li, Zhou, & Li, 2009; McKinley et al., 2009) among others. Additionally environmental factors such as light levels (Schäfer & Kratky, 2006), temperature (Bruce-Low et al., 2006; Fox et al., 1991), and ambient noise (van Amelsvoort et al., 2000), have been shown to influence HRV. Therefore for clinically relevant changes in HRV induced by a manual therapy technique to be deemed significant, the changes must be greater than normal individual day to day variations and greater than the influences of activities of daily life and normal environmental change.

Additionally, as yet there are no defined HRV parameter values that are considered to be healthy or normal, and without this, clinically relevant change is difficult to define.

What is Normal Heart Rate Variability?

Attempts have been made among researchers to define what healthy normative values of HRV parameters are, yet no defined values have been agreed upon. A study (Kobayashi, Park, & Miyazaki, 2012) enrolled 417 healthy young Japanese men with a mean age of 21.9 years ± 1.6 years. Heart rate variability parameters were recorded for 2 minutes between 6:30 am and 7:30am and were recorded again at the same time 24 hours later. Results showed that the mean log-transformed HF component was 9.84 ln-ms^2, and the mean log-transformed LF component was 10.42 ln-ms^2. Another study (Aysin, 2006) observed similar findings to Kobayashi, Park & Miyazaki (2012). Aysin (2006), enrolled 100 healthy participants (mean age 36 years ± 14 years) and measured their HRV parameters. They found that the log-transformed values of LF and HF ranged between 0.55-10.35 ln-ms^2 and between 0.50-10.30 ln-ms^2 respectively. These are similar values to what were found by the Kobayashi, Park & Miyzazki (2012), study, however the larger range reported by Aysin (2006) may be caused by the larger and older age range of enrolled participants in this study (mean age 36 years ± 14 years) compared to the mean age of 21.9 years ± 1.6 years reported in the Kobayashi, Park & Miyzazki (2012), study. This larger age range of enrolled participants better represents a normal population.

Perhaps the best evidence for healthy normative HRV parameters comes from a quantitative systematic review of ‘normal’ values of HRV parameters. The authors (Nunan, Sandercock, & Brodie, 2010) reviewed and included 44 studies, which involved over 21,438 participants. Based upon the data of 18 studies in the systematic review (Nunan et al., 2010) it appears that a normative healthy LF would be a log-transformed LF value of 5.01 ln-ms^2 with a range between 2.05-7.31 ln-ms^2. Additionally based upon another 18 studies, it was found that the normative healthy HF log-transformed value was 4.76 ln-ms^2 with a range between 0.08-6.95 ln-ms^2. For the non-log transformed values of HRV parameters, those that are expressed in normalised units; 29 studies showed that the mean LF was 52 nu (range: 30-65 nu), and 30 studies showed that the mean HF was 40 nu (range: 16-60 nu). Based on the data from the systematic review (Nunan et al., 2010) it appears that a normative healthy LF would be approximately 52 nu or 5 ln-ms^2, and a normative healthy HF would be approximately 40 nu and 4.76 ln-ms^2. Therefore any value outside or approaching the edge of the reported ranges could be considered a deviation from healthy and might form criteria for inclusion or exclusion in future studies.

Effects on the Autonomic Nervous System After Application of Osteopathic Manipulative Treatment and Other Manual Therapy Treatment Techniques

This section discusses and critiques the literature addressing manual therapy technique and its influence on autonomic function. It is divided into three sections. The first section discusses studies that have shown no change in autonomic response following manual therapy. The second section reviews studies which have shown an increase in sympathetic activity, and the third section discusses studies which demonstrated a reduction in sympathetic activity.

Studies Which Found No Effect

Osteopathic manipulative treatment applied to the thoracic spine and its influence on HRV

Several studies have found no effect on cardiac autonomic response following application of OMT. A study (Buchmueller, 2007) on 31 young and healthy participants investigated the effects of HVLAT delivered by an osteopath on changes in HRV compared with a sham HVLAT. The researcher found that "there was no statistically significant difference in high frequency and low frequency variables of pre-intervention and post-intervention HRV data for either HVLAT or the sham intervention" (Buchmueller, 2007). The mean pre LF:HF ratio was 6.07 nu and immediately post genuine HVLAT the mean ratio was 5.67 nu ($z = -.431$, $p>.05$). The participants that were enrolled in this study were naive to HVLAT techniques and therefore the risk of expectation bias was minimised. The study concluded that HVLAT does not influence HRV parameters in asymptomatic individuals.

Physiotherapy treatment applied to the thoracic spine and its influence on HRV

Another osteopathic study (Sillevis et al., 2010) found similar evidence to Buchmueller (2007). The study aimed to investigate the immediate effect of a T3–T4 spinal thrust manipulation on autonomic nervous system activity in subjects with chronic cervical pain. One hundred participants were enrolled. They were assigned to a genuine T3-T4 thoracic segment HVLAT, or a light touch placebo group. The researchers used pupillary reflex diameter as a measure of ANS activity. The mean pupil size pre-HVLAT was 152.49 computer pixels (SD= ± 27.54) and the mean post-HVLAT measurement was 154.21 computer pixels (SD= ± 27.17). A change of 1.86 computer pixels was observed. Friedman's test showed that there was no statistically significant change in the mean pupil diameter (P=1.0). There was a statistically significant difference in the mean pupil diameter within the placebo group (P<0.001) as pupil diameter decreased over time

for the placebo group (mean pre-placebo = 142.79 [SD= ± 27.4] computer pixels, mean post placebo = 138.51 [SD= ± 23.58] computer pixels [*P*<0.001]
[-4.28 change]). Due to the participants having chronic cervical pain and since pain has been shown to influence autonomic function (Rajendra Acharya et al., 2006; Roy et al., 2009; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996) the participants pain may have confounded the changes observed in pupillary reflex diameter after HVLAT and placebo intervention. Nevertheless, results of this study demonstrated that genuine HVLAT did not result an increase in sympathetic activity as no significant change in pupillary reflex diameter was observed.

Since there are only a two studies (Buchmueller, 2007; Sillevis et al., 2010) that demonstrated no significant changes in ANS activity post-OMT application, additional studies are needed to investigate the reproducibility of no effect and this must be investigated across multiple populations such as the young, elderly, pain or pain free, etc. in an attempt to clarify OMT and its effects on the ANS.

Studies Which Found Increases in Sympathetic Activity

<u>Physiotherapy manipulative treatment applied to the cervical spine and its influence on HRV</u>

Many studies have demonstrated an increase in sympathetic output in response to spinal manipulation through various manual therapy treatment modalities. A physiotherapy study by McGuinness et. Al (1994), enrolled 23 individuals. Each participant received a ‘central posteroanterior grade III mobilisation technique’; a placebo technique which involved manual contact of the therapists thumb tips over the spinous process of C5; and no treatment (control). The ‘central posteroanterior grade III mobilisation’ technique and the placebo were both applied to cervical level C5. Participants were deemed ‘naïve’ to the treatment technique of ‘central posteroanterior grade III mobilisation’ technique as never having received one before. The authors found that there was a significant increase in heart rate (P=0.0028, mean increase of 7.33 beats per minute), respiratory rate (P=0.0001, mean increase of 5.7 breaths per minute) and blood pressure (P=0.001, mean increase in systolic pressure by 5mmHg and mean increase in diastolic of 9mmHg) after cervical spine manipulation compared to the control group and placebo group (McGuiness et al., 1994). If the participants were ‘naïve’ to the technique applied, it could be assumed the risk of expectation bias was low. If the participants have never received a ‘central posteroanterior grade III mobilisation’ technique before, then the ‘click’ or ‘popping’ sound heard upon successful application may alarm and frighten some of the participants as they could associate the sound with something ‘breaking’ in their cervical spine. This could possibly cause an acute stress response whereby the sympathetic nervous system becomes activated due to physical or mental stress, which is commonly referred to as the ‘fight-flight-fright’ response (Bracha, 2004). Because of this reaction, measurements of sympathetic activity would be easier to detect. Additionally, rather than a direct result of the mobilisation technique, the sympathetic response observed in the participants may actually be a result or combination of head tilt and/or supine positioning of the participants, as the supine position is shown to elevate sympathetic activity (Jean-Louis et al., 2004; Watanabe et al., 2007), and positions of up to 10 degrees of cervical flexion (head tilt) have been shown to increase sympathetic activity (Malliani et al., 1997; Sharma et al., 2009).

Chiropractic manipulative treatment applied to the cervical spine and its influence on HRV

A study by Budgell & Hirano (2001), enrolled 25 young asymptomatic adults. The participants were randomised into 2 groups. One group received a genuine supine cervical spine ‘Chiropractic Manipulative Adjustment’ (CMA) applied to cervical levels of C1 and C2, and the other group received a sham procedure. It was found that there was an increase in LF:HF ratio (increase in sympathetic activity) of HRV in the CMA group whereas the sham group had no significant change. The mean pre-sham LF:HF ratio was 1.28 nu and the post-sham LF:HF ratio was 1.41 nu (P=0.948). The mean LF:HF ratio increased from 1.03 nu pre-CMA to 1.46 nu post-CMA (P=0.0037). The HF component of the power spectrum stayed relatively stationary (mean pre-CMA (54.1 nu) and mean post-CMA (52.2 nu) [P=0.671]), however the LF component of the power spectrum, representing sympathetic activity showed a significant increase (P=0.0061) from a mean of 38.3 nu pre-CMA to a mean 45.0 nu post-CMA (P=0.0061). These results suggest that CMA causes and increase in sympathetic activity immediately after application. However, the risk of expectation bias was high in this study as the participants were informed of the nature of the intervention (as they were chiropractic students) and this knowledge may have influenced the study’s outcome. Additionally the ‘cracking’ or ‘popping’ sound heard upon successful CMA could generate pre-conditioned physical response in the sample population used. It is likely that the participants were in a ‘sympathetic environment’ as they were positioned supine and head tilt may have been induced as a result of the applicator applying the CMA intervention or from the participants resting their head on a pillow during the intervention. Due to the potential exposure to this environment, post-intervention related changes in sympathetic autonomic activity would have been easier to detect in this study.

Chiropractic manipulative treatment applied to the thoracic spine and its influence on HRV

This same effect (increase in sympathetic activity) was observed in a study by Budgell & Polus (2006), where 28 healthy adults were enrolled and either assigned to a genuine thoracic adjustment group, a placebo adjustment group or control group. They found that a genuine application of spinal manipulation to the thoracic spine caused the mean ratio of the powers of the LF and HF components of power spectra to increase. The genuine thoracic manipulation group had a mean pre-manipulation LF:HF ratio of 0.9562 nu, post-intervention this increased to 1.304 nu (P=0.0030). Additionally the mean LF power spectra increased from 40.25 nu to 46.6 nu post manipulation (P=0.0210) with an accompanying decrease in mean HF power spectra values from mean 57.34 nu pre-manipulation to a mean 49.86 nu post manipulation (P=0.0043) in the genuine spinal manipulation group. These changes were not present in the placebo spinal manipulation group. No significant changes in the LF:HF ratio occurred in the control group either. Further examination of the methods cited by Budgell & Polus (2006), highlighted a predominance of male subjects (n=28; 23=male, 5=female) enrolled in their study. This gender discrepancy was also present in the previous study by Budgell & Hirano (2001), where 20 males and 5 females were enrolled. It is possible that in the above studies (Budgell & Hirano, 2001; Budgell & Polus, 2006) a gender specific response occurred due to the predominance of male subjects. It has been shown that males have a higher LF and LF:HF ratio then females (Mendonca et al., 2010; Ramaekers, Ector, Aubert, Rubens, & Van de Werf, 1998; Umetani, Singer, McCraty, & Atkinson, 1998) and therefore a sympathetic response as a result of spinal manipulation would be easier to detect in the sample used by Budgell & Polus (2006), and Budgell & Hirano (2001) due to the larger number of male participants. Additionally participants were placed in the supine position during the spinal manipulation to the thoracic spine. Since the supine position is associated with an increase in LF component of HRV (Jean-Louis et al., 2004; Malliani et al., 1991), this would likely cause the participants to express a greater LF component of HRV and therefore risk biasing the HRV recordings to detect a sympathetic increase in response to spinal manipulation. In this study (Budgell & Polus, 2006) HRV was recorded for 5 minutes for both pre and post-intervention data points. Short-term (5-15 minutes) HRV recordings have shown highly variable reliability coefficients in several investigations (Sandercock et al., 2005; Tarkiainen et al., 2005). If such variability exists within short-term HRV recordings, then the observed changes in HRV in response to the manual therapy intervention (Budgell & Hirano, 2001; Budgell & Polus, 2006) may actually be the normal day to day variations of HRV power spectra being observed.

Several studies (Budgell & Hirano, 2001; Budgell & Polus, 2006; Mc Guiness et al., 1994) have found that various manual therapy modalities of thoracic and cervical spinal manipulative treatment increase the LF component and the LF:HF ratio of HRV, which indicates that sympathetic autonomic output may increase immediately post-intervention. Despite these studies demonstrating an effect, other studies have observed decreases in sympathetic activity after manual therapy treatment intervention.

Studies Which Found Decreases in Sympathetic Activity

<u>Osteopathic manipulative treatment applied to the cervical spine and its influence on HRV.</u>

A study (Henley et al., 2008) enrolled 17 healthy participants. The authors were investigating the effects of OMT on participants that were exposed to a sympathetic environment which was a position of sustained 50-degree cervical flexion referred to as head tilt. Once in this position the researchers either administered OMT to the cervical spine, or a placebo technique, or nothing at all (control group). The OMT administered was a "cervical myofascial release" technique. Each participant was randomised and enrolled into one of the three groups, with crossover occurring at the end of each day over a 3 day period, such that each participant received the OMT, placebo, and acted as control. Heart rate variability data was gathered to measure changes in autonomic function. The researchers found that the participants when subjected to a sympathetic environment (50-degree head tilt) and who received the genuine 'cervical myofascial release' intervention, produced a parasympathetic response that was strong enough to substantially reduce the sympathetic activity induced by being in a sympathetic environment. Those participants in the control group had a pre-intervention mean LF:HF ratio of 1.46 nu, upon head-tilt this ratio increased to 4.85 nu. Those in the placebo group had a pre-intervention mean LF:HF ratio of 1.17 nu, upon head-tilt with the application of the sham OMT, this ratio increased to 4.44 nu. It can be seen that the placebo OMT had little effect at reducing the post-intervention head-tilt LF:HF ratio when compared to the control group. However if these results are compared with the results of the participants who were in the genuine OMT group, there is a noticeable reduction of the head-tilt LF:HF ratio post-intervention. The pre-intervention mean ratio of LF:HF in the genuine OMT group was 1.09 nu. Upon head-tilt and then application of the genuine OMT, the ratio only slightly increased to 1.83 nu ($P<0.001$, 95% CI for the mean change in LF:HF ratio for cervical myofascial release group: 1.11 nu to 2.56 nu; for the placebo group: 2.92 nu to 5.96 nu; and for the control group 3.62 nu to 6.08 nu) whereas the LF:HF ratio with head-tilt and application of sham intervention increased almost four times its baseline (from 1.17 nu at baseline to 4.44 nu after head-tilt and sham). Cervical myofascial release therefore resulted in a lower LF:HF ratio in the head-tilt phase by decreasing LF and increasing HF power in comparison to control and placebo groups (Henley et al., 2008). By placing a participant in a sympathetic environment this could mimic a participant that could be symptomatic, since OMT has a theorised therapeutic effect, the treatment effect induced by OMT may be greater if participants are symptomatic. It should also be noted that the participants were osteopathic faculty, staff, and students from the university where the research was conducted. This could increase the risk of expectation and social desirability bias confounding the results. However it could be argued that the treatment effect induced by expectation and social desirability bias would unlikely be strong enough to reduce sympathetic output due to the large sympathetic autonomic response produced from being positioned in a sustained sympathetic environment (head tilt).

Chiropractic adjustment applied to cervical and thoracic spine and its effect on autonomic function

Another study (Welch & Boone, 2008) found similar evidence to suggest that there is an increase in sympathetic activity immediately after application of manual therapy adjustment technique. Forty participants aged between 25-55 years old, who had normal blood pressure, no history of heart disease and were asymptomatic were enrolled in the study. The participants were enrolled into two groups. One group would receive cervical spine chiropractic adjustments and the other group would receive thoracic spine chiropractic adjustments. These adjustments would be non-standardised and applied to the spinal segment deemed necessary based upon chiropractic palpatory assessment. The participants were evaluated pre and post-chiropractic adjustment for changes in blood pressure and pulse rate, and 7 of the 40 participants additionally had their HRV recorded. It should be noted that the post-adjustment measurements were recorded one week after application of the adjustment and during that timeframe lifestyle factors such as stress, exercise, caffeine consumption, diurnal rhythm etc. may have had a chance to influence the patients HR, blood pressure and HRV, additionally during this time the spinal adjustments effects may have had sufficient time to 'washout' and weaken the causality. The researchers found that the mean diastolic pressure dropped significantly from 80.9mmHg to 75.3mmHg ($p=0.038$) among those receiving cervical adjustments, which was accompanied by a moderate clinical effect (0.50). Systolic pressure showed no significant difference pre to post-adjustment in those subjects receiving either cervical or thoracic adjustments. The mean LF:HF power spectra ratio decreased post-adjustment in 4 of the 7 participants that received the cervical adjustment, but an increase in the LF:HF ratio was observed in 3 of the 7 participants that received the thoracic adjustment. Perhaps if a larger sample size was used and more participants were assigned to the HRV recordings, then external validity would be improved. The observations made from this study weakly suggest that cervical spine chiropractic adjustments are linked to a shift to parasympathetic dominance of the ANS and thus a decrease is sympathetic activity albeit in a small sample population.

Chiropractic rib adjustment and its effect on tachycardia

A case study (Julian, 2008) that also reported a reduction in sympathetic output post-manual therapy intervention, reported on a 58 year old man with symptoms of tachycardia. He underwent surgery for a mitral valve repair. The 4th and 5th ribs on the right were separated by 3 cm during the operation. Upon chiropractic examination 5 days post-operatively there were 'misalignments' in his thoracic spine and most notably the 4th right rib. Ten days postoperatively he developed paroxysmal supraventricular tachycardia (SVT) occurring 5-6 times a week lasting between 30s to 20min. Conventionally he was treated with Soltalol (an antiarrhythmic drug), but the patient developed atrio-ventricular block and the medication was withdrawn. It was reported that a chiropractic manipulative adjustment applied to his 4th right rib was performed while the patient was experiencing an acute tachycardia attack. His pulse reportedly returned to 60bpm within 2 minutes after treatment. The author suggests that with on-going chiropractic treatment the frequency and duration of episodes of tachycardia were reduced, with reoccurrences of SVT only 2 to 3 times per month. It should be noted that this study involved a single participant that was symptomatic, whereas the majority of the above mentioned studies (Budgell & Hirano, 2001; Budgell & Polus, 2006; Henley et al., 2008; Mc Guiness et al., 1994; Welch & Boone, 2008) involving various rib, thoracic and cervical manual therapy treatment techniques involved multiple individuals that were asymptomatic at the time. Due to the nature of case studies, no inferences about causation can be drawn between the chiropractic rib manipulation and reduction in sympathetic output to the heart. For the same reason the results cannot be generalised to any external population. Despite this, the case study (Julian, 2008) highlights a potentially interesting relationship that requires more systematic investigation.

Rib raising technique and its effects on the autonomic nervous system.

Another study (Henderson et al., 2010) found similar evidence to Julian (2008), which suggests manual therapy applied to the rib head may result in a decrease in sympathetic activity. A pilot study of a randomised placebo controlled trial design enrolled 14 healthy participants. A RRT was applied to half of the participants, while a placebo (light touch) was applied to the other half. Salivary α-amylase concentration was used as a measure of ANS activity. Acinar cells within salivary glands produce α -amylase, among other components of saliva. Acinar cells have a sympathetic and parasympathetic autonomic innervation. Salivary α-amylase concentration increases are associated with increased levels of sympathetic activity (Bosch, de Geus, Veerman, Hoogstraten, & Nieuw Amerongen, 2003; Nater et al., 2006). Studies have shown that salivary α-amylase concentration has increased in response to adrenergic agonist drugs (Speirs, Herring, Cooper, Hardy, & Hind, 1974), physical (Speirs et al., 1974) and mental stress (Rohleder, Nater, Wolf, Ehlert, & Kirschbaum, 2004). Additionally salivary α-amylase concentration has decreased in response to adrenergic antagonist drugs (Laurikainen, Laurikainen, Tenovuo, Kaila, & Vilja, 1988; van Stegeren, Rohleder, Everaerd, & Wolf, 2006). A decrease in salivary α-amylase concentration was seen in all participants who received OMT, suggesting a reduction in sympathetic output, but the extent of the decrease varied between participants. Subjects in the genuine RRT group had a mean salivary α-amylase baseline concentration of 76.2 U/ml. After application of RRT there was a statistically significant decrease with a small to moderate effect size in α-amylase immediately after application (mean salivary α-amylase 57.3 U/ml) (P=0.014; effect size 0.52), and 10 minutes after application (mean salivary α-amylase 46 U/ml) (P=0.008; effect size 0.85). Such a change in α-amylase activity was not seen in the placebo group at either immediately or 10 min post-intervention. Salivary α-amylase concentration change is a recent measure of ANS activity and further research is needed for its validation as an effective measure of ANS activity (Fuentes et al., 2011).

Summary

Many studies have investigated the influence of manual therapy techniques on autonomic function. Currently there are two studies that found evidence of reasonable quality that OMT has no effect on ANS function (Buchmueller, 2007; Sillevis et al., 2010). Despite this, the majority of the evidence discussed suggests that there is an initial increase in sympathetic activity immediately after rib head stimulation or manual therapy spinal adjustment (Budgell & Hirano, 2001; Budgell & Polus, 2006; Mc Guiness et al., 1994) followed by an indeterminate period of decreased sympathetic activity (Henderson et al., 2010; Henley et al., 2008; Julian, 2008; Welch & Boone, 2008). There are only a few studies upon which to base this conclusion and verification by further research is necessary. Additionally, further study is needed to investigate the temporal characteristics of the supposed effects of manual therapy treatment on the ANS and the physiological mechanisms by which the theoretical effects occur. Despite the limited evidence to support it, the notion of RRT causing an increase in sympathetic activity followed by a decrease appears to be accepted within educational osteopathy texts (Gibbons & Tehan, 2006; Greenman, 2003; Nelson & Glonek, 2007; Ward, 2003).

Although changes were observed in HRV in response to numerous manual therapy studies (Budgell & Hirano, 2001; Budgell & Polus, 2006; Henley et al., 2008; Julian, 2008; Welch & Boone, 2008) it could be argued that these changes are not clinically relevant as currently there are no criteria as to what constitutes a clinically relevant change (Maestri et al., 2009; Pinna et al., 2007) in HRV or autonomic activity. Therefore the observed effects of manual therapy technique on HRV have little therapeutic value in a clinical environment until the magnitudes of clinically relevant change are defined. Changes in HRV in response to factors of everyday life and environmental change have shown similar magnitudes of change as the changes observed due to manual therapy intervention (Budgell & Hirano, 2001; Budgell & Polus, 2006; Henderson et al., 2010). These lifestyle factors include body position, anxiety, stress, expectation bias, gender, caffeinated beverage consumption, cigarette consumption, alcohol consumption, drug use, exercise, diurnal rhythm, symptomology, ambient noise and light and room temperature among other factors. If the magnitude of change of HRV in response to manual therapy is similar to the magnitude of change in HRV observed from activities of daily life, then the therapeutic ability of manual therapy technique influencing autonomic function remains unclear.

It is therefore evident that new and additional research is needed to generate data in an attempt to clarify the pre-existing differing evidence surrounding the use of various modalities of manual therapy treatment technique and their effects on the ANS.

In response to this need for further research, ‘Section 2’ of the thesis reports on an experimental investigation that addresses the research question: What effect (if any) does RRT applied to ribs 1 to 5 bilaterally, in young and healthy participants have on HRV power spectra parameters? Additionally if there is an effect on HRV parameters what is the duration?

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Section 2

Manuscript

Note: This manuscript was prepared in general accordance with the Instructions for Authors (See thesis Appendices) for the *International Journal of Osteopathic Medicine*, however, there are three main deviations: i) The manuscript exceeds the prescribed word count in the journal guidelines in order to address the learning outcomes inherent in a research thesis; ii) For ease of reading the Tables and Figures are typeset in the text; and iii) The style of headings and sub-headings also differs from that prescribed for ease of reading.

The immediate effect of osteopathic ‘rib raising’ technique on heart rate variability: A randomised sham controlled experiment

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Abstract

The immediate effect of osteopathic 'rib raising' technique on heart rate variability: A randomised sham controlled experiment

Objective: To investigate application of an Osteopathic Manipulative Treatment (OMT) known as Rib Raising Technique (RRT) and measure its effects on the autonomic nervous system (ANS) by detecting changes in Heart Rate Variability (HRV) parameters.

Design: A randomised, participant blinded, sham controlled experimental design.

Participants: Eighteen healthy asymptomatic volunteers (n=18; 9 males, 9 females; mean age = 23.9 ± 2.3 years) were recruited from a university population.

Methods: Participants were randomly allocated to sham or 'genuine' intervention groups. Participants in the genuine intervention group received a RRT applied to the upper five ribs within a single session. Those in the sham intervention group received a sham intervention designed to mimic the RRT intervention in a single session. Pre-test and post-test measures of the low frequency (LF), high frequency (HF), and low frequency: high frequency ratio (LF:HF) of the power spectra components of HRV analysis were recorded, immediately post-intervention, 24 hours post-intervention, and 7 days post-intervention.

Results: No significant difference was detected in either the RRT or sham groups between mean pre-intervention compared with immediate post-intervention; or between mean pre-intervention compared with post-intervention at 24-hour or 7-day follow up measures for any of the calculated HRV indices (LF, HF, LF:HF ratio).

Conclusion: The findings of this study indicate that RRT was not accompanied by statistically significant changes in the power spectra parameters of HRV in healthy participants.

MeSH Keywords: Therapeutics; Physical Therapy Modalities; Musculoskeletal Manipulations; Manipulation, Osteopathic

Introduction

The osteopathic profession has long recognised a relationship between the autonomic nervous system and the function of the body in health and disease,[1] although there is relatively little quantitative data evaluating the effectiveness of osteopathic manipulative treatment (OMT) modifying autonomic nervous system functionality or the mechanism behind its action.[2-6] The supposed mechanism of action of OMT is based on autonomic activation causing associated vasodilation, smooth muscle relaxation and increased blood flow, resulting in improved range of motion, decrease in pain perception and change in tissue quality.[1] Until recently this association remained largely putative due to the inability to accurately and directly measure autonomic activity. Over the past two decades indirect methods of autonomic nervous system (ANS) function measurement have been developed and refined to provide non-invasive markers of autonomic balance with heart rate variability (HRV) being commonly used.[7, 8] Currently further research is needed to investigate the mechanisms underlying alterations in the function of the autonomic nervous system associated with OMT technique.[5, 6]

Rib Raising Technique (RRT) is an osteopathic manual technique that is commonly used within the osteopathic profession.[1] Kuchera & Kuchera[9] make the claim that RRT is "the primary manipulative method by which the osteopathic physician affects the hyper-sympathetic activity initiated by dysfunction or disease". Kuchera & Kuchera[9] assert that effective rib raising technique "lifts and rotates the rib heads; they, in turn, pull on the surrounding fascias that are common to a rib head and its sympathetic chain ganglion" but this has not been investigated despite being claimed in many osteopathic texts.[1, 7-10] Rib raising technique has claimed to exert several effects, these include: reduction of pain;[9] increase in joint range of motion;[9, 10] improvement of lymphatic flow;[10] and normalization of autonomic nervous system modulation.[1, 6, 9, 10]

To date various manual therapy modalities have investigated the effects of their respective treatment techniques on ANS function. These manipulative techniques are applied to the thoracic spine;[5, 11, 12] cervical spine;[4, 13-15] and costovertebral and costotransverse joints.[6, 16] Some studies have demonstrated a statistically significant change whether it be an increase[12-14] or decrease[4, 6, 15] in sympathetic or parasympathetic activity. Additionally, other studies have found little correlation[5, 11] regarding manual therapy influencing autonomic function.

The aim of this study was to investigate the effect of an OMT known as RRT on ANS function as measured by changes in heart rate variability (HRV) parameters. The study further aimed to quantify the duration of the observed changes (if any) of HRV in response to RRT.

Methods

Design

A sham controlled pre-post experimental design was undertaken in the clinical research environment. Participants were blinded to the intervention. See Figure 3 for study flow diagram.

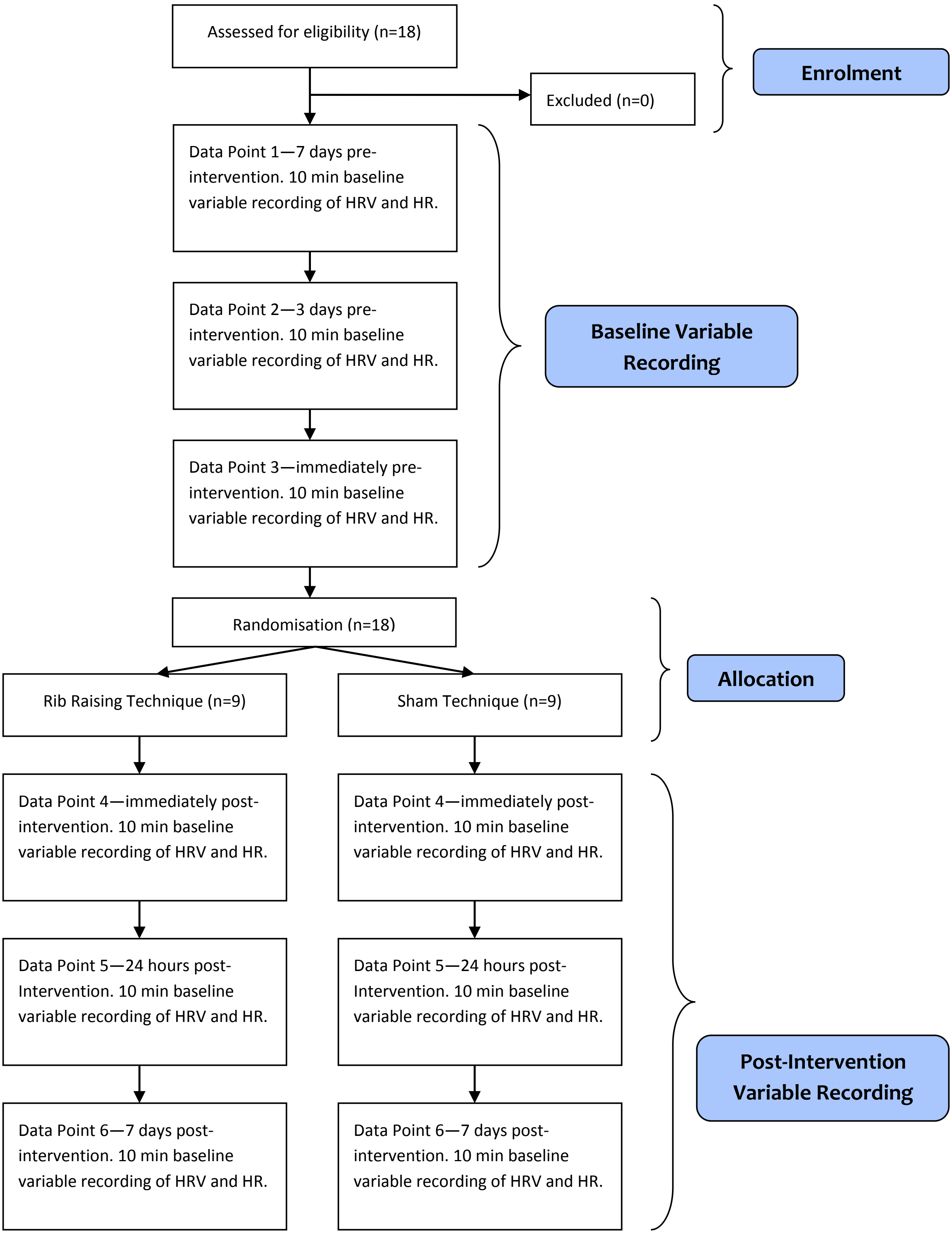

Figure 3 – Study Flow Diagram

Variables

Independent Variables

- Rib raising technique as described by Nelson & Glonek.[10]

- Sham technique based upon a RRT sham used in previous studies.[6, 16, 17]

Dependent Variables

- The power spectra components of HRV. These include: low frequency, high frequency, and low frequency: high frequency ratio, as outlined in Task force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology[24] standards of measurements.

Participants

Participants were recruited via word of mouth and poster advertising at Unitec New Zealand. All participants satisfied exclusion and inclusion criteria.

Participants were excluded if:

- They had current pain anywhere in their body.
- They had a systolic blood pressure of 140mmHg or higher or a diastolic blood pressure of 90mmHg or higher.
- They reported a history of cervicothoracic surgery, fracture or dislocation, or known anatomical abnormality in the cervicothoracic region.
- They reported a history of cervicothoracic trauma within the previous three months or persistent symptoms from an earlier trauma.
- They reported a history of cancer.
- They reported a history of stroke or any other cardiovascular disease.
- They reported a history of positional vertigo.
- They reported that they were currently taking any medications to manage a cardiovascular disease or a steroid medication.

To be included in the study participants must:

- Be aged between 20 and 30 years.
- Speak read and comprehend English.

Attempts were made to recruit participants on the basis that they were naïve to RRT. Naivety was defined as people who had not received RRT and had no knowledge of RRT supposed effects. Preferentially, participants were enrolled from the general public. Participants were asked to avoid vigorous exercise and caffeinated beverage consumption 24 hours prior to commencement of data collection.

Practitioner

The osteopath applying the intervention was recruited using convenience sampling from the teaching staff of the Department of Osteopathy, Unitec Institute of Technology. The practitioner had 6-years clinical experience and held a current annual practicing certificate from the Osteopathic Council of New Zealand.

Ethics

Written informed consent was obtained from all participants prior to study commencement. The study was approved by the Unitec Research Ethics Committee. Unitec Research Ethics Committee Approval Number: 2011-1235.

Experimental Procedure

Measurement Equipment

A heart rate monitor (Polar s810i, Polar Electro Oy, Finland)[18] was used to record each participant's heart rate (HR) using R-R intervals. The following process was used as described in the manufacturer's user manual[18] to setup the equipment and begin recording.

1. The transmitter was attached to the elastic strap which was then placed around the participant's chest.
2. The transmitter was placed just inferior to the participant's xiphoid process. The strap was sufficiently tight so that it would not move if the participant moved, but loose enough so that it would not interfere with breathing function.
3. The watch receiver was strapped on to the participant's wrist.
4. The red button on the watch was pressed to allow HR data to be received by the watch. It was pressed a second time to begin recording.

Pre Data Collection

Before beginning HR and HRV measurement the participant's blood pressure was measured and confirmed to be within between 120/70 and 130/80 mmHg. Blood pressure was measured with an aneroid sphygmomanometer and a standard stethoscope (Littmann Classic II SE, 3M).

Baseline Variable Recording

The first data point for the recording of baseline variables for the intervention group and sham group occurred 7 days prior to the application of the intervention (See Figure 1). The participants were seated in a quiet research room. The primary researcher entered the room and attached the Polar S810i heart rate monitor transducer around the participant's chest and attached the watch receiver to the participant's wrist as described by the Polar S810i user manual.[18] The researcher ensured that each participant's HR was detected by the watch receiver and then waited for a period of 2 minutes to allow the HR to return to a resting state. Then the researcher pressed the red record button on the receiver and the participant's HR was recorded continuously for a period of 10 minutes. The same process was used to record the same variables again, 3 days prior to the intervention and once again immediately before the application of the intervention. Thus there were three points of data collection before the RRT or sham intervention was applied.

Randomisation

Randomisation order was tabulated prior to commencement of data collection. The participants were assigned a unique identification number and then block randomized using Random Allocation Software v1.0[19] into 2 groups of 9. The two groups represent the RRT intervention group and the sham group.

Intervention

The researcher would inform the osteopath which intervention to apply to the participant, based upon the aforementioned randomisation. The osteopath would then enter the research room and apply either a RRT or a sham intervention as described below.

Procedure of the Genuine Rib Raising Technique

A seated RRT was applied as described by Nelson & Glonek,[10] see Figure 4 for details.

Step 1
The participant was seated on the treatment table with their arms crossed in front of their chest. Their hands are touching their opposite elbows. Their arms and elbows are flexed to 90°. The participant then rested their forehead on their folded arms.

Step 2
The osteopath was standing facing the participant. The osteopath then reached with their hands through the gaps between the participant's lateral side of their face and their adjacent folded arms. The osteopath's hands then reached over the participant's shoulders and come into bi-lateral contact with the participant's rib angles.

Step 3
The osteopath then induced gentle extension of the participant's thoracic spine and simultaneously leans backwards with his body, at the same time inducing a superior-anterior-lateral movement over the angle of the rib with the applicator fingers (direction of movement shown with arrows).

Figure 4 – Rib Raising Technique Procedure

The osteopath applied the RRT whereby they moved superior to inferior from rib 1 to rib 2 and so forth, until reaching and stopping at rib 5. Here the osteopath restarted back at rib 1 and proceeded in the sequence of rib 1,2,3,4,5,1,2,3,4,5 and so on. The RRT was applied for 10 min one bi-lateral articulation of each rib level per 8s (0.133Hz) equating to approximately 80 repetitions in total. The frequency was signalled by silent metronome set to 0.133Hz that was placed behind the participant out of their view, but in the view of the osteopath applying the RRT which allowed the osteopath to stay in synchronicity.

Procedure of the Sham Intervention

The sham RRT was based upon light touch and examination procedures. It was applied by the osteopath to the participant's cervical, thoracic and costal region, with no intention to influence the thoracic paravertebral ganglia. The sham used in this study was based upon a successful sham to RRT used in previous studies.[6, 16, 17] The sham intervention procedure was applied to the participant whilst they were in a seated position. This procedure took 10 min and was applied by the same osteopath who applied the genuine RRT intervention. The procedure is described in Figures 5 and 6.

Step 1
The osteopath was standing facing the participant. The participant was seated on the treatment table with their arms crossed in front of their chest. Their hands were touching their opposite elbows. Their arms and elbows were flexed to 90°. The participant then rested their forehead on their folded arms. The osteopath then reached with his hands through the gaps between the participant's lateral side of their face and their adjacent folded arms. The osteopath's hands then reached over the participant's shoulders and came into bi-lateral contact with the participant's rib angles and remained in contact for 1 minute. No movement was induced.

Step 2
The participant then returned their arms to their side and sat comfortably. The osteopath then faced the participant's back. The osteopath then lightly placed his hands on the participant's rib cage in a systematic and deliberate manner and palpated for preferred rib motion. At the same time observation of the subject's respiratory motion was noted. The osteopath then palpated the upper, middle and lower ribs and palpated them when the patient inhaled and exhaled.

Step 3
The osteopath then placed his hands on the participant and lightly palpated their paraspinal muscles starting at the thoraco-lumbar junction and slowly worked his way superiorly up the thoracic spine, taking care not to articulate the ribs. The osteopath observed segmental restrictions but did not engage the tissues for myofascial release.

Figure 5 – Sham Intervention Procedure

Step 4
Next, one hand was lightly placed posterior on the thoracic-lumbar junction and the other in the epigastric region. The osteopath's hands were held there for 1min. Tissue direction preference was tested, but no myofascial release was attempted.

Step 5
The osteopath applied light touch to the skin on the participant's cervical spine, followed by lightly placing his hands over the participant's thoracic outlet. Light motion testing was used for tissue direction preference but without using myofascial release.

Figure 6 – Sham Intervention Procedure (Continued)

Post-Intervention Variable Recording

Once the application of the RRT or sham intervention had been applied the osteopath exited the research room and the researcher would re-enter the room. Immediately, recording of the participants HR began for a duration of 10 minutes. The participants returned (24 hours later) and again 7 days post-intervention and had their HR measured using the same process as described above (See Figure 1).

Data Extraction

Offline analysis was performed on the 10 min of data recording for all of the data points for all the participants. Heart rate variability data was extracted from the wrist watch receiver using Polar ProTrainer 5 software.[20] The data was then imported into and analysed using HRV analysis software Kubios HRV 2.1.[21] R-R intervals were first displayed in a tachogram format and any ectopic beats or artefacts were identified. Ectopic beats were replaced and a new beat was interpolated between the previous and subsequent normal beat, as outlined by the Task force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology.[22] Data was excluded from analysis if ectopy was present that was greater than 1% of the total number of beats. Power spectral analysis was performed using Fast Fourier Transform calculations to determine how the variance, or power, was distributed as a function of frequency.[22] Spectral power was separated into the four frequency bands conventionally described: ultra-low frequency (ULF, <0.003Hz); very low frequency (VLF, 0.003-0.04Hz); low frequency (LF, 0.04-0.15); and high frequency (HF, 0.15-0.5).[22, 23] For the purposes of this study, only the LF and HF bands were used for data analysis.

Data Analysis

A group sequential approach to sample size was employed. The *a priori* plan was to collect data from 20 participants (n=10 genuine; n=10 sham) and then conduct a preliminary power analysis using statistical software G*Power[24] to determine the observed effect sizes in order to determine the power necessary to detect the observed effect. Raw data for all variables was tabulated and checked for normality using Shapiro-Wilk's test of normality together with inspection of P-P and Q-Q plots. In the case of normally distributed data, paired samples t-tests were used to investigate differences between time points. A 95% confidence interval for the mean difference between pairs was constructed. In the case of non-normally distributed data Wilcoxon signed-rank test was used. Effect sizes for parametric data were calculated using the Cohen's *d*.[25] Descriptors for magnitudes of effect are based on those described by Hopkins.[25] All data was analyzed using SPSS v19 (IBM Corp. Armonk, NY).[26] The threshold for statistical significance was set at alpha = 0.05.

Results

Visual inspection of individual tachograms showed that none of the HRV data recordings were affected by ectopy. Hence, there was no need for interpolation of heartbeats. Additionally no artifacts were present. All 18 participants completed the study. Of the 18 participants that provided complete data sets 9 were females and 9 males with an age range 21-29 years (mean age 23.9 years, SD ± 2.3 years). All participants were normotensive and pain free on the first day of baseline recordings and immediately prior to receiving the intervention (RRT or Sham).

The experiment was suspended after data from 18 participants was collected (n=9 RRT; n=9 sham). The observed magnitudes of effect for all contrasts in the genuine group were calculated to be 'practically zero' to 'trivial' ($d \leq 0.13$). Therefore the experiment was ceased at that point because interim power calculations indicated that to achieve a minimum power of 0.8 a total sample of n=467 would be required.[24] Such a sample was beyond the resources available for the project and therefore the data collection was ceased at that point.

The HF, LF, LF:HF ratio of HRV data for the RRT and sham was analyzed using a paired-sample *t* test. There was found to be no statistically significant difference in mean HF, LF and LF:HF ratio of immediately pre-intervention compared with immediately post-intervention, 24 hours post-intervention and 7 days post-intervention in either the RRT or the sham groups. See Table 1 for data and Figures 7 and 8.

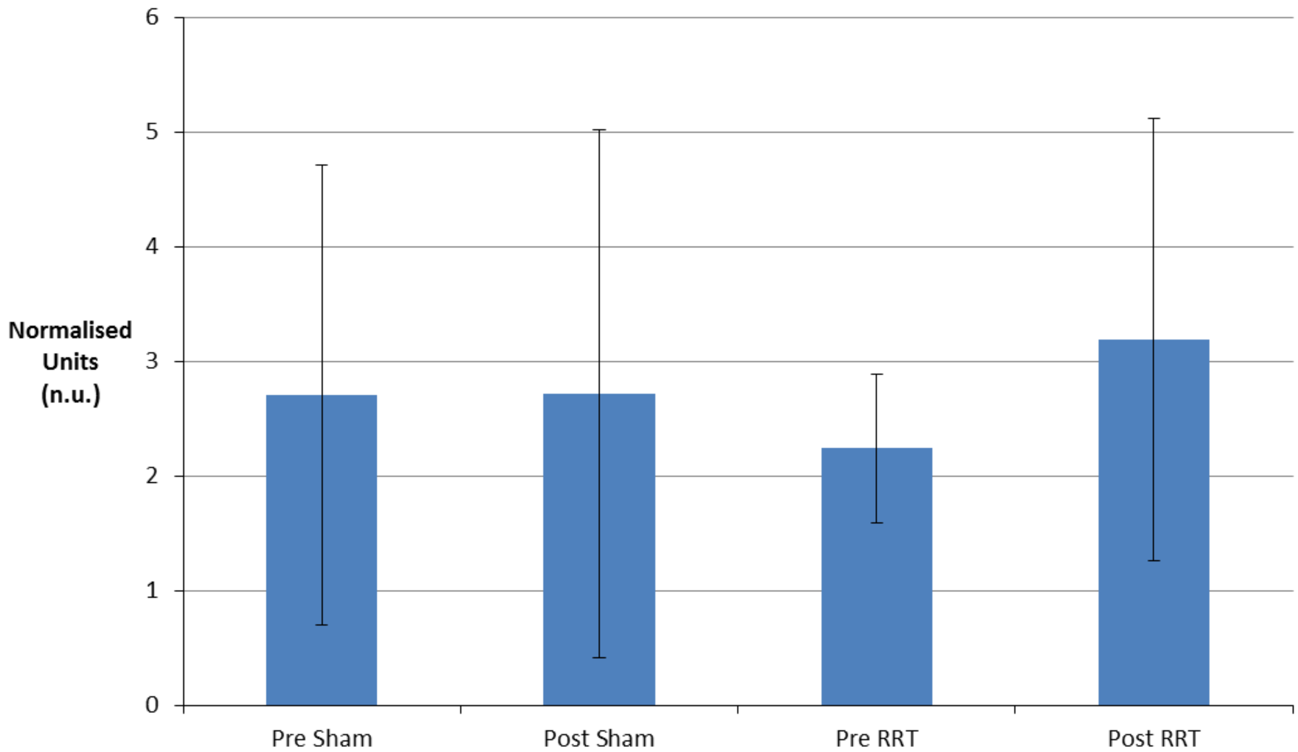

Figure 7 – Mean LF:HF Ratio Before and After Intervention Between Groups

A histogram illustrating the mean baseline LF:HF ratio compared with the mean immediately post intervention LF:HF ratio between sham and RRT groups. Error bars represent standard deviation

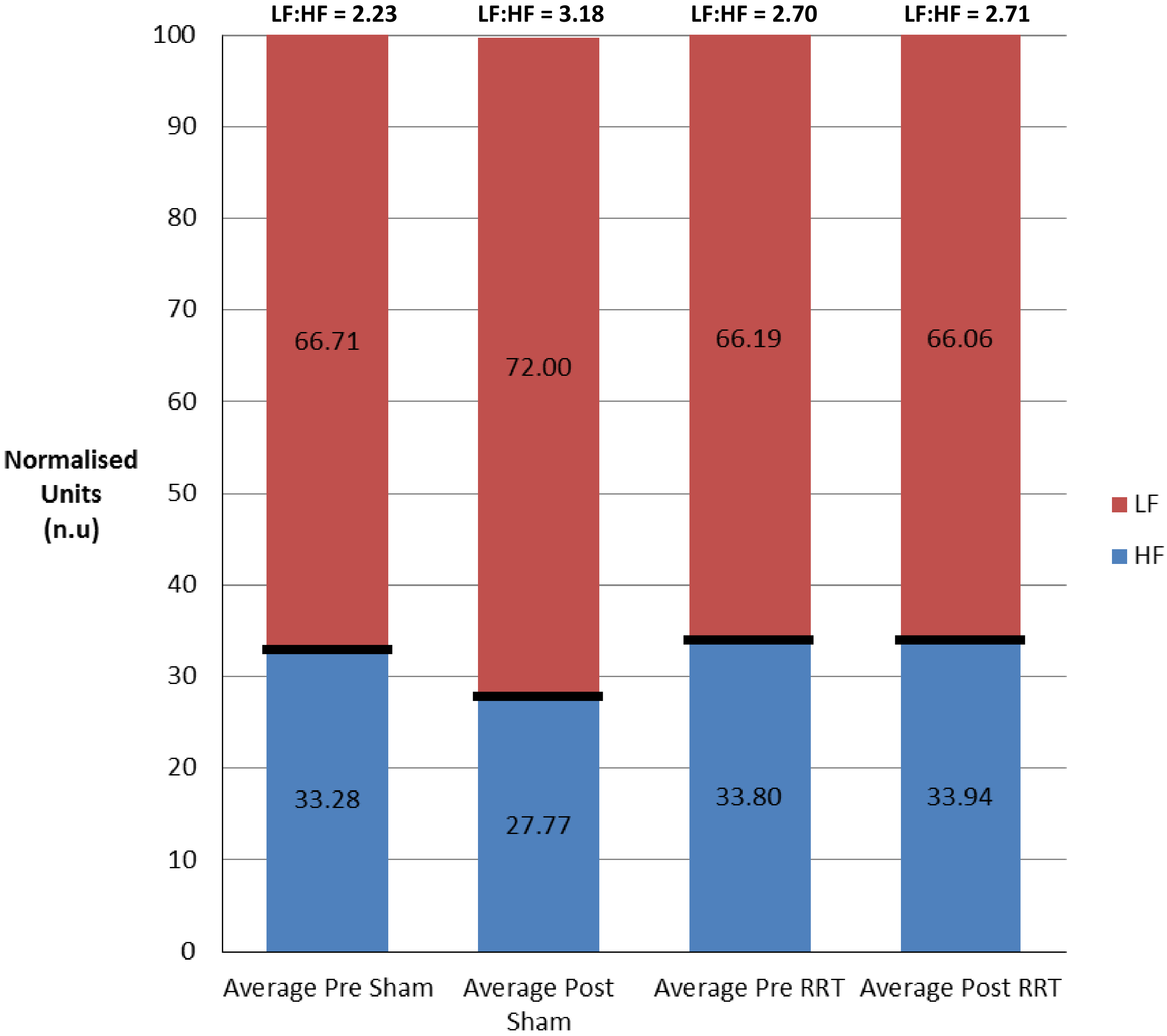

Figure 8 – Mean HRV Parameters Between RRT and Sham Groups

A stacked bar graph illustrating the average baseline LF, HF, LF:HF ratio compared with immediately post intervention LF, HF, and LF:HF ratio between RRT and sham groups. Note that figures on the bars represent the pooled mean LF and HF of all participants irrespective of RRT or sham. Also note that the LF:HF ratio represents the mean LF:HF of individual participants and not the ratio of the mean LF components over the mean HF components.

Table 1 – Results Table Showing Contrast Between Mean Baseline and Post-Intervention HRV Parameters

Variable	Group	Mean Difference	Mean Difference SD	95% CI for Difference		p-Value	Effect Size[a]	Descriptor[b]
				Lower	Upper			
Mean Baseline Pre LF - Mean Immediately Post LF	RRT	0.13	4.47	-3.3	3.57	0.92	0.01	Trivial
	Sham	-5.29	12.34	-14.78	4.2	0.23	0.8	Moderate
Mean Baseline Pre LF - Mean 24 Hours Post LF	RRT	-1.69	9.21	-8.78	5.39	0.59	0.12	Trivial
	Sham	2.88	10.15	-4.92	10.69	0.41	0.43	Small
Mean Baseline Pre LF - Mean 7 Days Post LF	RRT	-0.85	14.51	-12.04	10.27	0.85	0.06	Trivial
	Sham[c]	-0.71	9.11			0.76[c]	0.09	Trivial
Mean Baseline Pre HF - Mean Immediately Post HF	RRT	-0.14	4.47	-3.58	3.3	0.91	0.01	Trivial
	Sham	5.51	12.01	-3.72	14.75	0.2	0.83	Moderate
Mean Baseline Pre HF - Mean 24 Hours Post HF	RRT	1.8	8.75	-4.93	8.54	0.55	0.13	Trivial
	Sham	-0.89	10.13	-10.69	4.89	0.41	0.43	Small
Mean Baseline Pre HF - Mean 7 Days Post HF	RRT	0.65	14.87	-10.77	12.09	0.89	0.5	Small
	Sham	0.7	9.14	-6.33	7.73	0.82	0.1	Trivial
Mean Baseline Pre LF:HF - Mean Immediately Post LF:HF	RRT	-0.01	0.82	-0.65	0.62	0.97	0.01	Trivial
	Sham	-0.94	1.86	-2.38	0.49	0.16	1.45	Large
Mean Baseline Pre LF:HF - Mean 24 Hours Post LF:HF	RRT	0.21	1.16	-0.68	1.11	0.59	0.11	Trivial
	Sham	0.07	1.03	-0.72	0.87	0.83	0.12	Trivial
Mean Baseline Pre LF:HF - Mean 7 Days Post LF:HF Ratio	RRT	0.18	1.47	-0.95	1.32	0.72	0.9	Moderate
	Sham	-0.19	0.89	-0.88	0.5	0.54	0.29	Small

Notes

a. Effect sizes for non-parametric data were calculated using r = z/√n where n=9. Effect sizes for parametric data were calculated using Cohen's d.[25]
b. Descriptors for magnitudes of effect are based on those described Hopkins.[25]
c. Indicates that these variables are non-normally distributed. P-values were calculated using the Wilcoxon signed rank test.

Discussion

The aim of this study was to investigate the effects of RRT on HRV compared to a sham procedure. RRT is an osteopathic technique used for many indications, including rib restriction,[10] increasing thoracic mobility[1] and conditions associated with sympathetic hypertonia.[1, 9] This technique is claimed to initially stimulate sympathetic efferent activity followed by a prolonged reduction in sympathetic outflow from the treated region.[1, 10] Currently, there is limited evidence on the physiological effects of manual therapy techniques applied to the rib cage and the mechanisms through which these might exert their effects on the ANS.

This study investigated the existing claims regarding the effects of OMT including RRT influencing the ANS function as proposed by Kuchera & Kuchera[9] and Ward.[1] Because RRT is theorized to initially stimulate sympathetic nervous system (SNS) activity followed by a period of decrease in activity,[1, 9] an increase in the LF:HF ratio was predicted immediately after the application of a RRT, followed by a gradual decrease in LF:HF ratio. However, this effect was not observed in the current study. The results of the study showed that the application of the RRT technique to the T1-T5 ribs and spinal segments did not elicit statistically significant changes in the HRV parameters of LF, HF and LF:HF ratio compared to the sham intervention.

The design of the current study consisted of three baseline HR and HRV data points followed by three post-intervention data points. In other research designs such as single-subjects research designs, a minimum of 5 baseline points is recommended to provide an indication of baseline stability.[27, 28] For this study a larger number of baseline HRV data points would have enhanced the ability to define the baseline and to evaluate any changes observed after the application of the RRT, particularly proportional changes in HRV parameters.

In the current study the research environment where HRV was recorded was under limited control. Factors such as light levels,[29] ambient temperature,[30, 31] and ambient noise[32] were not closely controlled, which all have been shown to influence HRV. Although these factors were not specifically controlled, the research environment was typical of that in which the technique would be routinely applied in clinic.

The Polar S810i Heart Rate Monitor used in this study has demonstrated sound reliability[33, 34] and good validity.[35, 36] In the current study short-term (5-15 min) HRV recordings were used. Short-term HRV recordings have shown highly variable reliability coefficients in several investigations.[37, 38] If such variability exists, studies that demonstrated changes in HRV in response to manual therapy that used short-term HRV recordings[6, 12, 14] may have just been detecting the normal day to day variations of HRV in their enrolled participants. These results indicate that large random changes in HRV indices are to be expected in the same subject from day to day measurement, which could make the detection of treatment effects in individual participants difficult. Future studies should have baseline and post-intervention recordings of HRV of greater duration. It has been recommended[38] that HRV recordings of 40 min or greater demonstrate significantly less variation as opposed to short-term recordings and therefore recordings of this duration should be used in future studies.

A study by Budgell & Hirano,[14] reported a significant increase in the values of the LF band and the LF:HF ratio after application of a cervical chiropractic adjustment technique in 25 participants. This effect was not evident in participants that were enrolled in the sham intervention group. One of the limitations acknowledged by the authors was that participants were likely to be educated in the interventions outcome and therefore they may have had preconditioned expectations of the interventions outcome. Therefore a risk of expectation bias could have existed and this could have influenced the intervention of the chiropractic adjustment technique effects on HRV. Furthermore it has been suggested that the techniques of various manual therapies have substantial placebo effects.[39, 40] Adequate design of controlled experiments investigating the effects of manual techniques on ANS function should be designed to ensure high levels of blinding.[41] Those participants that demonstrated an increase in LF:HF may be considered as 'responders' to treatment. Due to the above-mentioned weakness in the research methods[14] it remains uncertain as to what the participants were responding to; either the observed changes in HRV are a response to HVLAT, expectation bias, or 'sham effects'. When cause and effect can be easily linked by participants, overestimations of causal relationships are common, especially when this relationship is associated with a desired outcome.[42] Hence, desired outcomes are associated with positive emotions, which lead to the reinforcement of individuals' speculations. As desired outcomes of an ANS response are associated with positive emotional responses, they are less likely to be abandoned by individuals and may therefore remain to be viewed as evidence.[43] In the current study it could be argued that most of the participants were informed of the nature of the intervention, as they were mostly osteopathic students (10 participants were osteopathic students and 8 participants were considered to be naïve to previous education or experience of OMT). The risk of expectation bias is considered to be high and therefore those educated in the effects of OMT on the ANS would likely bias the results of the study toward the theorised outcome of an increase in LF:HF ratio immediately post RRT intervention. However, contrary to the likely presence of expectation bias, the results of the study demonstrated that RRT had no significant effect on LF:HF which indicates there was no expectation bias amongst participants. Future studies, however, should still attempt to minimise expectation bias by strictly enrolling participants who are naïve to the manual therapy modality technique and associated theory, or previous exposure to the procedures being applied.

In this study the participants were seated, whilst the osteopath repetitively lifted the ribs in a rhythmic fashion as described by Nelson & Glonek.[10] However other authors[1, 10, 44] have described that RRT can be applied when the participant is in a supine position. It is known that body position can influence the LF and HF components of HRV,[45-48] with an increase in sympathetic activity in the standing position compared with the supine position and supine being greater than seated. These observed effects of body position on HRV may offer an explanation for the differences in results obtained by the current study compared with findings in previous studies where manual therapy technique was applied to participants in a supine position.[6, 12, 14] Therefore changes in sympathetic modulation of the heart would have been easier to detect in the studies where the participants were supine when the intervention was applied compared with the current study where the participants were seated.

Although being placed in the supine position supposedly creates elevated sympathetic activity, contrary to this notion; it has been demonstrated that the seated position is associated with a greater LF and LF:HF ratio, compared with prone and supine positions.[49] In this case, if a seated position is likely to create a greater sympathetic response, then the increased LF power spectra of HRV should have been easier to detect in the current study as the RRT was applied in a seated position. Although the seated positioning of the participants could have influenced their ANS activity, the current study still demonstrated no observable effect of RRT on HRV parameters. However, the relationship between RRT and participant positioning with regard to changes in HRV has yet to be investigated. The current study aimed to investigate changes in HRV as a result of RRT regardless of the common posture of participants.

The seated RRT required the use of sufficient force over the rib head to induce anterior-cephalad movement, so that by the end of the lift, minimal to no soft-tissue movement was palpated. It is likely that the amount of force that is needed to reach this endpoint in tissue movement would vary between participants and therefore the RRT would vary in application between participants. The association between the magnitude of force applied to the rib head and the change in power spectra components of HRV can be investigated in subsequent studies as it cannot yet be demonstrated that the force applied correlates linearly with the magnitude of change in HRV power spectra components.

All of the RRT and the sham technique interventions in this study were performed by the same qualified osteopath in an attempt to standardise the applied technique. The chance that slight variations in procedure among different osteopaths could induce different reactions in the participants was not considered. Different osteopaths with different levels of skill may produce variable levels of effectiveness when applying a RRT. Thus if several osteopaths were selected to apply the RRT in the current study, this could have changed the likelihood of observing an effect on the LF and HF components of HRV. Perhaps RRT effects on HRV can be investigated with different practitioners applying the RRT.

Respiratory rate has been shown to affect HR and HRV, causing an increase HR with inspiration and a decrease with expiration.[23, 50] Fluctuations of the R-R intervals in response to ventilation is termed respiratory sinus arrhythmia.[51] Metronome controlled ventilation has been employed in previous studies to limit breathing to certain frequencies, this was to allow the RSA to be confined within the HF band of the HRV spectrum.[12, 52, 53] Throughout the current study ventilation rate was not controlled. It has been proposed that the mental exertion necessary to concentrate on maintaining a desired ventilation rate may prevent the participants from adequately relaxing[23] and therefore tend to bias the results towards sympathetic predominance. This may be a contributing factor as to why the participants in previous studies[12, 52] demonstrated an observable increase in sympathetic activity following intervention.

In this study no observable effect on HRV power spectra as a result of RRT was observed. This result should be interpreted cautiously, as the result of no effect could be due to the likelihood of a Type II error given that the study was underpowered. The current study had a small sample size (n=18) that was recruited via convenience sampling. This method had the benefit of allowing easy recruitment, with the disadvantage of a greater risk of self-selection bias. Therefore those participants that were sufficiently interested and motivated to volunteer themselves for enrolment were selected for the study.[54] As a result of this, uncertainty exists about what the motive was behind why some people agreed to enroll, as opposed to those who did not. Although random samples are composed of participants that decide to participate voluntarily, unavoidably those who agree to be part of a random sample are self-selected and therefore cannot be assumed to represent the true population.[54] Therefore it is uncertain as to how typical the sample may be of any specific population, which may limit the ability of the current study's results to be generalized to the wider population. For this reason and because of the small sample size, the results of this study should be interpreted carefully. Future studies should address these issues by enrolling a larger sample and by utilizing random sampling methods.

Both Kuchera & Kuchera[9] and Ward,[1] do not specifically state whether the observed ANS effects of rib raising can be demonstrated in symptomatic or asymptomatic participants, although it may be implied that they refer to symptomatic patients when they discuss the effects of OMT influencing autonomic function since their writings are clinical textbooks. Rib raising technique may have different effects in symptomatic or asymptomatic participants, this may cause the RRT to modulate ANS activity in either direction depending on individual autonomic state of each participant.[55-58] It is possible that no autonomic effects were observed in the current study because the enrolled participants were asymptomatic at the time. It may be possible that symptomatic participants would be more likely to demonstrate a response to RRT than healthy asymptomatic participants due to the supposed therapeutic nature of the RRT. However, studies have shown that OMT can modify the sympathetic nervous system in asymptomatic participants.[12, 59] Possibly, people with elevated sympathetic activity could be used as symptomatic participants; however there are currently no criteria that exist that define elevated sympathetic nervous system activity. Perhaps future studies should recruit symptomatic participants defined as those with both an elevated SNS state and thoracic spine dysfunction with pain present in the region of the thoracic spine.

A limitation of the current study was that even though RRT was not contraindicated for the enrolled participants, it remained uncertain whether RRT would have been indicated in clinical practice. Additionally all of the enrolled participants were young and healthy, which is not representative of the population who would usually have received a RRT within the clinical environment. However, the aim of the current study was to investigate whether RRT can produce changes in HRV parameters with no intention of inducing a therapeutic effect, therefore it was appropriate for this study to investigate changes in HRV in young asymptomatic patients. Future research could investigate the effects of RRT on HRV in symptomatic participants compared to asymptomatic participants and investigate if RRT was indicated or not with these participants. This approach may resemble osteopathic practice more closely, rather than conducting trials on asymptomatic participants where RRT may not necessarily be indicated clinically. To investigate this comparison, it should be noted that pain in symptomatic participants has been shown to influence HRV recordings[22, 60, 61] which may confound the causality between RRT and HRV parameter changes if this was to be investigated in future studies.

Further examination of the methods cited by Budgell & Polus,[12] highlighted a predominance of male participants (n=28; 23 male, 5 female) enrolled in their study. It is possible that in the above study[12] a gender specific response may have occurred due to the predominance of male participants. It has been shown that males have a higher LF and LF:HF ratio then females[39-41, 62] and therefore a sympathetic response as a result of thoracic manipulative adjustment would be easier to detect in the male dominant sample used by Budgell & Polus.[12] By contrast, there was an equal ratio of male to female participants (n=18; 9=male, 9=female) recruited for the current study. In the current study a sympathetic response may have occurred due to the RRT but was masked from detection when the raw data was pooled for analysis. The combination of these two factors could result in a potential reduction of the mean sympathetic (LF) measure when the data was pooled for analysis. Future studies should consider comparing the effects of manual therapy techniques on HRV between gender groups.

Although HRV largely arises from ANS activity, HRV is an indirect measure of mean autonomic function.[22] In addition to ANS activity, HRV also reflects the state and function of the sinoatrial node, humoral factors, baro-receptors reflex, and central heart rate oscillators such as the respiratory centre of the brainstem.[22] Heart rate variability data is therefore not under the sole influence of ANS activity and should be interpreted as an indirect measure of autonomic function.

Future experimental studies should aim to reduce expectation bias by strictly enrolling participants who are naïve to the manual therapy modality technique being applied. Larger numbers of baseline and post intervention HRV data points should be used, with a greater duration HRV recordings to increase precision. Multiple measures of autonomic activity such as edge-light pupil cycle time, pupil diameter, salivary α-amylase and galvanic skin response in addition to HRV could be used to determine if autonomic changes are reflected across multiple measurements. The positioning of the participant must also be considered a factor that can bias measurements of autonomic activity. The contact forces the osteopath applies to the participant's ribs during RRT should be standardised using an instrumented pressure sensitive glove[63] or a treatment plinth mounted over a force plate.[64]

Conclusion

In this study, RRT was not accompanied by statistically significant changes in the power spectra parameters of HRV. Although the current study was under powered and observed effect sizes were determined to be tiny, the results of the current study do not support the theorised effects of RRT commonly described by osteopathic literature. Due to the evident lack of literature in this field and conflicting results in the research literature that does exist, further research is needed in people with musculoskeletal dysfunction and known elevated SNS states.

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Section 3

Appendices

Appendices

Unitec Research Ethics Committee Approval Letter

Unitec
Institute of Technology
TE WHARE WĀNANGA O WAIRAKA

Nicolas White
7 McMillan Road
Waiheke Island
Auckland

21.11.11

Dear Nicolas,

Your file number for this application: 2011-1235
Title: The effects of Osteopathic Manipulative Treatment known as Rib Raising on the autonomic nervous system as measured by changes in cardiovascular autonomic mediated variables in a cohort of young healthy adults: a randomised placebo controlled trial.

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: 16.11.2011
Finish date: 16.11.2012

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,

PP

Scott Wilson
Deputy Chair, UREC

cc: Jamie Mannion
Cynthia Almeida

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Henderson
Auckland 0612
New Zealand

Recruitment Advertisement

Research Participants Needed

We are investigating the effects of an Osteopathic treatment technique known as Rib Raising, on Heart Rate (HR) and Heart Rate Variability (HRV).

Ideal participants would be between 20-30 years of age, healthy, free of cardiovascular disease, who have no history of trauma to the neck, back or ribs.

If interested in participating, you will be asked to:

- Complete an eligibility form. This will determine if you are able to participate in the study.
- Attend a total of 4-5 measurement sessions over a 2 week period. Each session will approximately be 15-30 minutes in duration.
- During the measurement sessions you will have your heart rate recorded.
  - This will involve placing a heart rate monitor strap around your chest
  - HRV and HR measurements will be recorded while you are comfortably seated for a duration of 10 minutes.
- At the end of the third measurement session a qualified osteopath will apply the Rib Raising technique for 10 minutes.
  - Rib Raising technique is a gentle articulatory technique, where the ribs are slowly lifted up and forward.

Contact: **Nick White (Masters of Osteopathy Student)**
Phone: **02102423300**
Email:n.white.89@gmail.com

Or get an information sheet from the receptionist at Clinic 41.

UREC REGISTRATION NUMBER: 2011-1235
This study has been approved by the UNITEC Research Ethics Committee from 12/01/2012 to 12/01/2013. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162. Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

Research Information for Participants

Research Title:

Rib Raising osteopathic manipulative treatment and its immediate and short-term effects on heart rate variability in a cohort of young healthy adults: a randomised placebo controlled trial.

You are invited to participate in our research investigation. Please read carefully through this information sheet before you make a decision about volunteering.

Principal researcher:
Nicholas White (Bachelor of Applied Science (Human Biology). Nicholas is currently in his first year of the Masters of Osteopathy course at Unitec New Zealand.

What we are doing?
The purpose of this research is to observe an osteopathic treatment technique known as Rib Raising Technique (RRT) and measure its effects on the heart rate (HR) (speed at which the heart beats) and heart rate variability (HRV) (the change in time between heart beats).

Your voluntary participation.
Your participation in this study is entirely voluntary, and you may withdraw at any time during the study. There are no disadvantages, penalties, or adverse consequences to not participating or withdrawing from the research. If you agree to participate, you will be asked to sign a consent form. This does not stop you from changing your mind if you wish to withdraw from the research.

Who may participate?
We are looking for healthy young adults between the ages of 20 and 30 years old. Healthy; being free of cardiovascular disease and no known traumatic or pathological conditions of the neck, thorax and ribs.

What it will mean for you?
Should you agree to participate in the study, you will undergo the following process.

- First you will be required to attend three measurement sessions on a weekly basis. At these sessions you will have your HR and HRV measured.
    - An electrotonic heart rate monitor will be used to measure your heart rate and heart rate variability.
        - This will involve placing a band around your chest with a HR monitor attached.
- Your heart rate will be recorded while you are comfortably seated for the duration of 10 minutes.

- At the end of the third measurement session, you will be randomly assigned to one of two groups.
    - One group will receive an application of the rib raising technique and the other group will receive a placebo rib raising technique.
    - Rib raising technique is a gentle articulatory technique, where the ribs are slowly lifted up and forward.
        - At the end of the study you will be informed to which group you were allocated to.
- Immediately after the intervention has been applied (whether genuine or placebo) the HR and HRV will be recorded again.
- You will be required to return to the research room approximately 24 hours later (the same time the next day) and finally one last time one week after receiving the RRT to have the same measurements recorded again.

Overall you will be required to come to the research room five times over a four week period.

Discomforts/Risks?

No harmful effects of rib raising technique have been reported. However minor stiffness and discomfort is often reported following osteopathic manipulative treatment that should only last for a few days.

Data storage and privacy?

Personal information is collected and stored under the guidelines provided by the Privacy Act 1993 and the Health Information Privacy Code 1994.

Your name and information that may identify you will be kept completely confidential. All information collected and your identity will remain anonymous, the only means by which you will be identifiable is by an allocation of an identification number. If the information you provide is reported or published, this will be done in a way that does not identify you as its source. All information collected from you will be stored on a password protected computer file and any hard-data will be archived in a locked file room in the Unitec Student Osteopathic Clinic and will be stored for a minimum of 5 years. Only you, the researcher and the supervisor will have access to this information.

At any time if you wish to know more information or if you have any concerns about the research project you can contact the researcher or the supervisor.

Researcher: Nicholas White
Email: n.white.89@gmail.com
Phone: 02102423300

Supervisor: Jamie Mannion
Email: jaymannion@gmail.com
Phone: 021 0629007

UREC REGISTRATION NUMBER: 2011-1235

This study has been approved by the UNITEC Research Ethics Committee from 12/01/2012 to 12/01/2013. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162. Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

Participant Consent Form

Rib Raising osteopathic manipulative treatment and its immediate and short-term effects on heart rate variability in a cohort of young healthy adults: a randomised placebo controlled trial.

I have had the research project explained to me and I have read and understand the information sheet given to me.

I understand that I don't have to be part of this if I don't want to and I may withdraw at any time prior to the completion of the research project.

I understand that all the data recorded in this research project is confidential and none of this information will be able to identify me and that the only persons who will know what data is mine will be the researchers and their supervisor. I also understand that all the information that I give will be stored securely on a computer at Unitec for a period of 5 years.

I understand that I can see the recording of my data after completion of the research.

I understand that I can see the finished research document.

I have had time to consider everything and I give my consent to be a part of this project.

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

Signature: ………………………….. *Date: ……………………………*

Project Researcher: …………………………… *Date: ……………………………*

UREC REGISTRATION NUMBER:
This study has been approved by the UNITEC Research Ethics Committee from (date) to (date). If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

Research Title:

Rib Raising osteopathic manipulative treatment and its immediate and short-term effects on heart rate variability in a cohort of young healthy adults: a randomised placebo controlled trial.

Inclusion/Exclusion Criteria:

In order to participate in the above study all the below boxes must be checked.

Please tick the below boxes if it applies to you.

- ☐ I am between 20 and 30 years old.
- ☐ Can adequately speak, read and understand English.
- ☐ Have no history of cancer.
- ☐ Have no history of rib or cervico-thoracic surgery or fracture.
- ☐ Have no cervico-thoracic trauma within the previous 3 months or persistent symptoms from an earlier trauma.
- ☐ Have no known anatomical abnormality in the cervico-thoracic region.
- ☐ Have no medically diagnosed history of stroke or any other cardiovascular disease.
- ☐ I am not currently taking any medications to manage a cardiovascular disease or a steroid based medication.
- ☐ I have no history of positional vertigo.
- ☐ I am not pregnant or non-applicable.

I hereby proclaim that this information is correct and accurate to the best of my knowledge.

Participant Name:
…….

Signature: …………………………………………… *Date:* ……………………………

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The Guidelines are separated into the following sections:

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B Types of Contributions
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(B) TYPES OF CONTRIBUTIONS - word limits exclude tables, figures and reference list.

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

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These should be either **(i)** reports of new findings related to osteopathic medicine that are supported by research evidence. These should be original, previously unpublished works; or **(ii)** a critical or systematic review that seeks to summarise or draw conclusions from the established literature on a topic relevant to osteopathic medicine.

Short review (1,500-3,000 words)
The drawing together of present knowledge in a subject area, in order to provide a background for the reader not currently versed in the literature of a particular topic. Shorter in length than and not intended to be as comprehensive as that of the critical or systematic review paper. These papers typically place more emphasis on outlining areas of deficit in the current literature that warrant further investigation.

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

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Presentation of results from pilot studies which may establish a solid basis for further investigations. Format similar to original

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

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

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

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The IJOM accepts the submission of protocols of randomised interventions, systematic reviews and meta-analyses, observational studies, and selected phase I and II studies (novel intervention for a novel indication; a strong or unexpected beneficial or adverse response; or a novel mechanism of action), with the overall aim to encourage good principles in clinical research design.

The editors are looking for studies that will appeal to a wide general readership. The question being addressed and the planned design and analysis will need to be as original as possible, topical, and valid. All protocols will be subject to the journal's usual peer review process.

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

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Both qualitative and quantitative research approaches should be accompanied by a structured abstract of no more than 250 words. Commentaries and Essays may continue to use text based abstracts of no more than 150 words. All original articles should include the following headings in the abstract as appropriate: *Background, Objective, Design, Setting, Methods,*

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Examples:

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

Reference to a book:

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

Reference to a chapter in an edited book:

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

For journal articles, the abbreviated title of the journal should be used. Authors should refer to the National Library of Medicine database for journal abbreviations (http://www.ncbi.nlm.nih.gov/nlmcatalog/journals).

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Tables, illustrations and figures should be placed on separate pages as separate electronic files and not placed within the manuscript. Each table, illustration or figure should be accompanied by a number (e.g. Table 1) and a brief description of the content of the table, figure or illustration, below the table, illustration or figure. All tables, illustrations or figures should be referred to in the manuscript.

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At submission stage, authors of reviews and original research articles are required to provide three to four bullet points outlining the manuscript implications for clinical practice.

(E) SPECIFIC GUIDANCE FOR ORIGINAL RESEARCH ARTICLES

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

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

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

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

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

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

Conclusion
A summary of the pertinent findings and, relevance of the study and implications of the study for future research.

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Randomised (and quasi-randomised) controlled trial - CONSORT - Consolidated Standards of Reporting Trials http://www.equator-network.org/index.aspx?o=1032

Study of Diagnostic accuracy/assessment scale - STARD - Standards for the Reporting of Diagnostic Accuracy Studies http://www.equator-network.org/index.aspx?o=1032

Systematic Review of Controlled Trials - PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses http://www.equator-network.org/index.aspx?o=1032

Systematic Review of Observational Studies - MOOSE - Meta-analysis of Observational Studies in Epidemiology http://www.equator-network.org/index.aspx?o=1032

Qualitative researchers might wish to consult the guideline listed below:

Qualitative studies - COREQ - Consolidated criteria for reporting qualitative research. Tong, A., Sainsbury, P., Craig, J., 2007. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *International Journal for Quality in Health Care* 19 (6), 349-357. http://www.emgo.nl/kc/Analysis/statements/COREQ.pdf

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

(F) SPECIFIC GUIDANCE FOR PROTOCOLS

Organisation of a Protocol - the following need to be adequately addressed.
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• Aim(s).
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• Statistical analysis - including sample size and power calculations; type of analysis; statistical testing.
• Ethical issues - including ethics committee approval; informed consent form and information sheet.
• Publication plan.
• Time required - an estimation of the time required to run the protocol should be given per separate step and for the whole protocol, including reporting.
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(G) POST ACCEPTANCE

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