

**Estimation of instantaneous and cumulative  
loads on the low back and neck of osteopaths  
while performing the pre-thrust positioning for a  
high velocity, low amplitude thrust technique  
applied to the thoracic spine**

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A research project submitted in partial fulfilment of the requirement for the degree of Master of  
Osteopathy at Unitec New Zealand, 2008.



## **Declaration**

**Name of candidate:** Matthew Stewart

This research project is submitted in partial fulfilment for the requirements for the Unitec degree of Master of Osteopathy.

The regulations for this degree are set out in the Master of Osteopathy Program Schedule and are elaborated in the course handbook.

### **Candidate's declaration**

I confirm that:

- This research project represents my own work;
- The contribution of supervisors and others to this work was consistent with the Unitec Regulations and Policies.
- Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee (Research Ethics Committee Approval Number: 2006.476)

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

(Matthew Donald Stewart)

## **Abstract**

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*Background and objectives:* There is epidemiological evidence that musculoskeletal disorders of the back and neck are prevalent among healthcare professionals. The aim of this study was to quantify instantaneous and cumulative loads on the low back and neck of osteopaths while performing the pre-thrust positioning for a commonly used high velocity, low amplitude (HVLA) thrust technique applied to the thoracic spine.

*Method:* The sample included 8 undergraduate students and 16 graduate students in the osteopathy programme at Unitec New Zealand and two registered osteopaths (male n= 16, female n=10). Digital still images of operators performing the pre-thrust positioning for a thoracic spine HVLA thrust technique on a variable height table were analysed with motion analysis software. From the observed data, instantaneous compression and shear loads at the L5-S1 and C7-T1 segments were estimated using a static biomechanical model. Estimates of weekly and yearly cumulative compressive and shear loads were calculated based on assumptions from osteopaths' anecdotal clinical experience.

*Results:* Instantaneous compression loads on the L5-S1 segment ranged from 1023 N to 7575 N and 33 N to 477N on the C7-T1 segment. Instantaneous shear loads on the L5-S1 segment ranged between 160 N and 829 N and between 18 N and 112 N for the C7-T1 segment.

*Conclusions:* This study found a distinct correlation between body mass and instantaneous lumbosacral spinal loading (Pearson's  $r = 0.96$ ). The magnitude of instantaneous compressive lumbosacral spinal loads in this study were found to be within the range to cause vertebral endplate fracture. Lumbosacral shear forces were found to be above acceptable levels as recommended in spinal safety guidelines but below levels capable of causing pars interarticularis fracture. Therefore, manipulative techniques that involve forward flexion may increase instantaneous compressive and shear lumbosacral spinal loading above generally agreed acceptable limits for spinal safety.

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## List of Abbreviations

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BCE	Before common era
BMI	Body mass index
CT-discography	Computerised tomography discography
C7	7 <sup>th</sup> cervical vertebrae
EMG	Electromyography
Hz	Hertz
HVLA	High velocity, low amplitude
HLVAT	High velocity, low amplitude thrust
HVT	High velocity thrust
IDD	Internal disc disruption
kN	Kilo-Newton
L5	5 <sup>th</sup> lumbar vertebrae
LBP	Low back pain
mm	millimetre
MRI	Magnetic resonance imaging
N	Newton
NCCAM	National Centre for Complementary and Alternative Medicine
Nh	Newton hour
NIOSH	National Institute for Occupational Safety and Health
PT	Physical therapist
ROM	Range of movement
S1	1 <sup>st</sup> sacral vertebrae
SMTT	Spinal manipulative thrust technique
SPs	Spinous processes
TPs	Transverse processes

T1	1 <sup>st</sup> thoracic vertebrae
WMSDs	Work-related musculoskeletal disorders

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## **Glossary**

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*Cavitation* – The audible ‘popping’ sound occurring from high-velocity, low-amplitude thrust techniques believed to be caused by a cavitation mechanism that occurs with the separation of the facet surfaces within spinal zygapophyseal joint (Flynn, Childs, & Fritz, 2006).

*Direct technique* – Techniques in which the barrier is located and directly addressed (Hartman, 2001).

*High velocity, low amplitude (HVLA) thrust technique* – A direct technique which uses high velocity and low amplitude forces (Gibbons & Tehan, 2001).

*Manipulation* – The term is used in Europe and Australasia almost solely for procedures involving high velocity, low- amplitude thrusting movement to a joint slightly beyond its passive range of motion (Bourdillion, Day, & Bookhout, 1992; Schneider, Dvorak, Dvorak, & Tritschler, 1988). In North America, the term manipulation is used in a wider sense to describe any active or passive movement initiated or assisted by the operator (Eck & Circolone, 2000). The term manipulation is used in the following dissertation in the wider sense; the manual treatment of a part of the body (*Shorter Oxford English dictionary*, 2002).

*Mobilization* – a slower technique involving the application of repetitive oscillations of force within the passive range of the joint, without a high velocity, low amplitude thrust (Waddell, 2004).

*Set-up* – Movements and postures of both the operator and subject that are required for the effective and efficient performance of a treatment technique (Hartman, 2001).

*Slack* – A term used in manual medicine to describe the movement in myofascial tissues adjacent to the target joint complex before the palpation of requisite tissue tension is achieved to perform an HVLA thrust technique (Gibbons & Tehan, 2001; Schneider et al., 1988).

*Somatic dysfunction* – Impaired or altered function of related components of the somatic (body framework) system: skeletal, arthrodiar and myofascial structures, and related vascular, lymphatic, and neural elements (Binkerd et al., 2003).

*Barrier* – The resistance encountered in particular a movement pathway that has a characteristic feeling of potential or dynamic tension in a joint complex or tissue (Hartman, 2001).

## Overview

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The following dissertation is divided into three sections. Section I comprises a review of research regarding the history and core principles of osteopathic medicine, its use of HVLA techniques and a brief description of these techniques. This section also outlines musculoskeletal injuries, such as back pain, and the incidence of these complaints in healthcare workers. Guidelines for practitioner posture are discussed and the literature concerning instantaneous and cumulative loading explored. The purpose of this review is to contextualise a specific study investigating instantaneous and cumulative loads on the low back and neck in osteopaths while performing the pre-thrust positioning for a commonly used, high velocity, low amplitude (HVLA) thrust technique applied to the thoracic spine.

Section two details a specific study investigating instantaneous and cumulative loads on the low back and neck in osteopaths while performing the pre-thrust positioning for a commonly used high velocity, low amplitude (HVLA) thrust technique applied to the thoracic spine. This section is structured in the manuscript format specified for submission to the *International Journal of Osteopathic Medicine*. (Refer to 'Instructions for Authors' to IJOM in Appendix H)

Section three contains appendices that include ethics consent forms and materials utilised in the participant recruitment process.

## **Section I: Literature Review**

## **Introduction**

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This section reviews literature from osteopathic, chiropractic, physical therapy and ergonomic studies. Relevant articles were retrieved from searches using Medline, EBSCO, ISI Web of Science, Sports Discus, PEDro and ScienceDirect databases. In addition, the reference sections of published studies were reviewed for articles of relevance. The paucity of peer-reviewed research articles related to practitioner ergonomics necessitated reference to osteopathic and manual medicine texts.

The Part I of this review will introduce the history of osteopathic medicine and its use of high velocity, low amplitude (HVLA) thrust techniques. The first part will also include a description of the techniques; in particular, the thoracic HVLA thrust technique used in this study, and the classification and objectives of these procedures. Part II will briefly review musculoskeletal injuries including low back pain and consider selected papers on the epidemiology of low back pain and work-related musculoskeletal injuries of health care workers. Literature regarding guidelines for osteopathic clinicians will be summarized and selected studies on cumulative shear and compression loading will be reviewed.

## **Part I**

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### *Osteopathic medicine*

Osteopathic medicine is a diagnostic and therapeutic system based on the premise that the primary role of the physician is to facilitate the body's inherent ability to heal itself (Lesho, 1999). Osteopathic philosophy asserts four main principles in the practice of osteopathy (Dowling & Martinke, 2005). The first is that the body is a functional unit with all the component systems working to benefit the whole organism. An allied concept to this principle is the person is a whole, consisting of mind, body and spirit and therefore the interplay of mind and emotion can affect bodily functions and vice versa (Lee, 2005). Second, structure and function of the body are intimately interrelated, and therefore an abnormality in the structure of any body part can lead to abnormal function either locally or at a distance from the affected structure. Third, the body possesses self-regulatory mechanisms to control its physiological processes, all of which occur without conscious control. Fourth, the body has inherent healing mechanisms to heal itself from insults that disrupt normal homeostatic functioning. These four principles guide the osteopath in assessment, diagnosis and treatment of the neuromusculoskeletal system. By following these principles, the osteopathic physician may facilitate the healing process by removing the impediments to the body's self-healing processes.

Embedded in osteopathic philosophy is the rationale for the incorporation of manual manipulation. Korr (2004) has put forward four propositions in this regard. The first, that the vertical human frame is highly vulnerable to gravitational, torsional and

shearing forces. Second, because of this vulnerability, the musculoskeletal system is a common source of impediments to the function of other systems by virtue of its rich two-way communication with these other organ systems. Third, these impediments exaggerate the physiological impact of other detrimental factors in the patient's life and via the convergence of the central nervous system to impact on specific organs and tissues. Fourth, these somatic dysfunctions are accessible to the hands of the osteopath and responsive to manipulative treatment. Through the use of manual manipulative techniques, the osteopath seeks to optimise body mechanics for the fullest expression of health in the patient (DiGiovanna, 2005).

### *History of osteopathic medicine*

Andrew Taylor Still, the founder of the osteopathic profession, started developing his ideas from 1855 (Hamonet, 2003) however, it wasn't until 1874 that Still first articulated his osteopathic concept to improve the medical practices of his day (Still, 1897). Chikly (2005) has suggested that Still developed a medical philosophy designed to facilitate natural healing processes of the body by finding and correcting anatomical deviations that interfered with the free flow of blood and lymph and his treatment methods, which included manipulation, were designed to correct altered mechanics to improve circulation. The origins of osteopathy may be viewed as of only historical interest; however, the profession has developed considerably over time, which has significantly changed the scope and nature of clinical practice in different countries due to political and legal reasons<sup>1</sup>.

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<sup>1</sup> In the United States, osteopathic medicine has developed in parallel with the larger school of allopathic medicine. Doctors of osteopathic medicine educated in the United States (DOs), like allopathic doctors of medicine (MDs) are fully licensed physicians and surgeons who practice the full scope of medicine. While osteopaths in countries outside of the USA also place an emphasis on the importance of the optimal functioning of the musculoskeletal system to overall patient health, they are not medically licensed practitioners and therefore their practice is limited to manual manipulative technique and do not prescribe pharmacological agents or perform surgery (Lesho, 1999).

### *History of manipulation*

Manipulation is a commonly used modality in the manual medicine professions of osteopathy, chiropractic, and physiotherapy, as well as by some medical practitioners (Potter, McCarthy, & Oldham, 2005). The first recorded use of spinal manipulative techniques is attributed to Hippocrates in 400 BCE (Mattick & Wyatt, 2000) but rudimentary forms of manual medicine are thought to have been practiced for at least 4000 years (Waddell, 1996b). High velocity, low amplitude (HVLA) thrust techniques are perhaps the best known and distinctive of the manipulative techniques. These techniques are known by a variety of names in the literature; spinal manipulative thrust technique (SMTT) (McCarthy, 2001); adjustment (Byfield, 2005; Fryette, 1954) ; high velocity thrust (HVT) (Sammut & Searle-Barnes, 1998; Stoddard, 1959); mobilisation with impulse (Lesho, 1999); grade V mobilisation: manipulation with impulse (Gibbons & Tehan, 2001); and high velocity, low amplitude thrust (HVLAT) technique (Evans, 2002). To avoid the confusion caused by the multitude of terms and geographic variation in language, the term 'high velocity, low amplitude' (HVLA) thrust technique will be used in this review. Additionally, description of these techniques will relate to their application to the spine unless otherwise stated.

### *Manipulation in osteopathy*

It is believed that Still used very little in the way of HVLA thrust techniques in his practice of osteopathic manipulation and instead used predominantly articulatory (Van Buskirk, 2001), myofascial (Dowling, 2005) and indirect techniques (Schiowitz,

2005). Several authors have suggested reasons for this shift away from approaches favoured by Still to HVLA thrust techniques. Firstly, as Still withdrew from hands-on teaching, former students took over the teaching of technique classes (Trowbridge, 1991). Students often found Dr Still difficult to follow as he often described his concepts in allegory and parables. Still admonished his students not to copy his techniques and instead he urged them to use their anatomical knowledge and osteopathic principles to improvise their own techniques (Trowbridge, 1991). Secondly, learning myofascial and indirect techniques is perceived as being more difficult than HVLA thrust techniques because the novice operator may not possess skills in palpating motion patterns in myofascial tissues and responding to tactile and proprioceptive input from their hands (Kappler & Jones, 2003). Thirdly, it was widely believed by the osteopathic profession that Still did not write down his techniques (Dyer, 2000) and that this further hampered the transmission and survival of his treatment approach. Recently however, work by Van Buskirk (Van Buskirk, 1996, 2001, 2003) has elaborated on descriptions 'hidden' in the written work of Still (1902) and Hazzard (1905) to propose techniques to implement Still's approach .

A few years after Still's withdrawal from teaching at the American School of Osteopathy at Kirksville, HVLA thrust techniques were the predominant manual technique being taught (Kappler & Jones, 2003). This dominance continued in North America and Europe until the 1970s such that the term 'osteopathic manipulation' was essentially synonymous with HVLA thrust techniques. In clinical practice, HVLA thrust techniques continue to be amongst the most commonly used manipulative treatment techniques used by osteopaths (Johnson & Kurtz, 2003).

### *Description of HVLA thrust techniques*

High velocity, low amplitude thrust techniques are one mode of treatment, in the repertoire of the manual therapy professions (Greenman, 2003). Of the large numbers of techniques used within the field of manual medicine, HVLA thrust techniques are probably the most commonly used. The HVLA group of techniques involve the practitioner positioning a dysfunctional joint complex into at least one of its restrictive barriers with the practitioner thrusting through the barrier, often accompanied by a 'popping' sound (Flynn et al., 2006). When performing the technique, 'slack' is taken up in the tissues adjoining the target joint complex with the magnitude of the impulse force being sufficient to introduce movement in the target joint, but not beyond the anatomical barrier (Evans & Breen, 2006; Schneider et al., 1988).

Four distinct phases have been described in high velocity, low amplitude thrust techniques; an 'orientation phase', a 'pre-thrust phase', a 'thrust phase' and a 'resolution phase' (Evans & Breen, 2006; Herzog, 2000). The first phase, the orientation phase, describes the period when the patient and the operator are orientated into the appropriate position in preparation for the subsequent pre-thrust phase. The pre-thrust phase is a period when relatively constant force is applied by the operator to assess the physiological range of motion of the spinal segments and a 'barrier' is created by introducing different planes of joint movement. The third phase is the thrust phase in which the operator's thrust force increases rapidly. Force-time data measured using force plate instrumentation during HVLA thrust techniques has lead to the identification of 'thrust phase' characteristics (Herzog, 2000; Herzog, Kats, & Symons, 2001). It has been shown in biomechanical studies that HVLA thrust

techniques deliver the thrust force over a time period of 100-200 milliseconds (Herzog et al., 2001) During the resolution phase, the thrust force returns to zero.

Absent from the discussion of these phases of HVLA thrust techniques in topical reviews, (Evans & Breen, 2006; Herzog, 2000; Herzog, Kats, & Symons, 2001) is the common practice of the operator re-evaluating joint motion before releasing the 'slack' in the adjoining tissues of the targeted joint complex. Re-evaluation by the operator takes place while in the position of the pre-thrust phase. Also absent from descriptions of the phases of HVLA thrust techniques is the requirement for the operator to take themselves, and the patient, out the positioning required for the technique (Herzog, 2000). This is notable because spinal loading of the operator also occurs during these undescribed phases.

A common feature of these techniques is that a 'pop' or cracking sound emanates from joint complex on application of the thrust force (Flynn et al., 2006). While this sound is characteristic of HVLA thrust techniques, the major feature distinguishing these techniques from other manual therapy interventions is the velocity of the thrust phase (Evans & Breen, 2006; Gibbons & Tehan, 2001). Recent research by Flynn et al. (2006), using a HVLA thrust technique to the sacroiliac region on 70 patients suggested that there is no relationship between an audible 'pop' and patient outcomes such as increased range of motion or decreased pain. This finding was in agreement with an earlier study (Flynn, Fritz, Wainner, & Whitman, 2003) on HVLA thrusts to the sacroiliac region for low back pain that found no relationship between an audible pop during sacroiliac joint manipulation and improvement in range of movement (ROM), pain, or disability in individuals with non-radicular low back pain.

### *Classification of HVLA thrust techniques*

High velocity, low amplitude thrust techniques can be classified as either long lever or short lever (Eck & Circolone, 2000). Short-lever techniques involve applying mobilizing forces directly to the transverse processes of a specific segment that is to be treated (Greenman, 2003). Long-lever techniques involve the use of an extremity or multiple spinal segments to achieve optimal tissue tension. Long lever techniques are said to require precise localisation and limitation of force but have the advantage of requiring less force and increase the distance along which the energy of force application is applied (Shekelle, 1994).

In the past, long lever HVLA thrust techniques have been associated with osteopathy and physiotherapy and short-lever techniques with the practice of chiropractic (Eck & Circolone, 2000). The type of practitioner does not necessarily predetermine the type of manipulation used with many manual medicine practitioners selecting techniques based on a range of patient and practitioner centred factors. These factors include the morphology of the practitioner and patient (Hartman, 2001), the training and aptitude of the practitioner the nature of complaint, mechanism of injury and stage of patient recovery, among others (Lederman, 2005).

### *The objective of HVLA techniques*

The objective of either short or long lever HVLA thrust techniques is to direct forces to a specific anatomical point, area or structure (Gibbons & Tehan, 2001). Short lever HVLA thrust techniques do not require 'locking' of adjacent spinal segments to concentrate forces. To direct forces to specific joints and achieve cavitation in long lever techniques spinal 'locking' is necessary (Gibbons & Tehan, 2001). 'Locking'

can be achieved by facet apposition, the utilization of ligamentous myofascial tension or a combination of both. Gibbons and Tehan (2001) summarised both the principles of spinal coupling biomechanics, and the terminology used by the osteopathic profession to describe HVLA thrust techniques. Briefly, the facet joints of uninjured segments are opposed, giving the practitioner increased resistance in tissues adjacent to the target segments. Locking is avoided at the segment at which cavitation is targeted. To achieve locking, the spine is placed in a position opposite to that of normal vertebral coupling that is dependant on spinal positioning in flexion, extension or neutral. Experienced practitioners are said to be able to quickly locate and engage the barrier as they are able to effectively locate the barrier in multiple planes whereas novice operators tend to add vectors of movement one plane at a time (Kappler & Jones, 2003). With the barrier located, a low amplitude, high velocity thrust is applied toward the barrier. A popping or cracking sound is often present upon application of the thrust force.

Models of spinal coupling as outlined by Gibbons and Tehan (2001) and McCarthy (2001) are a useful clinical and teaching tool. These models are simplifications of the complex kinematics of spinal motion (Bogduk & Mercer, 2000; Herzog, 2000); however, they are beneficial in teaching the essential clinical elements of spinal motion patterns as they relate to effective technique performance.

A number of researchers have sought to quantify the forces involved in HVLA thrust techniques. Herzog (2000), noted, from studies in their laboratory over a 10-year period, that while peak force can vary across clinicians by a factor of 10, the time of thrust application is fairly constant. In a subsequent study of short lever HVLA thrust techniques to the thoracic spines of 20 volunteers, Herzog et al. (2001) found the

average peak force delivered by a thoracic HVLA thrust technique was 238 N. The peak thrust force was delivered within 100 to 200 milliseconds with a mean of 160 milliseconds. Forand, Drover, Suleman, Symons, and Herzog (2004) found the biggest variation in the magnitude of the peak thrust force appears to be the operator related factors such as size and weight, rather than the technique used, body area treated or the problem being treated. Triano and Schultz (1997) found that the forces transmitted to the torso of a subject during lumbar HVLA techniques are comparable to activities of daily living such as lifting a heavy weight with one arm. The authors concluded that experimental biomechanical evidence benchmarks the loads transmitted during HVLA procedures as equivalent to loads generated during activities of daily living.

#### *Thoracic HVLA thrust techniques*

High velocity-low amplitude thrust techniques for the thoracic spine can be performed with the subject in a supine, standing, sitting or prone position (Gibbons & Tehan, 2000; Greenman, 2003; Hartman, 2001). The orientation phase of supine positioning involves crossing the subject's arms over their chest so that their hands are holding their opposite shoulders. The operator leans over the supine subject and applies their sternal or upper abdominal area to the subject's crossed elbows. The area under the folded arms of the subject is usually bolstered with a pillow or towel and the operator's lower sternum or abdominal area is also cushioned from the elbows. The operator's hand is applied 'palm up' under the subject to the transverse processes (TPs) of the thoracic spine to act as a fulcrum for the thrust phase. During the pre-thrust phase, combined levers of rotation, side-bending compression and side-shift movements are introduced by the operator, as required, to focus tension on the

specific spinal level. Once tissue tension has been developed and spinal ‘locking’ achieved, this position is the end of the ‘set-up’ or ‘pre-thrust positioning’ and the operator is ready to deliver the HVLA thrust to the patient’s crossed elbows via the operator’s sternum.

Figure 1 below illustrates the positioning of the operator and subject. With the practitioner and subject positioning shown, the thrust force is directed through the operator’s lower sternum with the tissue tension localised to the fulcrum provided by the operator’s hand placed on the TPs of the thoracic spine. The operator can reassess the treated area for tissue and range of motion changes from this position. The thrust phase of the HVLA thrust technique typically occurs over a duration of 100-200 milliseconds with a mean of 160 milliseconds (Herzog et al., 2001). The operator will, however, maintain the pre-thrust positioning for several seconds both before and after the thrust phase to assess joint motion. Therefore, the operator maintains the relatively static pre-thrust position for a time greater than the thrust phase itself. In the research literature, to date, the focus has been on characterising the forces developed in the thrust phase of the technique in the spine of the patient. Little literature is available that characterises or estimates the forces developed in any of the phases of HVLA thrust techniques in the body of the operator. Literature relating to operator ergonomics and work-related musculoskeletal disorders is reviewed in Part II of this review.



**Figure 1 Demonstration of a supine thoracic HVLA thrust technique**

The figure illustrates the operator's pre-thrust position of the subject for supine thoracic HVLA thrust technique.

*High velocity, low amplitude thrust techniques in research literature*

In the past, the indications for, and use of, manual medicine treatment has been compromised by a lack of basic science and clinical studies. In the past two decades, the literature on manual medicine has enlarged considerably. The majority of research into manipulation has focused on two areas, mechanism of action and clinical effectiveness. Gibbons and Tehan (2001) suggest that research is needed to establish the clinical efficacy of osteopathic intervention and elaborate the biological basis and physiological mechanisms that underlie practice in modern healthcare's drive to evidence based practice and limited health care funding. However, Bogduk and Mercer (1995) suggest that demonstrating the efficacy of a therapy before

exploring its mechanism is more valuable and a more efficient use of scarce resources. The challenge for the manual medicine professions is to demonstrate that symptom improvement is a direct result of treatment rather than natural history of the complaint and that the intervention is more effective and cost-effective than other treatments available in the marketplace.

The efforts of manual medicine researchers to show the clear indication of manual therapy for low back pain and other conditions has been hampered by poor definition and description of treatment procedures used, the identity of those administering the procedures, or a means of assessing the skill of the operators. Van Tulder, Koes, and Bouter (1997) found that replication of research methods is sometimes hampered by lack of a clear, objective description of the manipulative techniques employed.

Indeed, the field of spinal manipulation has been treated as homogenous in the literature because of poorly defined operational definitions of treatment procedures. Triano (2001), in a review of spinal manipulative therapy literature, found authors had not made any distinction between the types of spinal manipulation used in the studies. Scrutiny of the methods published in many manipulation studies usually reveals a limited description of the techniques employed.

Evans (2002), in a review of the theories on mechanisms and effects of HVLA thrust techniques, noted that a lack of basic knowledge of the techniques used had led to HVLA thrust techniques and mobilisation being grouped together as one intervention when scrutinized for efficacy in earlier systematic reviews. Although earlier systematic reviews of spinal manipulation tended to combine mobilisation and HVLA thrust techniques together, more recently, however, some authors of systematic reviews have made the distinction between different treatment approaches (Bronfort,

Haas, Evans, & Bouter, 2004). The confusion could have stemmed from the use of the term ‘manipulation’ in its broadest sense to describe all external movements applied to the body versus the narrow definition of the term relating only to HVLA techniques. In the USA and Europe, until the 1970s, ‘osteopathic manipulation’ and HVLA techniques were essentially synonymous (Kappler & Jones, 2003). Evans (2002) notes that it is important to distinguish mobilisation from HVLA thrust techniques, as the physiological effect of each technique is hypothesised to have a different physiological effect.

Another problem in identifying techniques used in research are the differences in terminology favoured by various manual medicine professions and groups in different geographical locations. In osteopathic medicine there are over 100 different techniques (Lesho, 1999) while in chiropractic, Cooperstein and Gleberzon (2004) estimate that 300 techniques have been described. Byfield (2005) notes that many chiropractic techniques have never been subjected to scientific scrutiny or clinical trials and jargonistic, yet traditional, terminology such as ‘cervical break’ and ‘lumbar roll’ may need review in light of trends toward enhanced patient-practitioner communication and describing the technique more accurately during the process of gaining informed consent.

There appears to be an emerging practice in the reporting of manual medicine research to describe manipulative procedures in greater detail. Furthermore, interdisciplinary research initiatives such as the United Kingdom back pain exercise and manipulation (BEAM) studies (UK BEAM Trial Team, 2004a, 2004b) have created

greater dialogue between manual medicine professions. These initiatives are a welcome development that may help to clarify the benefits of manual medicine.

## **Part II**

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### *Musculoskeletal injuries*

Musculoskeletal conditions are the most common cause of severe long-term pain and physical disability and affect hundreds of millions of people around the world (Woolf & Akesson, 2001). The burden of musculoskeletal conditions on health-care systems worldwide is considerable. In one survey (National Centre for Health Statistics, 1995), chronic musculoskeletal pain was reported by 1 in 4 people surveyed regardless of being from a less or more developed country. In the United States of America, of all chronic impairments, musculoskeletal impairments were the leading cause of disability (White & Harth, 1999). In 2003, musculoskeletal complaints were reported as the leading cause of disability for 34.2% of the four million Australians with a disability (Australian Bureau of Statistics, 2007).

Despite the considerable financial cost and personal disability caused by musculoskeletal conditions, only 5% or less of national research councils' spending in developed countries is allocated to musculoskeletal conditions (Woolf & Akesson, 2001). The situation may have arisen because many of these conditions are associated with lower mortality rates when compared with more pressing health conditions such as ischemic heart disease, cancer and diabetes. Secondly, these conditions are viewed as a normal part of the aging process and therefore inevitable.

According to World Health Organisation criteria, musculoskeletal conditions include osteoarthritis, rheumatoid arthritis, osteoporosis, repetitive strain injuries, severe limb trauma and spinal disorders from specific and non-specific causes (Woolf & Pfleger, 2003). Musculoskeletal disorders of the spine are classified as non-specific if there is

no identifiable underlying pathology (e.g. osteochondritis), pathophysiological mechanism (e.g. trauma or malignancy) or anatomical source of pain (e.g. disc herniation or nerve root) identified by simple clinical means such as clinical examination or radiological studies. Non-specific spinal disorders account for 80% to 85% of all spinal disorders and are often described as 'simple low back pain' (Accident Compensation Corporation, 2003; Waddell, 1996a).

### *Back pain*

Low back pain is among the most prevalent musculoskeletal injuries and the epidemiology of low back pain is a huge subject that could fill several volumes. The purpose of the following brief review is to give a précis of pertinent factors associated with the aetiology of back pain. After triage for serious spinal disease and nerve root impingement, non-specific musculoskeletal conditions are by far the most common causes of spinal disorders. World-wide estimates of the lifetime prevalence of low back pain (LBP) vary from 50 to 84 percent (Nyland & Grimmer, 2003) and the point prevalence (proportion of population studied that are suffering back pain at a particular time) as 4–33% (Woolf & Pfleger, 2003).

A wide range of variables has been studied in an attempt to explain the risk factors associated with low back pain (LBP) including physical, psychosocial and environmental factors. Regarding physical factors, there appears to be no evidence of difference in prevalence rates for back pain due to gender or leg length discrepancy (Nachemson & Vingard, 2000). Similarly, physical fitness and strength of back and abdominal muscles do not appear to be risk factors for LBP (Adams, Mannion, & Dolan, 1999; Biering-Sorensen, 1984). Factors such as being overweight, leading a

sedentary lifestyle and smoking have been associated with increased prevalence rates of back problems and exacerbation of pain (Samanta, Kendall, & Samanta, 2003).

The relationship between back pain and psychosocial and psychological factors has received much attention in recent years. There has been a tendency for the terms psychological and psychosocial to be used interchangeably in the literature, which causes confusion (Adams, Bogduk, Burton, & Dolan, 2002a). It has been argued that the term psychological be used for psychological constructs while factors involving a social element be described as psychosocial. Psychological factors include, among others, anxiety; depression; stress; and social introversion (Adams, 1997; Linton, 2000). Psychosocial factors include job satisfaction, high-perceived workload (Marras, Davis, Heaney, Maronitis, & Allread, 2000), time pressure and job stress (Svensson & Andersson, 1989; Waddell, 2004). Few studies have attempted to control for biomechanical effects when exploring psychological or psychosocial factors and LBP, making clear associations difficult (Davis & Heaney, 2000). Not surprising, is the conclusion that there appears to be a complex interrelationship between psychosocial work factors and job demands (Marras et al., 2000). Despite an extensive body of literature on LBP, an exclusive causal relationship has not been established for any single factor predicting the incidence of low back pain. It is widely accepted that LBP is a multi-factorial, heterogeneous problem that includes biopsychosocial factors that make standardised treatment and assessing individual treatment effects 'difficult' (Waddell, 1992).

A difficulty with reviewing evidence on low back pain is, in part, the lack of consistent classification, definition and identification of low back pain in the

literature. Indeed, low back problems do not constitute a single identifiable disease. The difficulty, in epidemiological terms, is compounded by the fact that there is no clinically identifiable entity that can be reliably identified as a source of symptoms. Ideally, it is preferable to establish what is being studied (e.g. simple mechanical back pain, internal disc disruption, etc.) before the 'at risk' population is characterised. Adams et al. (2002a) have suggested that the usual term 'low back pain' be replaced by 'low back trouble', which covers a range of symptoms and pathology that are not closely related to each other.

Low back trouble can refer to the consequences of back pain such as disability, absenteeism and compensation issues. In many studies, it is not made clear whether the pain is troublesome or of nuisance value as opposed to disabling and causing absence from work or avoidance of certain tasks. Low back trouble should not be trivialised because of nuisance value, and more accurate information on disability and absenteeism is required for assessing the cost and disruption to industry, particularly amongst the health professions. With any person absent from work due to LBP, there are costs associated with treatment, rehabilitation and income compensation, and loss of productivity. When the individual is a member of the health professions, there is the considerable additional governmental expenditure in the specialist education of these workers. Loss of clinical experience associated with the disruption in the workplace caused by low back problems in the clinical workforce may require further investigation. Moreover, in professions such as nursing and physiotherapy, which have high turnover of highly trained staff (Kleinman, 2004), the costs of staff retention and training may potentially impact the adequate provision and delivery of health services.

### *Work-related musculoskeletal injuries*

Musculoskeletal injuries that occur in the workplace create a considerable burden for industry, the healthcare system, taxpayer and patient. Work-related musculoskeletal disorders (WMSDs) are thought to represent approximately one third of compensation costs in US private industry (United States Department of Labour, 2001). In New Zealand, occupational injuries resulted in 207,097 claims being accepted by the Accident Compensation Corporation between 1 July 2001 and 30 June 2002 (Driscoll et al., 2004).

The US Department of Labor defines work-related musculoskeletal disorders as an injury or disorder of the muscles, nerves, tendons, ligaments, joints, cartilage, blood vessels, or spinal disks in the neck, shoulder, elbow, forearm, wrist, hand, abdomen (hernia only), back, knee, ankle, and foot associated with exposure to risk factors (Barbe & Barr, 2006). 'Work-related musculoskeletal disorder' is an umbrella term for previously used terms such as repetitive strain injury, over-use injury, cumulative trauma disorder and repetitive trauma disorder (Yassi, 2000). The wide variety of clinical presentations of WMSDs can be classified into seven sub-groups. These include tendon related disorders, peripheral nerve entrapment, neurovascular/vascular disorders, muscular disorders, joint and joint capsule disorders, spinal disorders, and the category 'others' (Buckle & Devereux, 2002).

Evidence from epidemiological and field studies suggests a relationship between the onset and severity of WMSD and the performance of highly repetitive or forceful work tasks. Occupational factors, such as tasks that involve heavy lifting (Brinckmann, Biggemann, & Hilweg, 1989; Davis, Marras, & Waters, 1998),

repetitive lifting exposure (Fathallah, Marras, & Parnianpour, 1998; Marras et al., 2006), lifting speed (Marras et al., 1995; Marras et al., 1993), bending and twisting (Hoogendoorn et al., 2000) and pulling and pushing (McGill, 2004; McGill & Kavcic, 2005), have been implicated as risk factors for the development of LBP.

### *Back pain amongst healthcare workers*

There is some evidence that workers in health professions experience a higher incidence of musculoskeletal disorders, in particular, low back pain. It has been suggested that the incidence of LBP is in part due to tasks carried out in the care of patients (Cromie, Robertson, & Best, 2000; Lagerstrom, Hansson, & Hagberg, 1998).

Nurses, physiotherapists, x-ray technicians, orthodontists, osteopaths and chiropractors have all been the subject of previous epidemiological studies, which will be briefly reviewed here.

### **Nursing**

Nursing has been one of the most studied health care professions with reference to incidence and prevalence of work-related musculoskeletal disorders including low back pain (Hignett, 1996). In the profession of nursing, patient transfers have often been implicated as the cause of low back problems; therefore this task has been the focus of many epidemiological studies and biomechanical analyses. The large number of epidemiological studies and biomechanical analyses on nurses reflect that nurses typically represent approximately 33% of hospital work staff but account for 60% of all reported occupational injuries (Lewy, 1981).

Hignett (1996) in a review of 80 studies over the previous 30 years, found the lifetime prevalence of LBP among nurses ranged between 35-80%. More recent studies have continued to indicate a high prevalence of low back pain among nurses. Mohseni-Bandpei et al. (2006) in a retrospective survey of 1226 nurses randomly recruited from 13 hospitals in northern Iran, found LBP was reported by over 50% of respondents. In this study, time off work in the month preceding the survey was investigated with 33.7% of respondents' absences from work because of low back problems.

### **Physiotherapists**

Physiotherapists have also been the subject of epidemiological studies as they are exposed to many of the same occupational risk factors that lead to WMSDs as nurses. The lifetime prevalence of WMSDs experienced by physiotherapists has been estimated to be between 29% (Molumphy, Unger, Jensen, & Lopopolo, 1985) and 91% (Cromie et al., 2000).

In a study of physiotherapists in Victoria, Australia, Cromie, et al. (2000) used a questionnaire to gather data from state registered physical therapists relating to the prevalence, severity, risks and responses to work-related musculoskeletal disorders. The researchers found that 91% of physical therapists reported experiencing work-related musculoskeletal disorders at some point in their career. An important finding was that 1 in 6 therapists changed speciality to less physically demanding roles such as management, or out of the profession, because of their injury.

With regard to LBP, in a retrospective survey of University of Iowa physiotherapy program graduates, 45% of respondents reported experiencing LBP in the preceding 12-month period (Bork et al., 1996). Bork et al. also found that the factor reported by physiotherapists to most likely contribute to work-related musculoskeletal disorders was “lifting or transferring dependent patients” (Bork, et al. 1996, p. 827). Patient handling had previously implicated as a risk factor for LBP, with one study reporting 83% of physical therapists were handling or treating a patient at the time of injury (Molumphy et al., 1985). The authors of Bork et al. study made considerable efforts to ensure a high response rate and reduce the effect non-response bias by inter-group and inter-study respondent comparisons. The Bork et al. study had a response rate of 80% and analysis of the demographic characteristics of responders and non-responders were undertaken to assess non-response bias. The demographic characteristics of both groups were similar and the characteristics of the respondents of the Bork study were compared to respondents to a national physical therapy association membership survey and found to be similar in age, years of experience and work setting.

Cromie et al. (2000) found a 12-month prevalence of low back pain in 62.5% of respondents in a study of physiotherapists in the state of Victoria, Australia. A sampling method was used that selected every fourth physical therapist (PT) from a randomly selected starting point on the Victoria state register. The authors reported a 67.9% response rate and telephoned 1 in 10 non-respondents to determine their characteristics to investigate non-response effects. Cromie et al. found the differences between respondents and non-respondents were not significantly different in gender balance, mean age or musculoskeletal symptoms ( $P = 0.85$ ). They also found that

younger therapists reported more low back symptoms than older therapist ( $P < 0.001$ ). Other authors have also reported high LBP prevalence amongst young physiotherapists (<30 years of age) (Mierzejewski & Kumar, 1997; Molumphy et al., 1985) and physiotherapists within the first five years of employment (Mierzejewski & Kumar, 1997).

Mierzejewski & Kumar (1997) conducted a retrospective questionnaire study of physical therapists in Edmonton, Alberta to determine the prevalence of work-related LBP and the characteristics of those reporting LBP. A response rate of 67.3% ( $n = 311$ ) was achieved with this questionnaire mailed to all PTs in the Edmonton city area registered with the College of Physical Therapists of Alberta; registration with the College is mandatory for practice in the province of Alberta. Of those that completed the questionnaire, 49.2% of respondents reported back pain due to work.

A limitation of this study, which therefore requires caution in the interpretation of the findings, was the reliance on therapist recall. Inaccuracy in reported episodes of LBP may be inevitable, resulting in recall bias. The authors claim that this bias was minimised because the majority of respondents were young and within 5 years of entering the profession. The greater proportion of young therapists in the sample may reflect self-selection or non-response bias, although the representativeness of the sample is difficult to identify in the study. To assess non-response bias, demographic characteristics of the physical therapist population in Edmonton should have been compared with those of the study sample. The authors claimed they established the validity and reliability of the study sample by conducting a pre-study pilot survey of 24 physical therapists and compared the characteristics of these respondents with those of the entire physical therapy population in Edmonton. This comparison was

flawed as it did not compare the main study sample to the whole Edmonton PT population. Neither was the sampling method for the pilot study disclosed. The only detailed comparison made was between respondents with and without LBP with a variety of attributes (age, gender, workplace setting, specialty, current job duration). The only comparison that seems to have occurred to assess any non-response bias was in gender distribution; the distribution being similar between study respondents and the entire PT population in Edmonton.

The wide range of LBP prevalence data in the literature regarding health care professions may be due to several factors. Firstly, the variation in LBP prevalence may reflect non-response or self-selection bias due to the sampling method employed. Mierzejewski and Kumar (1997) mailed a questionnaire to all PTs in the Edmonton city area, however, not all completed and returned the survey, so non-response and self-selection bias is likely to have occurred. Mierzejewski and Kumar reported that orthopaedics was the most common area of specialty for respondents with LBP (24.1%, n = 75) but without comparison to non-respondents' specialty area the influence of non-response or self-selection bias on these results cannot be known, nor can an assessment be made of whether orthopaedic PTs were over-represented or under-represented in the study sample. Molumphy et al.(1985) sent a questionnaire to 500 PTs randomly selected from a state physical therapy association mailing list and achieved a 69% response rate. No attempt was made to assess the non-response bias in the study by comparing demographics of questionnaire respondents to the physical therapist association mailing list members. The respondents were predominately young (48% 26-35 years old) and in acute care settings, but no comparison was made to the national or state PT population to assess differences.

Another explanation for the wide range of LBP prevalence data is that work behaviour and job tasks are not homogeneous in the various specialties and workplace settings of physiotherapy or nursing practice. The task of patient transfer has been identified as the most common risk factor for developing LBP symptoms in physiotherapists and nurses (Bork et al., 1996; McGill & Kavcic, 2005; Mierzejewski & Kumar, 1997). In physiotherapy, there is a range of exposure to patient transfer (Bork et al., 1996; Cromie et al., 2000) because some specialties involve more patient transfers and handling. The frequency of patient handling will influence the occurrence of low back injury and therefore the specialty or setting of the worker must be considered. In hospital settings, there is likely to be greater patient handling than in private practice, where physiotherapists typically work in ambulatory clinics. In the first study of the incidence of work-related LBP in physical therapists, Molumphy et al. (1985) noted that 46.6% of respondents worked in primary care facilities when they first experienced LBP. Molumphy et al. proposed that hospital PTs treat patients who are less independent than patients in ambulatory settings and therefore the amount of physical therapy treatment is greater, increasing the physical demands on the therapist. Cromie et al. (2000) found differences in risk factors and the development of WMSDs by specialty area and reported that staff turnover is highest where the incidence of LBP was greater (42% of PTs that changed specialty area worked in neurology and rehabilitation). For nurses, the degree of exposure to LBP risk factors may vary according to the speciality they work in, with LBP reporting rates likely to vary due to different work tasks routinely performed in each speciality.

Nyland and Grimmer (2003) pointed out a further reason for the wide range of LBP prevalence data in their study of 346 Australian physiotherapy students, in which most of the sample reported the onset of their LBP in their mid-teens, before the commencement of their studies. The most common activity related to onset was sport. Perhaps the students' positive response to physiotherapy for their LBP led to them pursuing physiotherapy as a career or perhaps those interested in sports are more likely to enter a physiotherapy program. As the investigators noted "the teenage years are often a time of intense physical growth and the potential for lifetime experiences of LBP to commence at this time needs to be carefully considered with a view to reducing adulthood LBP incidence" (Nyland & Grimmer, 2003, Discussion section, ¶ 10). Following this line of reasoning would suggest that the occurrence of LBP during physiotherapy training and practice might have little to do with training and more to do with the characteristics and prior experiences of the sample population.

Finally, the wide range of LBP prevalence data must be treated with caution as different operational definitions of back pain were used by the authors of different studies (Cromie et al., 2000; Mierzejewski & Kumar, 1997; Molumphy et al., 1985) limiting the opportunity for direct comparison. In a review of 22 studies on Italian nursing personnel and musculoskeletal disorders (Lorusso, Bruno, & L'Abbate, 2007), the authors noted difficulty in comparing 12 month prevalence rates because different definitions of LBP were used. Comparison of LBP prevalence was only possible in two large multi-centre studies, because a standardised assessment was made of study participants. These two studies reported similar acute LBP prevalence rates, which were lower than other studies in the review that did not have more stringent criteria for definition of LBP. Consensus of an appropriate LBP definition for use by

researchers would be a welcome development so that comparisons can be made between studies in different populations.

### **X-ray technologists**

X-ray technologists, like nurses and physiotherapists have been the subject of epidemiological studies to ascertain the prevalence of LBP within the profession. In a study of 20 X-ray technologists randomly surveyed from two university hospitals (Kumar, Moro, & Narayan, 2004), found that despite their young age (mean age 37.9 years) and active lifestyles (89% percent of the samples were physically active), the X-ray technologists had “significant and diverse” musculoskeletal problems. Eighty-three percent of the sample had backache. The findings were based on a small sample (n=20) and only drawn from two hospitals that may not reflect the prevalence of x-ray technologists in the wider population.

Bos, Krol, van der Star, and Groothoff (2007) conducted a cross-sectional survey of 3,169 nurses and x-ray technicians in the Netherlands to estimate prevalence rates of musculoskeletal complaints and determine the relation between physical and psychosocial work-related risk factors. This study found an overall prevalence rate of low back complaints within the past 12 months of 76% for the entire sample. The 12-month prevalence of low back complaints in x-ray technicians was 75.1%, which was similar to the rate for operation-room nurses (76.6%), non-specialized nurses (76.2%), and intensive-care nurses (74.9%). Bos et al. concluded that X-ray technologists as a professional group have comparable prevalence rates to nurses. The work-related factor perceived by X-ray technicians as being predictive for low back complaints was dynamic load involved in a task. Given this study’s larger sample size, the findings

have more strength than the earlier study by Kumar and co-workers (2004).

X-ray technologists have also been the subject of biomechanical analysis. A study of seven x-ray technologists sought to determine the biomechanical loads experienced by x-ray technologists performing their routine daily tasks (Kumar, Moro, & Narayan, 2003). The participants were recorded on videotape to document joint angles, while working. This data was used along with participant weight, height and input into the static strength model for calculation of the lumbosacral load. The investigators concluded that the X-ray technologists' work was found to be biomechanically demanding with tasks such as repositioning patients horizontally and lifting a patient from a wheelchair resulting in lumbosacral compression loads of 7,936N and 8,335N respectively, which exceeded the maximum permissible lumbosacral compression limit set by National Institute for Occupational Safety and Health (NIOSH, 1981).

### **Chiropractors & osteopaths**

There is little research literature documenting the incidence of WMSDs in chiropractors and osteopaths. There is some evidence that osteopaths and chiropractors experience a high incidence of LBP. Mior and Diakow (1987) in a retrospective survey of Canadian chiropractors found the prevalence of back pain to be 87% of respondents, while 52% attributed clinical practice as an aggravating factor to their back pain. The authors suggested that chiropractors experience musculoskeletal disorders due to the physical demands of high velocity, low amplitude (HVLA) thrust techniques used in the treatment of their patients. Mior and

Diakow also suggest that incorrect table height may be a contributing factor in the causation of LBP.

In a survey of 1000 American chiropractors Holm and Rose (2006) found that 40.1% of the 397 respondents had experienced a musculoskeletal injury or condition, with low back injuries accounting for 24.6% respondents complaints. Two thirds of respondents (66.7%) sustained their injury while performing a manipulation with 37.3% of injuries occurring in the first five years of practice. Holm and Rose concluded that most injuries occurred when manipulating the lumbar spine of patients and that greater effort should be aimed at injury prevention education for students' learning HVLA thrust techniques. A possible explanation for the high rate of incidence of LBP in chiropractors and osteopaths may be that those who undertake training to enter these professions have had LBP prior to training, and had positive experiences with treatment which led them to pursue a career in the profession. Previous history of LBP is a known risk factor for future LBP (Frymoyer, 1988), therefore these chiropractors and osteopaths were predisposed to LBP before they entered their respective professions.

There are few studies that report on musculoskeletal injuries in osteopaths. In an unpublished dissertation by Rasmussen (1991), a survey was distributed to 100 British osteopaths. Fifty-six of the 69 osteopaths that responded (81%) reported spinal complaints at some point in their life. However, the study failed to classify spinal pain into lumbar, thoracic or cervical areas. The low number of respondents (n=69) limited the power and generalisability of the study. A latter study by Szmelskyj (1997) using a survey sent to 250 British osteopaths found "95.8% of respondents

reported the prevalence of spinal pain” (p.100). The response rate in this retrospective survey design was poor (19.2%) and sub-analysis of the affected spinal level was not undertaken. Factors for the development of LBP were not investigated in this study. Szmelskyj’s claim that the lifetime prevalence of back or neck pain was 95.8% is flawed, given the survey sample was small, the survey was self-administered and subject to non-response bias. The author did not report any analysis to reveal the extent of non-response bias. The author noted that the survey return rate was weakened because self-addressed, postage paid envelopes were not included in the mail out and follow-up reminder telephone calls were not initiated. The survey had previously been used on other health professions but had not been validated. There also appears to be confusion the terminology used in the study; the author using the terms ‘spinal pain’, ‘back pain’ and ‘low back pain’ interchangeably and with no definition of these terms. Shortcomings in design and procedure in Szmelskyj’s study threaten internal and external validity and therefore require a high degree of caution in applying the author’s conclusions to the osteopathic profession.

In a self-administered retrospective survey of New Zealand osteopaths, Chemeris (2001) reported a low response rate (22.9%) when investigating musculoskeletal complaints. Low back pain prevalence was reported as 55% (this was not clarified as point prevalence or lifetime prevalence by the author), with female respondents reporting higher rates of musculoskeletal injury than males. The higher musculoskeletal injury rate for female versus male practitioners echoed the findings of Mior and Diakow (1987), however weak study design, the small sample size and response rate in the Chemeris study may have resulted in the differing male and female rates. Chemeris concluded that the study confirmed anecdotal evidence that

practitioners using fixed-height tables may have an increase in the risk of developing WMSDs, especially low back injuries. While this assumption appears straightforward and intuitively correct, the scope of the study was to investigate injury prevalence rates and this conclusion regarding table heights was not based on data presented in this report. There appears to be little recent research investigating the incidence and prevalence of WMSDs in osteopaths and no research to date investigating the ergonomic characteristics of osteopaths in clinical practice.

#### *Summary of musculoskeletal disorders in the health professions*

Some authors have asserted that, in general, the health professions have a high prevalence of LBP (29% to 87%) (Bisiacchi & Huber, 2006; Bork et al., 1996; Hignett, 1996; Lorme & Naqvi, 2003; Mior & Diakow, 1987). However, lifetime LBP prevalence in the general population ranges between 50 and 84% (Nyland & Grimmer, 2003). When lifetime prevalence data from the general population is compared with data from the health professions, it appears that LBP prevalence rates from health professions are similar to the prevalence rates from the general population.

Retrospective survey designs are a useful preliminary approach at the early stages of exploring a research issue (Barker, Cooper, & Rose, 1998). However, retrospective survey designs have limitations. Firstly, using cross-sectional survey designs, as were used in the majority of the epidemiological studies reviewed above means that causal inferences cannot be made concerning the associations observed. Secondly, questionnaires were filled out retrospectively in most cases and therefore, the possibility of recall bias may be present. Since prevalence and incidence of WMSDs

including LBP in the health professions, especially nursing and physiotherapy, seems to be established in the literature; research should move to examining the risk factors involved in the development of LBP in the health care professions. As Callaghan and McGill (2001) suggest, epidemiological studies should be coupled with an understanding of the resultant tissue loading that leads to occupationally related disorders to justify injury prevention strategies on a scientific basis. Using biomechanical studies, coupled with tissue based approaches (mechanistic evidence) and epidemiological studies, will serve to place ergonomic guidelines on a solid evidence-based platform.

#### *Guidelines for practitioner posture*

Despite the long history and popularity of HVLA techniques in manual medicine, the ergonomics of practitioners while performing HVLA techniques has received little research attention. In a review of scientific literature, the National Centre for Complementary and Alternative Medicine (NCCAM) (National Institutes of Health, 2004), commented that little is known about manipulative and body-based practices from a quantitative perspective. The authors noted significant gaps in the field, including a “lack of biomechanical characterization from both practitioner and participant perspectives”. Since the NCCAM report there appears to be little change in the amount of literature investigating this field.

The goal of manipulation is to “restore maximal, pain-free movement of the musculoskeletal system in postural balance [in the subject]” (Greenman, 2003, p. 5). Notably, this definition focuses on subject-centred outcomes but lacks reference to factors relating to the operator. The definition provides objective and subjective

parameters that can be quantified to establish the effectiveness of the HVLA thrust techniques from the perspective of patient outcomes. Range of motion can be measured and the subject's response to active and passive movement and experience of pain can be quantified with well-validated patient-oriented outcome measure instruments (e.g. Oswestry Neck Disability Index). While the goal of manipulation is well defined in reference to subject-centred outcomes, the definition lacks reference to factors relating to operator comfort and safety. Without reference to the safety of the practitioner performing techniques, the definition reflects the lack of attention in the literature concerning practitioner biomechanics and ergonomic issues.

In his popular osteopathic technique textbook, Hartman (2001) states his opinion that the posture of the operator is critical to the effective performance of manipulative techniques. The author suggests that the ability to transmit forces in a precise manner utilizing the operator's weight, balance and application of force via hands, arms and body must be efficient for the technique to be effective. Further, he suggests that operators should critically appraise aspects of posture when learning new techniques so that the best positioning is achieved for their own comfort. With less effort and strain, the operator may avoid physical problems as well as increasing the effectiveness of each technique for the subject.

Hartman (2001) divides the components of operator posture into: weight of the operator in relation to gravity; contact with the floor or table; and operator stance in relation to the subject and table. The author's expression "operator's weight in relationship to gravity" is not conventional terminology and a better description would be the operator's centre of gravity in relation to their base of support (foot

position) that is used in standard biomechanical texts (Hamill & Knutzen, 1995). While many popular manipulation texts regarding HVLA techniques describe such factors as the direction of applied forces, placement of operator's hands on the subject and subject positioning on the table there is little information regarding practitioners' ergonomics and safety. Although practitioner posture for effective HVLA techniques is discussed by Tehan and Gibbons (2000), Greenman (2003) and Hartman (2001) it would appear that no formal investigation has been undertaken. However, advice on the key factors for optimal practitioner posture based on the authors' clinical experience and observation is offered in these texts (see Appendix A for an example from Gibbons and Tehan, 2000).

#### *Instantaneous loading in manual therapists*

Only one article could be located that investigated instantaneous spinal loads of manual medicine clinicians performing HVLA thrust techniques. Lorme and Naqvi (2003) studied the effect of three treatment table heights on lumbar spine loading of chiropractors performing HVLA thrusts to the cervical, thoracic or lumbar spine. The authors of this study suggest that chiropractors are a high-risk group for low-back pain and sought to determine if workstation (plinth) height was a contributing factor. They reported the study by Mior and Diakow (1987) as evidence that chiropractors who use manual methods are at a higher risk of LBP than those who use non-force methods. However, mention of this finding could not be located in the paper by Mior and Diakow. Lorme and Naqvi (2003) found that workstation height does affect low-back loading in chiropractors while performing HVLA thrusts to cervical, thoracic and lumbar regions. Using a static biomechanical model, the authors estimated disc compression force (DCF); however, the magnitude of the force was not clearly

reported in the study and could only be approximated from a diagram as between 1900 to 2600N at the L5/S1 level. Shear forces at the L5/S1 level were not investigated. It was noted that having the treatment table adjusted to the height of least spinal loading, an average 20% decrease in sagittal flexion was achieved. The authors suggested that adjusting table height appropriate to the task would lead to a great reduction in the cumulative lumbar disc compression and ligament strain and over the course of the chiropractors' career. However, even the least straining task produced an unacceptable amount of sagittal flexion, disc compression and ligament strain and "could not be considered risk free to the lumbar spine of the chiropractor" (Lorme & Naqvi, 2003, p. 32). Lorme and Naqvi concluded that HVLA thrust manipulation produces an unacceptable level of spinal loading on the chiropractor performing the procedure and that variable height tables should be used to minimise cumulative low back loading. However, they were unable to specify one treatment table height for minimising lumbar spine loading and proposed that treatment table height was dependant on the spinal region the HVLA thrust was being delivered to. Lorme & Naqvi cautioned against generalising their findings from chiropractors using 'diversified technique' to other manual medicine professions, as other manual medicine professions might use different techniques with different postural implications.

A limitation of the study by Lorme and Naqvi (2003) was the small group of practitioners (seven) because the practitioners' height inclusion criterion was arbitrarily set for subjects in the 75<sup>th</sup> percentile. The influence of practitioner morphology was also not considered in this study, which may have influenced how the techniques were performed because of differences in height of the chiropractor

population. Furthermore, the techniques were not fully described with only the term 'diversified' technique being mentioned. Despite its limitations, this study was the first known ergonomic study of low-back strain on operators performing HVLA thrust techniques and provides a useful starting point for developing a research design and protocol in this area.

While not a study of manual therapists, one study was located that investigated instantaneous and cumulative loading of orthodontists in a clinical setting (Newell & Kumar, 2005). The authors noted that musculoskeletal disorders of the spine among orthodontists are prevalent but that rates of incidence and prevalence of musculoskeletal disorders in orthodontists have not been investigated. The study aimed to quantify and compare instantaneous and cumulative loads on the lumbosacral and cervicothoracic spinal segments in orthodontists. A convenience sampling method yielded nine orthodontic graduate students from the same program for inclusion in the study. Video recording using a 'micro-camera' with a wide-angle lens was used to capture images for later analysis. Subjects were videotaped in a profile view 90° to the sagittal plane to allow for biomechanical analysis. A video player allowed timing of recorded postures. Printouts of still frames from the recorded videotape were produced and protractors used to measure joint angles to the nearest 0.5°. Angles were then used in a biomechanical model to indirectly calculate estimates of compression and shear loads on lumbosacral and cervicothoracic spinal segments of the subjects. Direct placement of joint markers necessitating that participants wearing only underwear was deemed impractical in their clinical environment, therefore the hip was used as an approximation of L5-S1, and the

shoulder joint (later in the study defined as the acromion) was used as an approximation for the position of C7-T1.

A two-dimensional biomechanical model was used to calculate instantaneous compression and shear loads at the L5-S1 and C7-T1 segments. Cumulative biomechanical loads were determined by summing the overall load of all tasks of each subject over the course of a day. The results showed that there was a significantly greater instantaneous compression and shears loads in males than females (compression;  $p < 0.007$  and shear  $p = 0.035$ ). Average instantaneous compression loads on the L5-S1 segment for men ranged from 1149 N to 1635 N (mean = 1383 N) and 792 N to 1072 N (mean = 936 N) for women. When the investigators calculated the estimated cumulative loads for the orthodontists the daily loads were found to be 14.5 MN s for males (which conflicts with 16.2 MN s reported in the abstract) and 9.9 MN s for females on the L5-S1 segment. Concluding their study, Newell and Kumar suggested that smaller loads cannot be ignored and although the tasks appear innocuous, “by virtue of the frequency and duration of their performance they [tasks] are rendered hazardous” (p. 136).

One of the limitations of the Newell and Kumar study was subjects wearing clothing in the field study that obscured the landmarks used for the measurement of angles. The authors mentioned that subjective judgements of landmarks was validated with a study of one subject wearing only briefs with markers attached to the skin compared to another subject dressed in casual work clothing. The angle data from the unclothed subjects and clothed subjects did not show any statistical difference and yielded the same result, and on this basis, the authors claim that the technique was validated.

This process does not appear to be a rigorous validation technique and Newell and Kumar acknowledge some errors may occur with the subjective judgments of landmark position under clothing. Further errors may have occurred, as the landmarks measured in the field study were proxies for the landmarks used in the biomechanical model. At first, it was stated in the study that the shoulder was “approximated by C7-T1” (Newell and Kumar, 2005, p. 132). There is clearly a difference between the location of the shoulder (acromion) and the C7-T1 segment. It was also stated that the acromion was used as the marker for C7-T1 and L5-L1 was represented by the ‘hip joint’. From images presented in the study it appears that a point on the proximal, lateral thigh was used to represent the ‘hip joint’ landmark. Joint locations were marked using “Hall as a reference” (p.131) without further description of the method employed. The authors stated that each frame was “...carefully examined for anatomical landmarks (i.e. centre of gravity of the head)” (Newell and Kumar, 2005, p. 132). The authors do not elaborate on which landmark locates the centre of gravity of the head. The biomechanical model used in the study relies on standardised anatomical data that estimates the location of trunk, arm and head centre of gravity location as a percentage of segment length (Plagenhoef, Evans, & Abdelnour, 1983). An aspect of the study (Newell & Kumar, 2005) that introduces some uncertainty is that joint angles were not defined. Body segment angles used in the study as the basis for estimating instantaneous and cumulative shear and compression loading were not defined but based on the field study images provided the reader is able to infer that the trunk angle ( $\theta_1$ ) appears to be the inclination of the trunk represented as a line from the hip joint to the acromion in relation to the vertical (Newell and Kumar, 2005, p. 134). Neck angle ( $\theta_2$ ), appears to be the inclination of the head taken as a line from the acromion to the zygomatic process of the temporal

bone. Arm angle ( $\theta_3$ ), appears to be the inclination of the arm as a line from the acromion to the olecranon relative to the vertical. The lack of written definitions and the small images prevented a clear identification of the landmarks used and the angles based on them.

The use of a small 'micro-camera' with a wide-angle lens (make and model not disclosed) may have introduced error in the angle measurement, as wide-angle perspective distortion is evident in the field study images. This distortion is caused by an object in the scene being much closer to the camera than the remainder of the objects in the scene. Therefore, error is possible in measurement of the body segments closer to the plane of the camera such as the elbow and acromion. Use of a standard lens would reduce the magnitude of this perspective distortion. The authors did not mention how they maintained the plane of the camera  $90^\circ$  to the mid-sagittal plane of the orthodontists' being video taped.

Some factors in the Newell and Kumar study could not be adequately controlled because of the field study conditions. For example, some subjects were videotaped from the left, others from the right therefore, measurements of angles were extrapolated from close estimates of landmarks, which were obscured and may have limited accuracy of calculated loads for some postures. Direct placement of body markers was impractical as clothing was required in the clinical setting. Eliminating environmental restrictions on camera placement, and controlling other factors that may influence joint angle measurement would improve the rigor of such a study. Despite this study's limitations, it provides a simple, static, two-dimensional, single

moment arm, linked segment model for estimating instantaneous compression and shear loads that may be applied to other settings.

### *Spinal loading guidelines*

#### **Compression loads**

It has been conventionally assumed that spinal loading is equated with compression loading and that compression is the principal biomechanical mechanism associated with occupationally related low back disorders (Adams, Bogduk, Burton, & Dolan, 2002b; Waters, Putz-Anderson, Garg, & Fine, 1993). In order to reduce the risk of over exertion injuries to the spine, maximum lumbar disc compression recommendations have been published (NIOSH, 1981). The National Institute for Occupational Safety and Health (NIOSH) lifting equation uses the estimation of static compressive loads on the spine as the critical criteria for discerning between safe versus hazardous tasks (Waters et al., 1993). The L5-S1 segment is usually studied as this joint has the potential to incur the greatest lumbar stress during lifting and the disc between L5 and S1 is one of the most vulnerable tissues to force-induced injuries (Waters et al., 1993). Waters et al. based the NIOSH criteria for maximum disc compression force on findings from field study data in which compressive force estimates were linked with the incidence of low-back disorders. According to NIOSH, the suggested maximum compressive force on the L5-S1 segment, is 3.4 kN, however, maximum compression loads below 3.4 kN are not risk-free. Data derived from testing cadaver spinal segments found that 21 % of cadaver spinal segments fractured or developed end-plate fractures at loads below 3.4kN (Brinckmann, Biggemann, & Hilweg, 1988; Brinckmann et al., 1989).

Some authors have suggested that the NIOSH guidelines have less utility than previously believed because of the limited data upon which they are based, provide estimation of static forces only, and can be applied to a limited number of tasks (Jäger & Luttmann, 1999). Jäger and Luttmann suggested a different set of maximum compression load recommendations. Based on age they suggested 6kN for young males 4.1kN for middle aged and 2.3 kN for older adults (20/40/60 years of age) as more appropriate limits of maximum lumbar compression load. While there appears to be no consensus guideline, recently the emphasis on compression loads has widened to encompass other physical factors including shear and dynamic forces of the lumbar spine.

While the traditional emphasis on instantaneous compression spinal loading as a risk factor for LBP is evident in earlier literature, studies have disproved the hypothesis that compressive overload alone can directly damage healthy lumbar discs by causing prolapse (Roberts, Menage, & Urban, 1989). The significance of vertebral endplate fractures has been discussed in the literature as a likely aetiology for discogenic low back pain (Bogduk, 1991). Intervertebral discs are well designed to resist high compressive forces but the adjacent vertebral endplate has less structural resistance to these forces by the presence of foramina that allow the diffusion of metabolites to the avascular discs (Brinckmann et al., 1989; Yoganandan et al., 1994). The endplate is the first structure to sustain damage when compressive force rises to high levels. Vertebral endplate fractures disrupt the nutrient diffusion to cells in the nucleus pulposus triggering a cascade of pathophysiological processes leading to degradation of the nuclear matrix that in turn alters the biomechanical properties of the nucleus

pulposus; this process has been termed internal disc disruption (IDD). Bogduk (1997) has suggested four postulates that must be met for a structure to be deemed a cause of back pain. First, the structure should have a nerve supply; second, that it be capable of causing pain similar to that seen clinically; third, the structure should be susceptible to diseases or injuries that are known to be painful and ideally the disorder should be evident on investigation of the patient, and fourth, the structure is shown to be a source of pain in patients, using diagnostic techniques of known reliability and validity. Given that the outer third of the intervertebral disc is highly innervated with free nerve endings (Coppes, Marani, Thomeer, & Groen, 1997) and IDD can be demonstrated with CT-discography and MRI (Aprill & Bogduk, 1992) and identified in patients, the evidence so far indicates that IDD satisfies three of the four postulates necessary to establish it as a source of lumbar discogenic pain (Bogduk, 1997). Recent findings (Przybyla, Pollintine, Bedzinski, & Adams, 2006) also lend weight to the hypothesis that endplate fractures result in an immediate and widespread effect on intradiscal stresses and provides a greater stimulus for disc degeneration than annular tears.

### **Shear loads**

Several studies have indicated that compression forces on the spine are associated with low back problems (Bogduk, 1991; Davis et al., 1998; Duma, Kemper, McNeely, Brolinson, & Matsuoka, 2006; Yoganandan et al., 1994) however the weak correlation suggests that other factors are involved. In recent years there appears to be greater emphasis by researchers on the role of shear loading as a risk factor in the aetiology of low back problems (McGill, Norman, Yingling, Well, & Neumann, 1998; Yingling, Callaghan, & McGill, 1999; Yingling & McGill, 1999). A case-

controlled study investigating the incidence of low back pain reporting at a large automotive plant identified the magnitude shear force as a strong predictor of low back pain (Norman et al., 1998).

McGill, Norman, Yingling, Well, and Neumann (1998) suggested that the ‘action limit’ for instantaneous shear forces acting on L5-S1 is 500N (an action limit represents the value at which nominal risk is likely when lifting loads for more than 99% of male workers and 75% of female workers). This action limit is based on a study by Norman and co-workers (1998) who observed that repeated exposure to shear loads lowered the threshold magnitude for shear to about 500 N, above which, elevated risk was observed.

### **Cumulative load**

Peak instantaneous loading limits are relatively well established in the literature despite ongoing discussion about the versatility of lifting equations to other occupational tasks and the assumptions used in formulating those guidelines. The estimation of cumulative load however is an area where little research effort has been directed. By definition, cumulative load is the load history, that is, load over a time period. There appears to be no agreed guideline in the literature that has defined cumulative spinal load levels that are hazardous.

The absence of such a guideline may be, in part, due to a lack of consensus on the best method of field data collection that may decrease the considerable work in processing data without increasing measurement error (Andrews & Callaghan, 2003; Azar, Andrews, & Callaghan, 2005; Kumar, 1990). It was noted by Callaghan, Salewytch,

and Andrews (2001) that if the issue of error in different load estimation techniques is not addressed, this field of research may not be able to progress. Kumar and Narayan (2005) in their investigation of x-ray technicians using various video frame rates and algorithms to estimate cumulative spinal loading, remarked that there was still ongoing debate regarding the model that may best estimate cumulative load and offered three steps to clarifying the methodology. First, agreement is needed on an algorithm for the quantification of cumulative load over a single cycle of loading. Second, a method to calculate the cumulative load over a work shift, or other period of interest, that is scientifically valid is required. Last, researchers need to determine how exposures accumulate over a long period and a means of accounting for the partial recovery of tissues during rest breaks, overnight and at weekends between cycles of work. Kumar and Narayan (2005) when reviewing the field, noted that the determination of cumulative load is in its infancy and the search for techniques suitable to most researchers is still in progress. They noted that due to the volume of data collected there is a substantial degree of 'time tedium' associated with this field of endeavour.

German researchers (Jäger, Jordan, Luttmann, Laurig, & The DOLLY Group, 2000) have noted that cumulative loading has only been sporadically investigated outside of Germany. Within Germany, so called 'dose determination' has attained some importance in the context of workers compensation and disc-related disease. Jäger et al. reported a study published in German (Hartung & Dupuis, cited in Jäger et al., 2000) that suggested a dose threshold of 1700 Newton hours (Nh). However, Jäger and colleagues were cautious in applying the 1700Nh threshold in their study of cumulative load because of methodological differences. Using a different model and

data, a shift-related critical cumulative loading guideline of 5500 Nh was recommended by Jäger et al.. Kumar and Narayan (2005) in reviewing the work of Jäger et al., commented that it was difficult to assess from the description of the work presented if load and time integral was calculated at all, stating that it may be a convenient method of representing overall combined load but that it “fudges the facts for biological fidelity and makes it more difficult for any targeted intervention”(p.899). Due to methodological differences, it appears that the field of cumulative spinal load guidelines does indeed lack consensus among its professionals and further work is necessary before consensus and a valid set of guidelines are developed.

#### *Spinal loading measurement methods*

Various methods have been used to quantify instantaneous spinal loading by ergonomic and biomechanics investigators. The least intrusive methods use third-party observation to record subject posture which is classified into ranges of movement observed, e.g. forward flexion recorded in ranges of 0 to 10 degrees, 10 to 20 degrees, 20 to 30 degrees and so on. Video recording and analysis of subject posture has been extensively used to estimate spinal loading. The use of participant self-reporting of posture in logbooks has also been used. Slightly more intrusive methods include three-dimensional movement tracking and electromyography (EMG) in real-time. The most invasive methods include using a pressure-sensitive needle that is inserted directly into the lumbar disc of volunteers.

The ‘gold standard’ for measurement of instantaneous spinal compression is the use of pressure-sensitive needles inserted into the lumbar discs of conscious volunteers.

Nachemson and Morris (1964) were the first to use this technique to obtain disc pressure measurement data from the L3-4 discs of human volunteers. The authors then converted the compression measurements by using cadaveric studies to calibrate pressure against force. The results from this early experiment have been confirmed with more recent studies using more sophisticated technology (Sato, Kikuchi, & Yonezawa, 1999; Wilke, Neef, Caimi, Hoogland, & Claes, 1999). The disadvantage with this method, apart from the objection of most medical ethics review committees, is that subjects are unlikely to move in a natural or vigorous manner with a needle inserted into their backs. Additionally, it has been discovered that because compression forces are calibrated against cadaver specimens, which may have swollen with water in storage, there are discrepancies in spinal compression forces of up to 36% because experiments on human subjects were performed after hours of activity, which dehydrated their discs (Adams, et al., 1996).

Less intrusive methods than direct discometry include three-dimensional movement tracking and electromyography (EMG). An example of the use of three-dimensional tracking equipment was Lorme and Naqvi's (2003) investigation of the lumbar spine loading of seven chiropractors performing HVLA thrusts at three plinth heights. The investigators used a Lumbar Motion Monitor (LMM), (Chattanooga Group Inc, Chattanooga, Tenn.) which is a triaxial electrogoniometer, to provide lumbar spine range of movement and velocity data for a dynamic biomechanical model. Lorme and Naqvi noted that the LMM has been shown to be "highly reproducible when compared with other methods to measure motion and velocity". Similar electromagnetic goniometer equipment includes the 3-Space Isotrak (Polhemus, Colchester, VT) which records lumbar curvature up to 60 times per second.

When dynamic linked-segment models are used to calculate spinal loading, force plate data can be incorporated in the model to account for the effects of ground reaction forces (Rogers & Triano, 2003). Full dynamically linked-segment models are able to accurately measure three-dimensional forces acting on each joint of the body; however, the main drawback is that they are unable to determine antagonistic muscle activity, which can increase joint loading without affecting the movement of adjacent segments (Kingma, 1996).

Electromyography (EMG) can be used to indirectly estimate forces across the lumbar spine as most of the compressive force on the lumbar spine arises from tension of the back muscles (Dolan et al., 2001). This method uses the EMG activity of the erector spinae group to predict the extensor moment generated by the muscle group and then divide the moment by an effective lever arm, which is representative of the whole muscle group (Adams et al., 2002b). Electromyographic (EMG) assisted methods in which EMG measurements are combined with muscle cross-sectional data can be used to determine the relative activity of each muscle, so that moments can be distributed between the muscles (Granata & Marras, 1999). The advantages of an EMG approach are that the method directly accounts for the variable effects of muscle length and contraction velocity and is it especially suited to rapid movements of the trunk. The drawback of EMG methods is the variability of EMG signals which may be a result of variable motor unit recruitment strategies within a larger muscle (Kingma et al., 2001).

The least intrusive methods of measurement include video recording of subject posture and self-reporting of posture and loads by the subject. Video recordings of

subjects involve two approaches, one in which postures are classified in groups by the investigators and the other where joint markers are placed on the body of the subjects for later digitization and analysis with motion analysis software.

The posture classification system was used by Jäger et al. (2000) when investigating the lumbar loading in four manual handling occupations. Video recordings were made of a subjects work shift and the observer classified the degree of movement in a number of parameters. For example, sagittal trunk inclination was classified in steps of 15 degrees so that seven divisions were attributed between 'upright 0 degrees' and 'trunk held horizontally 90 degrees'. The length of time that this posture was held was recorded and the mass of any objects lifted was measured. This method was in a study that estimated cumulative spinal loading of massage therapists performing a standardised 44-minute massage session (Albert, Duncan, Currie-Jackson, Gaudet, & Callaghan, 2006). The inherent limitation of this method is the error that may occur between the observed posture and the increments of the classification system.

Measures may also be influenced by the position of the observer relative to the subject, especially as this method may be used in situations that prevent satisfactory simulation in a laboratory investigation such as the dustbin collection task in the study by Jäger et al. (2000). The obscuring of body posture by clothing also reducing the accuracy of body angle estimation (Andrews & Callaghan, 2003).

The more common method of collecting joint angle data is to attach reflective or non-reflective joint markers on subjects and digitize the video recording for video analysis. Video analysis is usually performed with a software package that allows for measurement of body segment angles and timing data to be extracted e.g. the PEAK

Performance system (Peak performance technologies Inc. Englewood, CO) or Silicon Coach motion analysis software (Silicon COACH, Dunedin, New Zealand). This method has been used by the majority of spinal cumulative load researchers (Andrews & Callaghan, 2003; Callaghan et al., 2001; Daynard et al., 2001; Kumar & Narayan, 2005). The advantages of this method are that shear and compression forces can be estimated, a permanent visual record of the subjects is obtained and the time base of the documented task is maintained (Andrews & Callaghan, 2003). The disadvantage is the method can be labour intensive and the attachment of markers, which obviates the removal of clothing, may not always be possible in the field. In an attempt to decrease the onerous data processing demands of this method, cumulative load researchers have investigated the sampling rate that yields the best estimation of load with the least error. Kumar (1990), in one of the first studies on cumulative loading, used a five frames per second rate (5 Hz). Callaghan et al. (2001) reported that the reduced sampling rate of 5 Hz resulted in very small errors when compared with a complete data set using 30 Hz. A subsequent study by Kumar & Narayan (2005) examined a range of frame rates (0.25, 0.5 and 1, 2, 4, 5 Hz), for least error in predicting cumulative loads versus a 'gold standard method (10 Hz)'. An examination of frame rate demonstrates an inverse relationship between the error of calculation and frame rate and they recommended 5 Hz as the optimal sampling method since the pattern of load/force traces can be highly variable depending on the task investigated.

The use of participant self-reporting of posture in logbooks has recently been reported as a method to reduce data collection and processing resources. Azar et al. (2005), in a laboratory study of 16 subjects carrying out a variety of work and rest tasks used

two self reporting protocols; a logbook and 2-hr recall. They reported that cumulative loads estimated from self-reported frequency and duration information were strongly associated with those derived from actual video and time records. Of the two methods, the logbook protocol resulted in less error than the recall method with error between actual and estimated cumulative loads being less than 10%.

In summary, investigations into spinal loading have used a variety of methods, each with inherent advantages and disadvantages. In the field of cumulative spinal loading, the volume of data collected is a concern of many researchers and efforts have been made to decrease the processing burden while minimising errors in load estimation (Andrews & Callaghan, 2003; Callaghan et al., 2001; Kumar & Narayan, 2005). The cumulative spinal loading field appears to be in its infancy and requires further work to refine methodological approaches that are acceptable to those in this area. The output of several Canadian biomechanical and ergonomic investigators seems to be working toward this end (Andrews & Callaghan, 2003; Azar et al., 2005; Callaghan et al., 2001; Kumar & Narayan, 2005). With further work towards a consensus of methodological approach, results may be compared with an aim to establish cumulative load safety guidelines in the future.

#### *Models to estimate spinal loading*

Various mathematical models have been developed that use a 'moment arm analysis' approach to measuring spinal compression in a less invasive manner. Linked segment models such as the University of Michigan 3-dimensional static model (Kumar, Moro, & Narayan, 2005), and the 2-dimensional static linked segment models such as GOBER (University of Guelph, Guelph, Ont., Canada) used by Andrews and

Callaghan (2003) and a model derived by Newell and Kumar (2005), are commonly used. Parts of the body such as the lumbar spine, pelvis and trunk are modelled as a chain of rigid segments linked by frictionless joint and moved by the action of muscles that join the segments together.

Muscle forces are often combined in simple models to give a single moment arm (Callaghan & McGill, 2001; McGill & Norman, 1987). Biomechanical models utilized for the analysis of spinal loading usually calculate a lumbar resultant moment. Subsequent reaction components of vertebral shear and compression are estimated assuming the lumbar extensor musculature and ligaments produce forces posterior to L4-L5 or L5-S1, which is considered the centre of rotation for the purposes of moment calculation (McGill & Norman, 1987).

High estimates of spinal loading from these models were observed and various mechanisms were explored to give more realistic estimates (intra-abdominal pressure, lumbodorsal fascia and hydraulic amplifiers). A study by Bogduk (Bogduk, 1980) and subsequently confirmed in a study by McGill (1987), revealed that there were marked variances between textbook descriptions of the erector spinae musculature and dissected cadavers. This led McGill to suggest that the use of the single muscle equivalent approach was sound and over-estimations in disc compression force were the result of the discrepancy in the representation of lumbar spine anatomy.

Single equivalent moment arm models for erector spinae have commonly used a centre of axis 5cm posterior to the disc centre. However, Nemeth and Ohlsen (1986), estimated that the centre of the erector spinae was 7.1 cm posterior to the disc centre

of L5-S1 using CT scans of eleven male subjects. McGill and Norman (1987) suggested that a moment arm of 7.5 cm be used based on the examination of the detailed geometry of lumbar extensor tissues. Five centimetre moment arm models have tended to over estimate spinal compression when compared with direct and EMG-assisted models. However, more recently 6-8cm 'lever arms' are currently accepted which have reduced the difference between methods (Adams et al., 2002b).

Measurement of the position of each body segment occurs at selected intervals by the observer directly, or from recorded video playback or subject recall. Anthropometric data regarding length and mass of each segment can be used to calculate the forces acting on the joint (Adams et al., 2002b). Researchers have compiled anthropometric data that allows biomechanical investigators to derive length, mass and centre of gravity of each segment from height measurements of subjects thereby simplifying the measurements required (Plagenhoef et al., 1983). By using a biomechanical model, body segment position and anthropometric data can be used to estimate instantaneous spinal loads.

Static models have often been used in cumulative loading studies (Albert et al., 2006; Callaghan et al., 2001; Daynard et al., 2001; Jäger et al., 2000; Kumar & Narayan, 2005; Newell & Kumar, 2005). Many ergonomic researchers have justified the use of static modelling because of the extra data collection and analysis time and expertise required to use dynamic modelling. These resources are typically not available or impractical in workplace and industrial settings. Static modelling has been shown to result in errors in peak low back loads relative to dynamic modelling approaches (McGill & Norman, 1985), because dynamic models can include extra forces required

to accelerate body segments and accurately measure three-dimensional forces acting on each joint of body. However, in situations where the task is relatively static, acceleration forces are minimal and static models provide a simple method to estimate spinal loading.

Various algorithms have been used to calculate cumulative load from instantaneous data. Norman et al. (1998) used peak load and the duration of the task to estimate cumulative load. This method is much less onerous in data collection, however, Callaghan et al (2001) found that the square method (peak load \* duration) overestimated the compressive load by 70% and the shear loads were overestimated by 150%. Kumar (1990), in a study of institutional aides, calculated instantaneous load every 200 milliseconds (5 Hz) and multiplied force (N) with time (s) to obtain a total time integrated force value (Ns). Subsequently, Kumar and Narayan (2005) investigated five different algorithms to evaluate the degree of error in estimating cumulative load. The methods were peak force and duration product; half of peak force and time product; average force and time product; half of the sum of initial and final force and time product; and total area under the force curve. Kumar and Narayan found that the variance in load estimation of the difference approaches was as much as 100%. Error rates were significant for peak force \* time,  $\frac{1}{2}$  peak \* time, there were also significant and erratic errors with average force \* time. With  $\frac{1}{2}$  (initial + final force) \* time had a constant error and even total area under the curve had significant errors up to 3 Hz. In the same study, they investigated the effect of different video frame rates sampling and found that examining the combination of load approach and frame rate revealed load values could differ up to 250% between

lowest and highest value. Area under the curve was the most reliable method of cumulative load estimation.

## **Conclusion**

Osteopathic medicine has undergone substantial changes since its inception. The use of HVLA thrust techniques is one of these evolutions. Various authors have proposed hypotheses for the mechanism of action for HVLA thrust techniques and that these therapeutic procedures may be useful in the treatment of low back pain.

It appears that although some authors of manual therapy textbooks discuss aspects of practitioner ergonomics, none cites relevant literature to substantiate their claims.

However, there is currently little published research investigating the ergonomics of manual medicine practitioners performing techniques that are commonly used in clinical practice. It would be advantageous for the osteopathic profession, and other manual medicine professions, to apply general ergonomic principles as a source of guidance for training and practice of HVLA thrust techniques.

When examining peak spinal loading literature, there is a reasonable level of consensus on which factors lead to the most demanding loads. These factors include greater external load and greater external moment arm. Different joint loading models have been employed in various studies and discussion continues on the validity of the assumptions that these models are based on. Despite this ongoing discussion, guidelines for safer instantaneous spinal loading have been published.

The studies that examined cumulative loading to date have all employed different approaches preventing researchers comparing calculated cumulative loading values, and progressing toward defining a threshold limit for cumulative loading.

The magnitude of instantaneous and cumulative spinal loads have not been studied in osteopaths during the application of techniques used in clinical practice, nor has the relevance of instantaneous and cumulative loads in the aetiology of WMSDs such as LBP been investigated.

The goal of the study reported in Section II was to gain some insight into the magnitude of spinal loading that occurs in osteopaths during performance of HVLA thrust techniques. Specifically, the primary aim of the study was to determine the instantaneous and cumulative loads on the lumbosacral and cervicothoracic spinal segments during the pre-thrust phase of a thoracic HVLA thrust technique and to subsequently compare this data with findings reported in the general ergonomic literature for safe spinal loading.

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## **Section II: Journal Manuscript**

**Estimation of instantaneous and cumulative loads on the  
low back and neck of osteopaths while performing the  
pre-thrust positioning for a high velocity, low amplitude  
thrust technique applied to the thoracic spine**

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## **ABSTRACT**

*Background:* There is epidemiological evidence that musculoskeletal disorders of the back and neck are prevalent among healthcare professionals. However, to date there are no known biomechanical studies to determine the instantaneous and cumulative loading in the low back and neck of osteopaths performing tasks encountered in daily practice.

*Objective:* The present study aimed to estimate instantaneous and cumulative loads on the low back and neck of osteopaths while performing the pre-thrust positioning for a commonly used high velocity, low amplitude thrust (HVLAT) technique applied to the thoracic spine.

*Method:* The sample included 8 undergraduate students and 16 graduate students in the osteopathy programme at Unitec New Zealand and two registered osteopaths (male n= 16, female n=10). Digital still images of operators performing the pre-thrust positioning for a thoracic spine HVLA thrust technique on a variable height table were analysed with motion analysis software. From the observed data, instantaneous compression and shear loads at the L5-S1 and C7-T1 segments were estimated using a static biomechanical model. Estimates of weekly and yearly cumulative compressive and shear loads were calculated based on assumptions from osteopaths' anecdotal clinical experience.

*Results:* Instantaneous compression loads on the L5-S1 segment ranged from 1023 N to 7575 N and from 33 N to 477N on the C7-T1 segment. L5-S1 instantaneous shear loads ranged between 160 N and 829 N and between 18 N and 112 N for the C7-T1 segment.

*Conclusions:* This study found a distinct correlation between body mass and instantaneous lumbosacral spinal loading (Pearson's  $r = 0.96$ ). The magnitude of instantaneous compressive lumbosacral spinal loads in this study were found to be within the range to cause vertebral endplate fracture. Lumbosacral shear forces were found to be above the acceptable levels recommended in spinal safety guidelines but below levels capable of causing pars interarticularis fracture. Therefore, manipulative techniques that involve forward flexion may increase instantaneous compressive and shear lumbosacral spinal loading above generally agreed acceptable limits for spinal safety.

*Keywords:* ergonomics, cumulative load, shear, osteopathy, high velocity low-amplitude thrust technique.

## INTRODUCTION

The incidence and prevalence of low back pain in the general and working populations has been extensively studied over a number of years.<sup>1-6</sup> Numerous studies have focused on industrial populations because of the high incidence of low back pain (LBP) in these groups and the consequent absenteeism, disability and treatment and compensation costs associated with this condition.<sup>7-10</sup> Some studies have attempted to determine biomechanical factors that predict LBP<sup>11-14</sup> while more recently psychophysical and psycho-social factors have been investigated.<sup>10, 15</sup> No single factor can be attributed as the cause of LBP and it is regarded as a multi-factorial, heterogeneous problem which includes a variety of biopsychosocial factors that make standardised assessment and treatment complex.<sup>16</sup>

Epidemiological studies on the health care professions of physiotherapy<sup>17-20</sup> and nursing<sup>21-23</sup> have sought to quantify the incidence and prevalence of work-related musculoskeletal disorders including low back pain. These studies have used retrospective survey designs to investigate the factors that respondents believed contributed to their LBP. In a review of 80 studies over the previous 30 years, Hignett<sup>24</sup> found the lifetime prevalence among nurses ranged between 35-80%. Findings from subsequent research in physiotherapy have fallen within the prevalence range quantified by Hignett. Bork et al.<sup>20</sup> found 45% of a American physiotherapy program graduates experienced LBP, while Cromie and co-workers<sup>19</sup> in a survey of Australian physiotherapists found the 12-month prevalence of low back pain to be 62.5%.

Some authors have asserted that the health professions have a high prevalence of LBP, ranging from 29%<sup>17</sup> to 87%<sup>18</sup>, which indicates they are a high risk group for low back problems.<sup>20, 24-27</sup> However, life-time LBP prevalence of the general population is in a similar range of 50 to 84%.<sup>18</sup> It would appear that LBP prevalence rates from health professions reflect the prevalence rates from the general population.

Retrospective survey designs are a useful preliminary approach at the early stages of exploring a research issue. Since incidence and prevalence of work-related musculoskeletal disorders (WMSDs) including LBP in the nursing and physiotherapy professions appears to vary in the literature as it does in the general population; research should move to examining the risk factors involved in the development of LBP in the health care professions. As Callaghan and McGill<sup>28</sup> suggest epidemiological studies should be coupled with an understanding of the resultant tissue loading that leads to occupationally related disorders to justify injury prevention strategies on a scientific basis.

There is less research literature investigating the WMSDs in chiropractors and osteopaths. There is some evidence that osteopaths and chiropractors experience a high incidence of LBP. Mior and Diakow<sup>25</sup> in a retrospective survey of Canadian chiropractors found the prevalence of back pain to be 87% of respondents, while 52% attributed clinical practice as an aggravating factor to their back pain. The authors suggested that chiropractors experience musculo-skeletal disorders due to the physical demands of high velocity, low amplitude (HVLA) thrust techniques used in the treatment of their patients. Mior and Diakow also suggest that incorrect table height may be a contributing factor in the causation of LBP.

Holm and Rose,<sup>29</sup> in a survey of 1000 American chiropractors, found 40.1% of respondents (response rate 42.2%) had experienced a work-related musculoskeletal injury or condition, with low back injuries accounting for 24.6% of respondents complaints. Two-thirds of chiropractors (66.7%) sustained their injury while performing a manipulation or positioning a patient for manipulation (11.1%). Injuries most commonly occurred in the first five years of practice (37.3%). Holm and Rose concluded that most injuries occurred when manipulating the lumbar spine of patients and that greater efforts should be aimed at injury prevention in students learning HVLA thrust techniques.

Lorme and Naqvi<sup>26</sup> studied the effect of treatment table height on lumbar spine loading of chiropractors performing HVLA thrusts to the cervical, thoracic or lumbar spine. They concluded that HVLA thrust manipulation produced an unacceptable level of spinal loading on the chiropractor performing the procedure. Despite a 20% decrease in sagittal flexion by having the treatment table adjusted to the height of least spinal loading, even the least straining task produced an unacceptable amount of sagittal flexion and “could not be considered risk free to the lumbar spine of the chiropractor” (p. 32). Using a static biomechanical model, the authors estimated disc compression force (DCF), however the magnitude of the force was not clearly reported in the study and could only be approximated from a graph as between 1900 to 2600N at the L5/S1 level. Shear forces at the L5/S1 level were not investigated. Lorme and Naqvi cautioned against generalising their findings from chiropractors using ‘diversified technique’ to other manual medicine professions as other manual medicine practitioners may use different techniques.<sup>30</sup>

There are few studies that report on musculo-skeletal injuries in osteopaths. In an unpublished dissertation by Rasmussen<sup>31</sup> spinal pain was reported in 56 of 69 British osteopaths (81%). However, the study failed to expand classification into lumbar, thoracic or cervical areas and the low number of respondents (n=69) which limited the power and generalisability of the study. A latter study by Szmelskyj<sup>32</sup> in a survey sent to 250 British osteopaths stated “95.8% (n=46) of respondents reported the prevalence of spinal pain” (p.100). Breakdown of spinal areas affected were not specified in the study. Factors for the development of LBP were not investigated in this study. The claim that the lifetime prevalence rate of back or neck pain was 95.8% was flawed, given the survey was small, self-administered and subject to non-response bias, for which no analysis was attempted to reveal. The response rate in this retrospective survey design was poor (19.2%) and the author noted that there was no follow-up on non-responders. The survey was not validated and had not been piloted on osteopaths. There also appears to be a confusion of terminology in the study; the author using the terms ‘spinal pain’, ‘back pain’ and ‘low back pain’ with no definition of these terms. Factors for the development of LBP were not investigated in this study.

In a self administered retrospective survey of New Zealand osteopaths, Chemeris<sup>33</sup> reported a similarly low response rate (22.9%) when investigating musculo-skeletal complaints. Low back pain prevalence was reported as 55% (this was not clarified as point prevalence or lifetime prevalence by the author), with female respondents reporting higher rates of musculo-skeletal injury than males. The higher musculoskeletal injury rates for female versus male practitioners echoed the findings

of Mior and Diakow.<sup>25</sup> The author concluded that practitioners' fixed-height tables may increase the risk of developing WMSDs.

Several studies from the ergonomic literature indicate trunk flexion and rotation and lifting at work,<sup>12, 34</sup> awkward postures and forceful movements<sup>35</sup> and increased lifting frequency, lifting height, weight and lifting position<sup>36</sup> are risk factors for LBP.

Techniques used by chiropractors and osteopaths involve the practitioner forward flexing the trunk, rotating and side bending under loading, moving patients and developing thrust forces.<sup>37-40</sup> Extrapolating general ergonomic principles it can be postulated that chiropractors and osteopaths are at risk of developing musculo-skeletal injuries because of the techniques used in their respective professions.

Newell & Kumar<sup>41</sup> investigated instantaneous and cumulative spinal loading of orthodontists in a clinical setting. The study aimed to quantify and compare instantaneous and cumulative loads on the lumbosacral and cervicothoracic spinal segments in orthodontists. Video recording using a 'micro-camera' with a wide-angle lens was used to capture images for later analysis. Subjects were videotaped in a profile view 90° to the sagittal plane to allow for biomechanical analysis. A video player allowed timing of recorded postures. Printouts of still frames from the recorded videotape were produced and protractors used to measure joint angles to the nearest 0.5°. Angles were then used in a biomechanical model to indirectly calculate estimates of compression and shear loads on lumbosacral and cervicothoracic spinal segments of the subjects. Direct placement of joint markers necessitating that participants wear only underwear was deemed impractical in their clinical environment, therefore the hip was used as an approximation of L5-S1, and the

shoulder joint (later in the study defined as the acromion) was used as an approximation for the position of C7-T1. The study used a two-dimensional biomechanical model to calculate instantaneous compression and shear loads at the L5-S1 and C7-T1 segments. Cumulative biomechanical loads were determined by summing the overall load of all tasks of each subject over the course of a day. The results showed that there was a significantly greater instantaneous compression and shears loads in males than females (compression;  $p < 0.007$  and shear  $p = 0.035$ ). Average instantaneous compression loads on the L5-S1 segment for men ranged from 1149 N to 1635 N (mean = 1383 N) and 792 N to 1072 N (mean = 936 N) for women. When the investigators calculated the estimated cumulative loads for the orthodontists the daily loads were found to be 14.5 MN s for males (which conflicts with 16.2 MN s reported in the abstract) and 9.9 MN s for females on the L5-S1 segment. Concluding their study, Newell and Kumar suggested that smaller loads cannot be ignored and although the tasks appear innocuous, “by virtue of the frequency and duration of their performance they [tasks] are rendered hazardous” (p. 136). While not a study of manual medicine practitioners, Newell and Kumar’s study provides a useful, simple model to estimate the instantaneous and cumulative loading of practitioners in a clinical environment.

The magnitude of instantaneous and cumulative spinal loads have not been studied in osteopaths during the application of techniques used in clinical practice, nor has the relevance of instantaneous and cumulative loads to developing WMSDs such as LBP been investigated. The goal of this study was to gain some insight into the magnitude of spinal loading of osteopaths. Specifically, the primary aim of this study was to determine the instantaneous and cumulative loads on the lumbosacral and

cervicothoracic spinal segments during the pre-thrust phase of the HVLA thrust technique and subsequently to compare this data with findings reported in the general ergonomic literature for safe spinal loading.

## **METHODS**

### *Participants*

A sample of twenty-six asymptomatic volunteers was recruited by way of convenience sampling from the osteopathy programme at the School of Health Science, Unitec, New Zealand to act as HVLA thrust technique ‘operators’. Sixteen male operators and 10 female operators enrolled and completed the study. Twenty-four of the study participants were osteopathy students and two participants were osteopaths registered with the Osteopathic Council of New Zealand. Anthropometric characteristics and clinical experience with HVLA thrust techniques of the sample are described in Table 1.

In addition to the twenty-six operators, one additional participant was used as a ‘patient’ for all operators performing the pre-thrust positioning for the HVLA thrust technique in order to eliminate a number of confounding variables. The patient was a consenting 33-year-old male (mass = 71 kg; height = 1.73m) who was screened for any pathology that may have been an absolute or relative contraindication to receiving an HVLA thrust technique including the presence of bone pathology and neurovascular compromise.<sup>42, 43</sup>

The exclusion criteria for the operators were the probable absence of any current musculoskeletal injury or pathology that could potentially affect their ability to participate, which was determined by a medical screening questionnaire. Informed consent statements were obtained from all participants. The study and all procedures were reviewed and approved by the Unitec Ethics Review Committee.

## *Procedures*

The study was conducted in a technique teaching laboratory at the School of Health, Unitec, Auckland, New Zealand. Prior to commencing the experiment, height and weight measurements of the participants were recorded and injury questionnaires completed.

Custom-made lightweight body markers were attached to the cervicodorsal and lumbosacral junction of the operator to enable accurate location of landmarks. The patient lay supine on the treatment table that was set at its lowest level therefore requiring adjustment by the operator. Operators were instructed to adjust the height of the table to a comfortable level, then position the supine patient as required for the pre-thrust phase of a HVLA thrust technique to the thoracic spine<sup>37, 38, 42</sup> (Figure 1). All operators were instructed to locate the T4-5 segment and use motion elements of spinal coupling to achieve a pre-thrust barrier.<sup>42</sup> The operator then verbally signalled to the researcher they had positioned the patient to their satisfaction to achieve the motion barrier. The operator was instructed to remain stationary for approximately 15 seconds while a series of photographs were taken of the operator's body position with the best image selected for further analysis. All photographs were taken from the left side of the operator with all operators using their right hand as a fulcrum at the T4-5 segment. The operator did not proceed to apply the thrust at the end of the positioning phase and the subject was returned to a neutral supine position. Data collection was held over two consecutive days; placement of body markers and photographing took on average 10 minutes per participant.

### *Apparatus*

A 3-section variable height treatment table (Aster, Metron Medical Australia Pty Ltd, Vic, Australia) was used by all operators for the pre-thrust positioning of the thoracic HVLA thrust technique. Images of the operator's final pre-thrust position were recorded using a digital camera with a 20-80mm zoom lens (Canon EOS 20D, Tokyo, Japan) mounted on a spirit-levelled tripod (Slik, 504QF II, Japan) with dolly (Slik, 6050, Japan). A spirit level and standard measurement tape was used to ensure the correct height and orientation of the digital camera position on the tripod between recordings. The position of the camera was adjusted as necessary to maintain the camera in a profile view as close to an estimated 90 degrees to the mid-sagittal plane of the operator as possible by line of sight from the camera lens barrel to a plane between the operator's greater trochanters. A cord (length = 3m) from the tripod to the centre of the table allowed the camera to be maintained at a fixed distance from the table, yet accommodate movement to retain the camera plane to that of the operator's mid-sagittal plane. A series of photographs were taken in rapid succession. Photographs with greatest visibility of the body markers and alignment of the camera plane and operator were selected for further analysis.

### *Data Analysis*

Images taken with the digital still camera were processed using Silicon Coach (v6.0) motion analysis software (Silicon COACH, Dunedin, New Zealand). Silicon Coach software allows for the accurate measurement of angles between body markers placed on the operators. The posture used by the operators was largely static thus it was

determined that a two-dimensional model would be sufficient to estimate the loads experienced by the operator. Figure 1 illustrates a representative image after marking of landmarks with the software.

The line diagram in Figure 2 illustrates the L5-S1 (fifth lumbar and first sacral segment) and C7-T1 (seventh cervical and first thoracic vertebrae) landmarks and three variables derived from these points: trunk angle ( $\theta_1$ ), neck angle ( $\theta_2$ ) and shoulder angle ( $\theta_3$ ) all with respect to the vertical. Newell and Kumar<sup>41</sup> did not define the body angles used to estimate instantaneous and cumulative shear and compression loading, but based on the field study images provided<sup>41</sup> the reader is able to infer that the trunk angle ( $\theta_1$ ) appears to be the inclination of the trunk represented as a line from proximal, lateral thigh to acromion in relation to the vertical; neck angle ( $\theta_2$ ), appears to be the inclination of the head taken as a line from the acromion to the external auditory meatus relative to the vertical. Arm angle ( $\theta_3$ ) appears to be the inclination of the arm as a line from acromion to the olecranon relative to the vertical. A simple two-dimensional, static biomechanical model outlined by Newell and Kumar<sup>41</sup> for the estimation of instantaneous compression and shear loading at L5-S1 and C7-T1 segments of the spine was used.

### *Lumbosacral load*

Three external forces act on the L5-S1 segment of the spine while standing; FT, FA and FH (trunk, arm and head force due to gravity respectively) are illustrated in figure 2. The primary internal force acting on the L5-S1 segment is generated from the muscle contraction of the erector spinae muscle group.<sup>44</sup> Muscle forces are often combined to give a single moment arm (single muscle equivalent approach<sup>45, 46</sup>) in

simple models such as the one presented here. Newell and Kumar<sup>41</sup> derived equations to enable estimation of instantaneous and cumulative spinal loading. The equations are outlined below (Equations 1 to 9).

Given that Torque = Force \* Distance<sup>47</sup>, the following equation results:

$$F_{Esp} = [(FT \times t) + (FA \times a) + (FH \times h)]/6 \quad \text{Equation [1]}^{41, 2, **}$$

Where,  $F_{Esp}$  = force of the erector spinae muscle group,  $t$ ,  $a$ , and  $h$  are the moment arms of the trunk, arm and head as shown in Figure 1, and 6cm is the moment arm of the erector spinae muscle group.<sup>48</sup>

Expanding the components of the equation above results in the following:

$$F_{Esp} = [9.81(TBM)(TBH)/6]\{(TM\%)(TL\%) * (TCL\%)(\sin \theta_1) + (AM\%)[(ACL\%) * (AL\%) \sin \theta_3 + (TL\%) \sin \theta_1] + (HM\%) * [(HCL\%)(HL\%) \sin \theta_2]\} \quad \text{Equation [2]}^{41}$$

Where, TBM = total body mass in kg, and TBH = total body height in cm. (TBM, TBH and other variables used in the equation above and below are described by Hall<sup>44</sup>).

TL%, AL%, and HL% = trunk, arm and head length as percentages of TBH.

TM%, AM%, and HM% = trunk, arm, and head mass as percentages of TBM.

TCL%, ACL%, and HCL% = trunk, arm, and head centre of gravity location relative to segment length.

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\*\* Equation [1] is modified from that used by Newell and Kumar by the addition of the moment arm of the erector spinae on the right-hand side of the equation

( $\theta_1$ ) = trunk angle (inclination of the trunk represented as a line from L5-S1 to C7-T1 in relation to the vertical)

( $\theta_2$ ) = neck angle (inclination of the head taken as a line from the C7-T1 junction to the external auditory meatus relative to the vertical).

( $\theta_3$ ) = Arm angle (inclination of the arm as a line from the C7-T1 junction to the olecranon relative to the vertical.)

Compression and shear loading at the L5-S1 segment can be estimated by substituting the calculated elements of the equation defined above into the final compression and shear equations:

$$FC_{L5-S1} = [9.81(TBM)(TM\% + AM\% + HM\%) \cos \theta_1] + [9.81(TBM)(TBH/6) \{ (TM\%)(TL\%)(TCL\%)(\sin \theta_1) + (AM\%)[(ACL\%)(AL\%)(\sin \theta_3) + (TL\%)\sin \theta_1] + (HM\%)[(HCL\%)(HL\%)\sin \theta_2 + (TL\%)\sin \theta_1] \}] \quad \text{Equation [3]}^{41}$$

$$FS_{L5-S1} = 9.81(TBM)(TM\% + AM\% + HM\%) \sin \theta_1 \quad \text{Equation [4]}^{41}$$

### *Cervicothoracic load*

Cervicothoracic compression and shear forces can be estimated by the using the logic and notation for the lumbosacral loading above, substituting 5cm as the moment arm of the cervical musculature. The forces can be expressed by the following equations:

$$FC_{C7-T1} = 9.81(TBM)(HM\%) \cos \theta_2 + [9.81(TBM)(HM\%)(HCL\%)(HL\%) \cdot (TBH) \sin \theta_2] / 5 \quad \text{Equation [5]}^{41}$$

$$FS_{C7-T1} = 9.81(TBM)(HM\%) \sin \theta_2 \quad \text{Equation [6]}^{41}$$

### *Cumulative load calculation*

The overall cumulative load was obtained by multiplying the instantaneous compressive and shear forces by the duration of activity:

$$\text{OCL} = L * t \quad \text{Equation [7]}^{41}$$

Where, L = the average compression (N) or shear force (N) of the task; t = time (s).

The unit of overall and cumulative load is ‘force time’ (Ns).

The cumulative biomechanical loads for longer periods were estimated by multiplying the overall load for the task by the frequency per day (*F*) of the task resulting in the following equation:

$$\text{CDC} = \sum (\text{FC}_1 * F_1) + (\text{FC}_2 * F_2) + \dots + (\text{FC}_n * F_n) \quad \text{Equation [8]}^{41}$$

$$\text{CDS} = \sum (\text{FS}_1 * F_1) + (\text{FS}_2 * F_2) + \dots + (\text{FS}_n * F_n) \quad \text{Equation [9]}^{41}$$

Where, CDC and CDS refer to the cumulative daily compression and shear loads. The unit of measure for cumulative daily load is kNs.

The estimation of cumulative loads for other time periods can be calculated by multiplying the daily cumulative load (CDL) with the relevant exposure time of the period of interest.

Following measurement of angles using Silicon Coach, the angle data along with operator height and mass measurements, were entered into a Microsoft Excel

spreadsheet (Microsoft Corp, Redmond, Washington). The customised spreadsheet used the formulae outlined above to calculate the shear and compression load values. Separate spreadsheets were developed for estimating the compressive and shear loads for male and female operators according to anthropomorphic parameters outlined by Plagenhoef, Evans and Abdelnour<sup>49</sup> for each gender. Statistical analysis was performed using SPSS v14.0 (SPSS Inc, Chicago, IL). Mean and standard deviation (SD) values were calculated for all instantaneous loads. Pearson's correlation coefficient was used to indicate correlation between variables.

## RESULTS

### *Instantaneous loads*

The characteristic posture of the operator in the pre-thrust phase of the HVLA thrust technique to the thoracic spine is illustrated in Figure 2. The range of postural angles observed across all operators included trunk angles between 47° and 87°; operators cephalad arm flexed between 6° and 74° and neck flexion between 71° and 142°.

Table 2 contains the mean instantaneous compression and shear loads for each individual operator in the study. Compression loads on the low back ranged from 1023 N to 7575 N while shear loads ranged between 160 N and 829 N. Compression loads for the C7-T1 segment ranged from 33 N to 477 N while shear forces were between 18 N and 112 N.

Further analysis of relationships between variables using Pearson's correlation coefficient, indicates that the key determinant of lumbosacral loading was total body mass (see Table 3). Total body height and trunk angle were not strongly correlated with increasing compressive loading of the spine.<sup>50</sup>

### *Cumulative Loads*

The cumulative load values for the low back and neck are presented in Table 4.

Weekly cumulative compressive load on the L5-S1 segment for three representative operators in this study (min, max and median BMI) ranged from 485 kNs to 1275 kNs. For the same group, yearly cumulative compressive load on the L5-S1 segments ranged from 23,262 kNs to 61,197 kNs while shear loads ranged from 2663 kNs to

7956 kNs. Cumulative compressive load on the C7-T1 segment calculated on a weekly time period ranged from 55 kNs to 166 kNs. The operators' yearly cumulative compressive load on the C7-T1 segment ranged between 1730 kNs and 2861 kNs for shear forces.

## **DISCUSSION**

To the author's knowledge, this is the first ergonomic study to estimate the instantaneous and cumulative spinal loading of operators performing the pre-thrust positioning for a thoracic HVLA thrust technique. The aim of the study was to estimate the instantaneous and cumulative loads on the lumbosacral and cervicothoracic spinal segments during the pre-thrust phase of the HVLA thrust technique and subsequently to compare this data with guidelines reported in the general ergonomic literature for safe spinal loading.

### *Instantaneous compression loads*

With regards to instantaneous load data in the current study, lumbosacral compressive forces were higher in male operators than female operators, reflecting the greater proportion of upper body weight in males which is a major determinant in lumbar spine load.<sup>44</sup> The lumbosacral compression loads in this study reached a maximum of 7.58 kN for one of the male operators and 3.08 kN for one of the female operators. Instantaneous compression loads at the cervicothoracic junction ranged from 33 N to 211 N for the female operators and from 113 N to 477 N for male operators in the study. The Newell and Kumar study<sup>41</sup> reported estimates for lumbosacral compressive forces of between 1149 N and 1635 N for males in the five seated tasks studied, and between 866 N and 1072 N for females for three seated tasks investigated. Compression loads for the cervicothoracic junction ranged from 137 N to 149 N for males and 69 N and 94 N for females. The higher compression figures in the lumbosacral and cervicothoracic junctions of the operators in current study likely result from the greater magnitude of forward flexion involved in the pre-thrust

positioning for the HVLA thrust technique compared to the seated posture of the orthodontic students in the Newell and Kumar study.<sup>41</sup> A direct comparison of body angle data is not possible as this data was not reported in the Newell and Kumar study. However, the degree of forward flexion of the orthodontic students can be ascertained from the field images provided. The operators in the current study had trunk angles ( $\theta_1$ ) of between  $47^\circ$  and  $87^\circ$ , neck angles ( $\theta_2$ ) of between  $71^\circ$  to  $142^\circ$  and arm angle ( $\theta_3$ ) of between  $6^\circ$  and  $74^\circ$ . The characteristic posture of the orthodontist students observed in the Newell and Kumar study was a seated posture with trunk angle ( $\theta_1$ ) between  $0^\circ$  and  $25^\circ$ , neck angle ( $\theta_2$ ) between  $50^\circ$  and  $95^\circ$  and arm angle ( $\theta_3$ ) between  $0^\circ$  and  $90^\circ$ .

Instantaneous lumbosacral compression data for seven male operators exceeded the NIOSH spinal loading guideline of 3.4 kN with the highest value for a male more than double that level. The highest instantaneous lumbosacral loading of 7.58 kN in this study is below the 8 kN threshold that Willen and co-workers<sup>51</sup> observed spinal fractures to occur in cadaver lumbar spines. Given that simple static spinal compression models, such as the one used in this study, can underestimate static spinal compression by 20-40% when compared with dynamic models,<sup>14, 52, 53</sup> the loads reported in this study are of concern.

For the procedure under investigation in the current study there are three factors that mitigate the high spinal compression loads. Firstly, that the loading rate for the manipulation task is likely to be lower than loading rates used to provoke vertebral fractures in experimental studies,<sup>54</sup> secondly, that the exposure time is shorter and frequency of performing the technique is less than in studies of tasks in industrial

settings such as automotive<sup>55</sup> or electronic assembly workers.<sup>56</sup> Thirdly, it was observed that some operators used their ‘fulcrum’ arm, i.e. their right arm, to prop themselves against the treatment table. Use of a ‘propping’ strategy will decrease the moment at L5-S1, although this can not be determined using the static model employed in this study. Additionally, operators rested his or her left hand on the crossed arms of the patient, resulting in a change in the position of the centre of gravity for the combined upper extremity. The so called ‘propping effect’ will result in the static model over estimating forces of those operators utilising the propping strategy.

#### *Instantaneous shear loads*

In the current study, instantaneous shear loads for the lumbosacral junction ranged from 209 N to 829N for males and 160 N to 426 N for females. For six operators instantaneous lumbosacral shear load was estimated to be above 500N. In the cervicothoracic junction, shear loads ranged from 33N to 112 N and 18 N and 74 N for males and females respectively. In the Newell and Kumar study, shear loading at the lumbosacral junction was estimated as 96 N to 171 N for males and 101 N and 130 N for females. For the cervicothoracic junction, shear loads ranged from 53 N to 70 N and 37 N to 49 N for men and women respectively. The higher shear loads in the current study again reflect the greater extent of forward flexion of the osteopathic students compared to the orthodontic students in the Newell and Kumar study. Spinal compression has been conventionally assumed to be the principal biomechanical mechanism associated with occupationally related low back disorders,<sup>14, 57</sup> however, the weak association suggests that other factors may explain the association. Studies

have discredited the hypothesis that compressive overload alone can directly damage healthy lumbar discs by causing prolapse.<sup>58, 59</sup> Although spinal loading guidelines have focused on compressive loading they have not emphasised spinal flexion and the impact on shear.<sup>50, 57</sup> Biomechanical and epidemiological studies reveal many occupations routinely involve shear loads.<sup>45</sup> Ergonomic analyses have identified margins of safety associated with compression loading as being much greater than in shear and the higher odds ratios for shear forces than compressive forces in their link to injury incidence.<sup>45, 55, 60</sup> In recent years there appears to be greater emphasis by researchers on the role of shear loading as a risk factor in the aetiology of low back problems. A case-controlled study investigating the incidence of low back pain reporting at a large automotive plant identified shear force magnitude as a strong predictor of low back pain.<sup>55</sup> McGill and co-workers suggested that the 'action limit' for instantaneous shear forces acting on L5-S1 is 500 N (an 'action limit' represents the value at which nominal risk is likely when lifting loads for more than 99% of male workers and 75% of female workers). This action limit is based on a study by Norman and co-workers who observed that repeated exposure to shear loads lowered the threshold magnitude for shear to about 500 N, above which, elevated risk was observed. Six operators in the current study did not exceed shear loads observed in other studies to generate the first measurable level of shear damage, but the operators did exceed 500 N which elevates risk of injury.<sup>55</sup> A preventative strategy for these operators may be adopting a neutral lumbar posture by bending from the hip while performing HVLA thrust techniques to buttress against anterior shear forces on the spine.

### *Cumulative compression loads*

By using a set of assumptions based on anecdotal evidence collected from the two practicing osteopaths in the study (see notes, Table 4), cumulative loading data was extrapolated from instantaneous data calculated in this study. When estimates of the frequency and duration of the HVLA thrust techniques are taken into account for the operator with the lowest body mass index (BMI), cumulative weekly compression load on the L5-S1 segment was 485 kN, while yearly compression was 23260 kNs. For the operator with the highest BMI in the sample, cumulative weekly compressive load on the L5-S1 segment was 1275 kN, and 61197 kNs for yearly cumulative compressive load. These estimates of cumulative lumbosacral loading will not reflect the spinal loading of practitioners in the field but are given as an indication of loading based on anecdotal evidence from two osteopaths regularly using HVLA thrust techniques.

### *Cumulative shear loads*

Cumulative yearly shear loads on the lumbosacral junction was estimated as 2660 kNs for the operator with the lowest BMI (19.2) and 7960 kNs for the operator with the highest BMI (35.4). Cumulative yearly shear loads on the cervicothoracic junction were estimated to be 417 kNs and 954 kNs for the operators with the lowest and highest BMI respectively. In the Newell and Kumar study, cumulative yearly shear loads on the lumbosacral junction of male orthodontic students was 340 MNs and 303 MNs for females orthodontic students. Cumulative yearly shear loads on the cervicothoracic junction were 163 MNs and 111MNs for males and female students respectively. The assumption made to calculate cumulative loading in the Newell and

Kumar study was orthodontists performed all the postures indentified in the study for 63% of the working day. The assumption for the cumulative spinal loading in the current study was based on an osteopath performing thoracic HVLA thrust techniques on 60% of patients in a working week (45 patients), which would result in a duration of four and a half minutes in the pre-thrust positioning per week. The considerable difference in cumulative yearly shear loads between the two studies reflect the duration of the work day spent in the work postures required in the respective occupations. Additionally, the current study did not investigate all the tasks involved in the daily routine of osteopaths because of the variety and frequency of techniques employed by individual osteopaths.

#### *Limitations of the study*

There are several limitations of the current study. First, the cumulative loading model only accounts for the static posture and does not take into account the stresses caused by dynamic forces prior to, during and after, the pre-thrust phase of the HVLA thrust technique. Images were captured after the dynamic phases of orienting the patient for the pre-thrust positioning had occurred and before returning the patient to a neutral position, thereby excluding these movement sequences with arguably greater dynamic forces at play. Various algorithms have been used to calculate cumulative load from instantaneous sampling. In the current study, peak load and the duration of the task were used to estimate cumulative load, as did Norman et al.<sup>55</sup> This method is considerably less onerous in data collection, however, Callaghan<sup>61</sup> found that the square method (peak load · duration) overestimated the compressive load by 70% and the shear loads were overestimated by 150%. The simple, two-dimensional static

model also simplifies the location of the centre of gravity of the body segments, particularly in the upper extremity by treating the limb as one segment. Such simplification will result in errors in the calculated loads due to the change in the value and position of the centre of gravity. A second limitation is the current study only estimated instantaneous spinal loads in the operator during the pre-thrust phase of a thoracic HVLA thrust technique and does not account for joint loading of the L5/S1 and C7/T1 segments due to dynamic forces delivered in the thrust phase. Estimation of forces in the lumbosacral and cervicothoracic spine of operators' associated with the delivery of the thrust phase of the thoracic HVLA thrust technique was outside the scope of this study. Measurement of such forces would require a different experimental approach and equipment (e.g. 3-D motion analysis system and force plate) that was not available at the time of the study. A third limitation is the static model does not account for torsional loading. During bending and lifting, there are three stress vectors transmitted through the spinal musculoskeletal tissues to the L5-S1 segment: compressive force; shear force and torsional force. While the static model does not account for torsional loading, the contribution of torsional forces in the aetiology of low back pain is not well understood and can be difficult to estimate.<sup>62</sup> Little is known about torsional forces in vivo, primarily because the full range of axial rotation is approximately 1° to each side of a lumbar level. While this limited movement generates little torsional force in the posterior annular fibres of the disc, contact stresses in the zygapophysial joints axial torque is generated rapidly with increasing angle of rotation.<sup>63, 64</sup> Even a small amount of experimental error measuring the limited amount of axial rotation would result in a large error in the prediction of torque.<sup>63, 65-67</sup>

High velocity low amplitude thrust techniques are one approach to treatment in the repertoire of therapeutic procedures available to manual medicine practitioners. For individual osteopaths, the relevance of this study's findings will be determined by their personal use and application of HVLA thrust techniques and therefore, exposure to instantaneous and cumulative spinal loading associated with these procedures.

Other manual techniques involving forward bending, particularly for sustained periods, are likely to incur instantaneous and cumulative loads potentially greater than those outlined in this study. A recent ergonomic study by Albert and co-workers<sup>62</sup> of the cumulative lumbosacral load in massage therapists using a selection of commonly used soft tissue and massage techniques found cumulative load to range from 2,800 to 4,600 kNs with a mean of 3,500kNs for one standardised 44-minute massage session. In their study, Albert et al. estimated the weekly cumulative load on the lumbar spines of massage therapists performing five massages a day over a five-day work week was 89,540 kNs, whereas in the current study, weekly cumulative lumbosacral loading ranged from 484.6 to 1275.0 kNs for the lowest to heaviest BMI operator respectively. The weekly cumulative lumbar load estimate of 89,540 kNs in the massage therapists' study surpasses the cumulative *yearly* load of the operators in the current study by an order magnitude. This can be explained by the massage therapists' using techniques that require postures involving trunk forward flexion between 20° and 45° for 50% of the 44-minute massage session whereas, osteopaths in the current study would assume the pre-thrust positioning for a thoracic HVLA thrust technique for 4 and a half minutes a week based on the assumptions given.

The range of exposure to cumulative spinal loading in orthodontists, osteopaths and massage therapists reflects the degree of trunk and neck forward flexion involved in work tasks and the duration these tasks. In the study by Newell and Kumar,<sup>41</sup>

orthodontists were seated and performed work tasks in a limited amount of forward flexion over a relatively long duration. Osteopaths in the current study, performed the pre-thrust positioning for the HVLA thrust technique in a greater range of sagittal flexion for shorter periods of time with lesser frequency than the orthodontists tasks.

### *Implications for further work*

To better estimate cumulative spinal loading, further work should be undertaken to document the duration and frequency of use of techniques utilised in clinical practice by manual medicine clinicians including osteopaths. Collection and processing of video-based cumulative loading quantification data is time-consuming and tedious. Recent work by Canadian researchers has sought to establish video sampling rates that decrease the volume of data and thus time tedium of processing while minimising errors in cumulative load estimation. Azar and coworkers<sup>66</sup> compared traditional video methods with self-reporting (logbooks and 2-hour recall) and found that use of logbooks resulted in estimated cumulative loading that was very similar to video based models of cumulative loading. Future fieldwork investigating cumulative spinal loading could use small, portable biaxial goniometers and EMG recording from the low back of clinicians to sample sagittal flexion and muscle activity which could be downloaded for later analysis. This method of field study would be both cost effective and minimally intrusive for patients and practitioners.

There appears to be no widely accepted guideline in the literature that has defined cumulative spinal load levels that are likely to cause tissue injury. Further work to estimate cumulative spinal load levels that are injurious would be a welcome addition

to the ergonomic literature. Such a guideline would be useful in educating manual medicine students in performing treatment techniques in ways that minimise potential work-related musculoskeletal disorders.

The current study investigated compressive and shear loads resulting from spinal flexion. Future studies should investigate the magnitude of side-bending and rotation movements of the spine in practitioners performing HVLA procedures. To date, few studies have examined the effect of cumulative loads and the relationship to work-related musculoskeletal disorders including low back pain.

## CONCLUSION

To the authors knowledge, this is the first ergonomic study to estimate the instantaneous and cumulative spinal loading of operators performing the set-up positioning for a thoracic HVLA thrust technique. The relevance of biomechanical stress can only be assessed through quantification and the comparison of basic science research with field work studies. Not surprisingly, the current study found a strong correlation between body mass and instantaneous lumbosacral spinal loading (Pearson's  $r = 0.96$ ). Compression loads on the low back ranged from 1.02 to 7.58 kN while shear loads ranged between 0.16 and 0.83 kN. The magnitudes of instantaneous compressive lumbosacral spinal loads in this study were found to be within the ranges that have been associated with vertebral endplate damage in laboratory experiments. Lumbosacral shear forces were found to be above acceptable levels, as recommended in occupational safety guidelines, but less than force thresholds associated with pars interarticularis fracture. Therefore, manual therapeutic techniques that involve operator forward flexion may have instantaneous compressive and shear lumbosacral spinal loading above generally agreed acceptable limits for spinal safety.

The current study investigated spinal flexion and the resultant instantaneous and cumulative compressive and shear loads. More sophisticated dynamic models should be utilised in future studies to more accurately quantify cumulative spinal loading in the clinical setting.

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Table 1. Anthropometric and educational characteristics of the student and osteopath sample.

<b>Group</b>	<b>Parameter</b>	<b>Age (year)</b>	<b>Height (cm)</b>	<b>Weight (kg)</b>	<b>BMI (kg/m<sup>2</sup>)</b>	<b>Experience<sup>1</sup> (Years)</b>
Total sample (n=26)	Mean	29	177.2	81.4	25.8	3.3
	SD	7.7	7.4	16.3	4.3	4.8
Females (n=10)	Mean	27.9	171.3	70.6	24.1	2.2
	SD	6.9	5.8	12.0	4.0	0.8
Males (n=16)	Mean	29.6	180.9	88.1	26.9	3.9
	SD	8.3	5.8	15.2	4.5	6.1
Osteopaths (n=2)	Mean	45.5	181.5	94.3	28.6	18.5
	SD	7.8	4.9	8.8	1.1	7.8

**Notes**

1. Experience of participants is measured in years of exposure to HVLA thrust techniques for students and years of post graduate experience for osteopaths.

Table 2. Anthropometric data of operators with mean instantaneous compression and shear load values

Operator	Gender	Age	Height (m)	Mass (kg)	BMI (kg/m <sup>2</sup> )	Clinical experience (years)	Angle 1 L/S (degrees)	Angle 2 C/T (degrees)	Angle 3 Arm (degrees)	Lumbosacral Compression (N)	Lumbosacral Shear (N)	Cervicothoracic Compression (N)	Cervicothoracic Shear (N)
1	M	21	1.820	78.9	23.82	3	61	114	18	2948.7	325.1	179.7	46.1
2	M	26	1.810	76.0	23.20	3	70	104	62	2957.2	324.1	182.8	45.4
3	M	23	1.800	75.0	23.15	3	85	90	51	2885.7	334.6	191.6	45.6
4	M	28	1.826	100.8	30.23	1	74	124	54	5317.2	577.0	253.5	68.3
5	M	27	1.842	119.4	35.19	1	77	104	32	7574.9	829.5	477.0	112.1
6	M	32	1.915	102.1	27.84	1	81	139	9	5948.5	614.8	216.8	55.4
7	M	28	1.729	74.4	24.89	1	78	113	74	2592.8	323.3	136.3	41.3
8	M	32	1.780	84.1	26.54	3	62	104	14	3183.0	372.9	212.2	55.6
9	M	51	1.780	88.0	27.77	24	52	83	47	3347.0	364.4	261.4	62.1
10	F	27	1.786	73.1	22.92	3	69	104	50	2364.5	284.7	155.4	41.7
11	F	33	1.684	58.4	20.59	3	70	120	49	1310.5	182.9	65.4	23.8
12	F	28	1.692	90.1	31.47	3	67	97	33	3079.2	426.4	211.1	64.8
13	F	22	1.816	63.3	19.19	3	64	92	44	1795.0	205.5	133.5	32.2
14	M	40	1.850	100.5	29.36	13	76	118	34	5421.1	585.2	291.4	72.3
15	F	43	1.711	85.6	29.24	1	69	107	52	2925.4	390.4	179.7	56.4
16	F	20	1.625	54.0	20.45	1	74	112	32	1023.4	160.0	56.3	21.7
17	M	20	1.775	69.2	21.96	1	47	71	16	1872.8	209.1	160.5	36.7
18	M	25	1.940	92.5	24.58	1	65	114	33	4945.1	463.1	305.2	63.3
19	M	33	1.786	77.9	24.42	2	81	111	40	3022.1	357.9	170.9	45.9
20	M	22	1.763	66.6	21.43	2	75	115	42	2125.2	255.8	113.5	32.6
21	M	40	1.810	99.1	30.25	2	87	142	55	5096.7	585.6	146.7	49.0
22	M	26	1.725	105.3	35.39	2	68	125	6	4722.0	613.9	220.8	73.6
23	F	23	1.642	60.7	22.51	2	81	142	50	1351.0	207.7	33.0	18.2
24	F	22	1.730	77.7	25.96	2	83	102	29	2480.9	341.9	161.5	47.5
25	F	29	1.729	77.0	25.76	2	80	125	58	2489.8	333.2	113.5	39.1
26	F	32	1.712	65.7	22.42	2	70	98	70	1750.5	231.5	115.5	34.4
<b>Mean</b>		29.0	1.7722	81.36	25.79	3.3	71.8	110.4	40.5	3251.2	380.8	182.5	49.4
<b>SD</b>		7.7	0.0745	16.32	4.34	4.8	9.7	17.1	18.0	1626.9	165.3	90.1	19.8
<b>Range</b>							47-87	71-142	6-74	1023-7575	160-829	33-477	18-112
<b>Median</b>										2937	338	175	46

Table 3. Pearson's correlation coefficient for selected measured variables against L5-S1 spinal loading

Pearson's r	Variable	Descriptor *
0.96	Body mass	distinct relationship
0.79	BMI	very large
0.70	Height	high
0.20	L5-S1 angle	low

**Notes**

\* 0.0-0.1 = insubstantial correlation; 0.1-0.3 = low; 0.3-0.5 moderate; 0.5-0.7 = large; 0.7-0.9 = very large; 0.9-1 = distinct. Descriptors derived from Hopkins.<sup>68</sup>

Table 4. Cumulative compression and shear loads values for three representative operators

<b>BMI</b> <sup>1</sup>	<b>Cumulative period</b> <sup>2</sup>	<b>Lumbosacral Compression (kNs)</b> <sup>3</sup>	<b>Lumbosacral Shear (kNs)</b> <sup>3</sup>	<b>Cervicothoracic Compression (kNs)</b> <sup>3</sup>	<b>Cervicothoracic Shear (kNs)</b> <sup>3</sup>
Lowest BMI (19.19)	Cumulative Weekly Load	484.6	55.5	36.0	8.7
	Cumulative Yearly Load	23262.6	2663.4	1729.6	417.4
Median BMI (24.73)	Cumulative Weekly Load	1017.6	106.2	59.6	14.1
	Cumulative Yearly Load	48845.6	5095.7	286.0	677.9
Highest BMI (35.39)	Cumulative Weekly Load	1275.0	165.8	59.6	19.8
	Cumulative Yearly Load	61197.0	7956.1	2861.4	953.8

Notes

1. The cumulative load calculations are given for operators with the lowest, median and highest BMI of the sample.
2. CWL (Cumulative Weekly Load), CYL (Cumulative Yearly Load).
3. Assumptions used for calculated cumulative loads are as follows; 10 seconds to perform a thoracic HVLA thrust technique; osteopath performs 1 thoracic HVLA thrust technique on 60% of patients; osteopath sees 45 patients a week on average; 48 working weeks in the year.

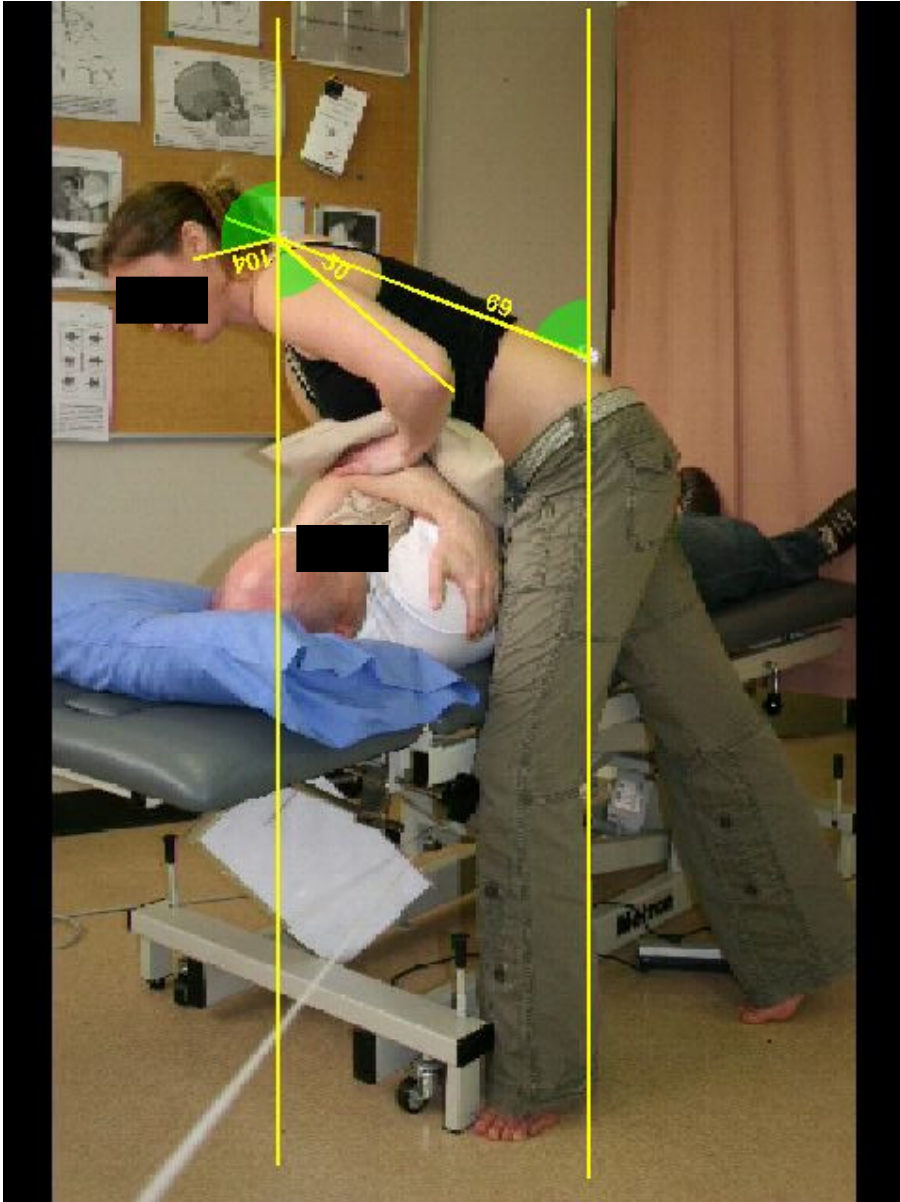


Figure 1. Practitioner posture in the set-up phase of supine HVLA thrust technique of the thoracic spine.

Photograph shows the location of body markers and markings used in data analysis using Silicon Coach software to establish body angles used in instantaneous loading calculations.

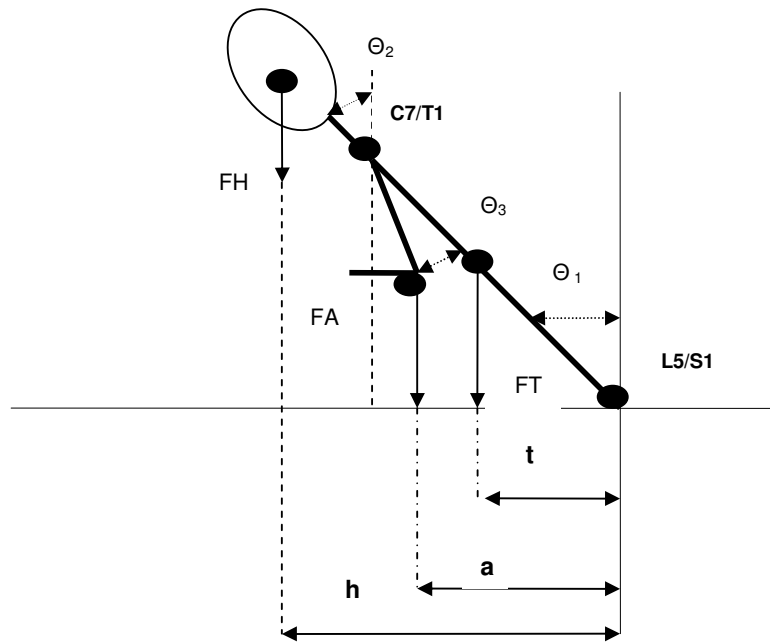


Figure 2. Forces about L5/S1 due to gravity.

Figure illustrates forces about L5/S1 due to gravity: FT, FA and FH (trunk, arm and head force) t, a and h represent distance from the centre of gravity of the trunk, arm and head to L5/S1. Reproduced by kind permission of Elsevier from Newell TM, Kumar S. Comparison of instantaneous and cumulative loads on the low back and neck in orthodontists. *Clin Biomech* (Bristol, Avon). 2005;**20**:132.

## **Section III: Appendices**

Appendix A: Practitioner posture guidelines (Gibbons & Tehan, 2000)

- Using as wide a base as possible
- Not relying solely upon arm strength and speed
- Using your body where possible to generate thrust force
- Not stooping or bending over the patient
- Keeping your spine erect
- Optimal treatment couch height

Appendix B: Ethic approval letter



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address Carrington Rd, Mt Albert, Private Bag 92025, Auckland, New Zealand

Matthew Stewart  
10 Florida Pl  
St Heliers  
AUCKLAND 1005

3 May, 2006

Dear Matthew

Your file number for this application: 2006.476

Title: An investigation into the reliability of practitioner posture when performing the set-up for a HVLAT technique

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: 3 May 2006  
Finish date: 31 December 2007

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.

This letter has been copied to the Principal Supervisor for Unitec student research projects.

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

Yours sincerely

A handwritten signature in blue ink that reads 'Postia Richmond'.

pp Dr Andrew Stewart  
Deputy Chair, UREC

RMO ref#: 730

cc: Rob Moran  
Cynthia Almeida



**An investigation into the consistency of practitioner posture when performing the set-up for a high velocity, low amplitude thrust technique**

**Operator Information Sheet**

**About this research**

You are invited to take part in a research project being undertaken as part of a Master of Osteopathy Degree.

This research investigates the posture of those performing the set-up for a thoracic high velocity, low amplitude thrust (HVLAT) technique. The technique is to be performed by the operator on a subject while the subject lies on a treatment table. This information sheet is designed to inform you as to the nature of the research and what will happen should you choose to take part.

**The researchers**

The researcher is Matthew Stewart. Robert Moran and Associate Professor Clive Standen are supervising the research project.

**What will participation involve?**

- Read and complete a screening questionnaire on musculo-skeletal injuries or other health conditions that may prevent you from performing a thoracic “dog” technique. At this appointment you will be weighed and your height will be measured.
- Be available for 1 data collection session lasting at most 5 minutes.
- Signing of the consent form.
- The removal of superficial clothing for the placement of anatomical landmark indicators on your back video recording of your posture.
- Performing the set-up positioning for a thoracic “dog” technique on a subject.
- Consent to the research teams use of the research data in preparing both a research project dissertation and an article for publication (all data will be anonymous).
- Consent to the storage of your anonymous research data indefinitely for future research.

**Getting help**

Please contact either one of us should you require help with this research project.

Matthew Stewart: E- mail [mattstewart@clear.net.nz](mailto:mattstewart@clear.net.nz)  
Phone: (09) 521 2431 or 021 771 407

Robert Moran: E-mail [rmoran@unitec.ac.nz](mailto:rmoran@unitec.ac.nz)  
Phone: (09) 815 4321 x 8642

**Potential risks to research participants**

There is no known published data indicating any risks associated with this research. However, the researcher accepts that it is possible there may be some undetermined risks involved in the research process. In the case that any potential risk of harm should arise for any research participant, it will be treated on an individual basis. In any such case, the research process will be halted immediately.

### **Confidentiality**

Confidentiality and your anonymity will be protected in the following ways:

- The raw video footage information pertaining to the participants stored on the digital tape will be secured in locked filing systems available only to the research team
- Digital tapes of the data collection will be secured and not shared or displayed without further permission being granted by the participant/operator.
- Only the researchers will see completed questionnaires and consent forms.
- All forms will be stored in a locked file. Only the researchers will have access to this file.
- Any data derived from the research will be anonymous and your identity will be kept confidential.

**You have the right not to participate, or withdraw from this research project at any time up until the point of data analysis (2 weeks after the last session). Contact Matthew Stewart or Robert Moran by telephone or email, or by telling us when we contact you that you no longer wish to participate.**

A copy of the final report will be available at the Unitec New Zealand library. All participants are welcome to view this. Summaries and recommendations may be published in research journals.

### **Information and concerns**

If you want further information about the project, you can call or email the above addresses.

At anytime if you are concerned or confused about the research project you may contact Matthew Stewart, the primary researcher on the details above.

If you have concerns about the way in which the research is being conducted you can contact the following:

Health Advocates: Advocates Network Services Trust, Phone (09) 623 5799, 0800 205 555, Fax (09) 623 5798, PO Box 9983, Newmarket, Auckland.

Finally, we would like to thank you for your valuable contribution to this research.

*This study has been approved by the UNITEC Research Ethics Committee from 3 May 2006 to 31st December 2007. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the Secretary (ph: 09 815-4321 ext 8041). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.*

Appendix D: Operator consent form



**An investigation into the consistency of practitioner posture when performing the set-up for a high velocity, low amplitude thrust technique**

**Operator Consent Form**

This research project investigates body posture of osteopaths when performing the set-up for a high velocity, low amplitude thrust (HVLAT) technique to the thoracic spine. The research is being done by *Matthew Stewart* from Unitec New Zealand, and will be supervised by *Robert Moran* and *Clive Standen*.

**Name of Participant:**.....

I have seen the Operator Information Sheet dated 3rd May 2006 for people taking part in the investigation into the consistency of practitioner posture when performing the set-up for high velocity, low amplitude thrust technique (HVLAT) technique project.

I have had the opportunity to read the contents of the information sheet and to discuss the project with the researchers and I am satisfied with the explanations I have been given.

I understand that taking part in this project is voluntary (my choice) and that I may withdraw up until the point at which data analysis is started and this will in no way affect my access to the services provided by Unitec New Zealand or any other support service.

I understand that I can withdraw from the experiment if, for any reason, I want this.

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

I have had enough time to consider whether I want to take part.

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

The principal researcher and first contact for this project is:

Matthew Stewart  
10 Florida Place  
St Heliers  
021 771 407  
mattstewart@clear.net.nz

Signature.....participant ..... (Date)

Project explained by.....

Signature..... (Date)

*This study has been approved by the UNITEC Research Ethics Committee from 3 May 2006 to 31 December 2007. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the Secretary (ph: 09 815-4321 ext 8041). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.*



## **An investigation into the consistency of practitioner posture when performing the set-up for a high velocity, low amplitude thrust technique**

### **Subject Information Sheet**

#### **About this research**

You are invited to take part in a research project being undertaken for a Master of Osteopathy Degree.

This research project investigates body posture of osteopaths when performing the set-up for a high velocity, low amplitude thrust (HVLAT) technique to the thoracic spine. The technique is to be performed by the operator on a subject while the subject lies on a treatment table. This information sheet is designed to inform you as to the nature of the research and what will happen should you choose to take part.

#### **The researchers**

The researcher is Matthew Stewart. Robert Moran and Associate Professor Clive Standen are supervising the research project.

#### **What will participation involve?**

- Read and complete a screening questionnaire on musculo-skeletal injuries or other health conditions that may prevent you from receiving a thoracic HVLA technique. At this appointment you will be weighed, your height will be measured.
- Be available for 2 data collection sessions lasting up to 3 hours. The sessions will be on consecutive weeks.
- Signing of the consent form.
- The removal of superficial clothing and the wearing of black “cycling short style” shorts.
- Placement of anatomical landmark indicators on various parts of your body for video recording of your posture.
- Being placed by an osteopathic practitioner into a position for a technique. There will be no sudden movements and your comfort will be monitored. You will be allowed rest breaks, as you require them. You are free to withdraw from the sessions at any point and do not need to state a reason for doing so. There will be no application of the low amplitude, high velocity thrust.
- Consent to the research teams use of the research data in preparing both a research project dissertation and an article for publication (all data will be anonymous).
- Consent to the storage of your anonymous research data indefinitely for future research.

#### **Getting help**

Please contact either one of us should you require help with this research project.

Matthew Stewart: E- mail [mattstewart@clear.net.nz](mailto:mattstewart@clear.net.nz)

Phone: (09) 521 2431 or 021 771 407

Robert Moran: E-mail [rmoran@unitec.ac.nz](mailto:rmoran@unitec.ac.nz)  
Phone: (09) 815 4321 x 8642

### **Potential risks to research participants**

There is no known published data indicating any risks associated with this research. However, the researcher accepts that it is possible there may be some undetermined risks involved in the research process. In the case that any potential risk of harm should arise for any research participant, it will be treated on an individual basis. In any such case the research process will be halted immediately.

### **Confidentiality**

Confidentiality and your anonymity will be protected in the following ways:

- The raw video footage information pertaining to the participants stored on the digital tape will be secured in locked filing systems available only to the research team
- Digital tapes of the data collection will be secured and not shared or displayed without further permission being granted by the subject.
- Only the researchers will see completed questionnaires and consent forms.
- All forms will be stored in a locked file. Only the researchers will have access to this file.
- Any data derived from the research will be anonymous and your identity will be kept confidential.

**You have the right not to participate, or withdraw from this research project at any time up until the point of data analysis (2 weeks after the last session). Contact Matthew Stewart or Robert Moran that you no longer wish to participate by telephone or email, or by telling us when we contact you.**

A copy of the final report will be available at the Unitec New Zealand library. All participants are welcome to view this. Summaries and recommendations may be published in research journals.

### **Information and concerns**

If you want further information about the project, you can call or email the above addresses.

At anytime if you are concerned or confused about the research project you may contact Matthew Stewart, the primary researcher on the details above.

If you have concerns about the way in which the research is being conducted you can contact the following:

Health Advocates: Advocates Network Services Trust, Phone (09) 623 5799, 0800 205 555, Fax (09) 623 5798, PO Box 9983, Newmarket, Auckland.

Finally, we would like to thank you for your valuable contribution to this research.

*This study has been approved by the UNITEC Research Ethics Committee from 3 May 2006 to 31st December 2007. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the Secretary (ph: 09 815-4321 ext 8041). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.*



**An investigation into the consistency of practitioner posture when performing the set-up for a high velocity, low amplitude thrust technique**

**Subject Consent Form**

This research project investigates body posture of osteopaths when performing the set-up for a high velocity, low amplitude thrust (HVLAT) technique to the thoracic spine. The research is being undertaken by *Matthew Stewart* from Unitec New Zealand, and will be supervised by *Robert Moran* and *Clive Standen*.

**Name of Participant:**.....

I have seen the Subject Information Sheet dated 3 May 2006 for people taking part in the investigation into the consistency of practitioner posture when performing the set-up for high velocity, low amplitude thrust technique (HVLAT) technique project.

I have had the opportunity to read the contents of the information sheet and to discuss the project with the researchers and I am satisfied with the explanations I have been given.

I understand that taking part in this project is voluntary (my choice) and that I may withdraw up until the point at which data analysis is started and this will in no way affect my access to the services provided by Unitec New Zealand or any other support service.

I understand that I can withdraw from the experiment if, for any reason, I want this.

I understand that my participation in this project is confidential and that no material that could identify me will be used in any reports on this project. I have had enough time to consider whether I want to take part.

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

The principal researcher and first contact for this project is:

Matthew Stewart  
10 Florida Place  
St Heliers  
021 771 407  
mattstewart@clear.net.nz

Signature.....participant ..... (Date)

Project explained by.....

Signature..... (Date)

The participant should retain a copy of this consent form.

*This study has been approved by the UNITEC Research Ethics Committee from 3 May 2006 to 31 December 2007. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the Secretary (ph: 09 815-4321 ext 8041). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.*



**An investigation into the reliability of practitioner posture when performing a high velocity, low amplitude thrust technique**

**Operator screening questionnaire**

	<b>Yes</b>	<b>No</b>
Have you ever experienced a musculoskeletal injury that has prevented you from practicing high velocity, low amplitude thrust (HVLAT) techniques?		
Are you currently experiencing any pain that prevents you from performing any osteopathic techniques?		

## Appendix H: Guidelines for submission to the International Journal of Osteopathic Medicine

### Guide for Authors

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

### Online Submission

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

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

### Types of contributions

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

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

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

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

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

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

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

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

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

The purpose of the Evidence in Practice report is to provide an account of the application of the

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

### **Presentation of Typescripts**

Your article should be typed on one side of the paper, double spaced with a margin of at least 3cm. One copy of your typescript and illustrations should be submitted and authors should retain a file copy. Rejected articles will not be returned to the author except on request.

Authors are encouraged to submit electronic artwork files with the original printed illustrations. Please refer to <http://ees.elsevier.com/ijom/> for guidelines for the preparation of electronic artwork files. Photographs scanned at lower resolution may be submitted for use in the peer-review process, provided that the original photographs are mailed to the Journal Editorial Office for use in the production process. To facilitate anonymity, the author's names and any reference to their addresses should only appear on the title page. Please check your typescript carefully before you send it off, both for correct content and typographic errors. It is not possible to change the content of accepted typescripts during production.

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

#### *Title page*

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

#### *Keywords*

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

#### *Abstract*

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

#### *Text*

The text of observational and experimental articles is usually, but not necessarily, divided into sections with the headings; introduction, methods, results, results and discussion. In longer articles, headings should be used only to enhance the readability. Three categories of headings should be used:

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

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

### **References**

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

Citations in the text: Please ensure that every reference cited in the text is also present in the reference

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

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

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

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

**Examples:**

Reference to a journal publication:

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

Reference to a book:

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

Reference to a chapter in an edited book:

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

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

## **Tables**

Tables should be double spaced on separate sheets and contain only horizontal lines. Do not submit tables as photographs. A short descriptive title should appear above each table and any footnotes suitable identified below. Take care to include all the units of measurement. Ensure that each table is cited in the text.

## **Illustrations/Figures**

All illustrations should be provided in camera-ready form suitable for reproduction (which may include reduction) without retouching. Photographs, charts and diagrams must all be referred to as "Figure(s)". They should accompany the manuscript, but should not be included within the text. They should be identified with Arabic numerals in parentheses (eg. Figure 1). Any symbols used in the figure must be identified and explained in the legend. Captions should be typed double spaced on separate sheets. All illustrations should be clearly marked on the back with the figure number, an indication of the top edge and the author's name. Do not use paper clips as these may scratch or mark an illustration.

*Photographs* Please submit high-quality black and white prints, clearly labelled, on the back with a soft crayon. Do not use ink.

*Line drawings and figures* Supply high-quality printouts on white paper produced with black ink. The lettering and symbols, as well as other details, should have proportionate dimensions, so as not to become illegible or unclear after possible reduction; in general, the figures should be designed for a reduction factor of two to three. The degree of reduction will be determined by the Publisher. Illustrations will not be enlarged. Consider the page format of the journal when designing the illustrations. Photocopies are not suitable for reproduction. Do not use any type of shading on computer-generated illustrations.

Computer-generated illustrations can be difficult to reproduce clearly unless there is good definition and clarity of outline.

Reproduction of borrowed illustrations or table or identifiable clinical photographs Permission to produce material (illustrations and tables) must be obtained from the original publishers and authors, and submitted with the typescript. Borrowed material should be acknowledged in the captions in this style - 'Reproduced by kind permission of?(publishers) from?(reference)'.

*Preparation of supplementary data.* Elsevier now accepts electronic supplementary material (e-components) to support and enhance your scientific research. Supplementary files offer the Author additional possibilities to publish supporting applications, movies, animation sequences, high-resolution images, background datasets, sound clips and more. Supplementary files supplied will be published online alongside the electronic version of your article in Elsevier Web products, including ScienceDirect: <http://www.sciencedirect.com>. In order to ensure that your submitted material is directly usable, please ensure that data is provided in one of our recommended file formats. Authors should submit the material in electronic format together with the article and supply a concise and descriptive caption for each file. For more detailed instructions please visit our artwork instruction pages at <http://www.elsevier.com/authors>.

Files can be stored on 3.5 inch diskette, ZIP-disk or CD (either PC or Macintosh).

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

### **Introduction**

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

### **Materials and Methods**

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

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

### **Results**

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

### **Discussion**

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

### **Acknowledgments**

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

### **IJOM Author Contribution Statement**

All manuscripts submitted to the journal should be accompanied by an Author Contribution Statement. The purpose of the Statement is to give appropriate credit to each author for their role in the study. All persons listed as authors should have made substantive intellectual contributions to the research. To qualify for authorship each person listed should have made contributions in each of the following;

- 1) Contributions to conception and design; data acquisition; data analysis and interpretation;
- 2) Drafting of manuscript, or critical revision for important intellectual content;
- 3) All authors must have given approval to the final version of the manuscript submitted for consideration to publish.

Acquisition of funding; provision of resources; data collection; or general supervision, alone, is not sufficient justification for authorship. Contributors who do not meet the criteria for authorship as outlined above should be listed in the Acknowledgements section. Acknowledgements may include contributions of technical assistance, proof reading and editing, or assistance with resources and funding. The statement may be published in the paper as appropriate.

Example of suggested format. Note the use of author initials.

*AB conceived the idea for the study. AB and CD contributed to the design and planning of the research. All authors were involved in data collection. AB and EF analysed the data. AB and CD wrote the first*

*draft of the manuscript. EF coordinated funding for the project. All authors edited and approved the final version of the manuscript.*

### **Copyright**

A "Transfer of Copyright" agreement will be sent to authors following acceptance of a paper for publication. A paper is accepted for publication on the understanding that it has not been submitted simultaneously to another journal in the English language. All authors must sign the "Transfer of Copyright" agreement before the article can be published. This transfer agreement enables Elsevier Ltd to protect the copyrighted material for the authors, without the author relinquishing his/her proprietary rights. The copyright transfer covers the exclusive rights to reproduce and distribute the article, including reprints, photographic reproductions, microfilm or any other reproductions of a similar nature, and translations. It also includes the right to adapt the article for use in conjunction with computer systems and programs, including reproduction or publication in machine-readable form and incorporation in retrieval systems. Authors are responsible for obtaining from the copyright holder permission to reproduce any material for which copyright already exists.

### **Page Proofs**

Proofs will be sent to the author (first named author if no corresponding author is identified of multi-authored papers) by PDF wherever possible and should be returned within 48 hours of receipt, preferably by e-mail. Corrections should be restricted to typesetting errors; any others may be charged to the author. Any queries should be answered in full. Elsevier will do everything possible to get your article corrected and published as quickly and accurately as possible. Therefore, it is important to ensure that all of your corrections are returned to us in one all-inclusive e-mail or fax. Subsequent additional corrections will not be possible, so please ensure that your first communication is complete. Should you choose to mail your corrections, please return them to: Log-in Department, Elsevier, Stover Court, Bampfylde Street, Exeter, Devon EX1 2AH, UK.

### **Author Enquiries**

For enquiries relating to the submission of articles (including electronic text and artwork) please visit <http://www.elsevier.com/authors>. The Author Gateway also provides the facility to track accepted articles and set up e-mail alerts to inform you of when an article's status has changed, as well as detailed artwork guidelines, copyright information, frequently asked questions and more. Contact details for questions arising after acceptance of an article, especially those relating to proofs, are provided when an article is accepted for publication.

**Language Editing.** International Science Editing and Asia Science Editing can provide English language and copyediting services to authors who want to publish in scientific, technical and medical journals and need assistance **before** they submit their article or **before** it is accepted for publication. Authors can contact these services directly: International Science Editing (<http://www.internationalscienceediting.com>) and Asia Science Editing (<http://www.asiascienceediting.com>) or, for more information about language editing services, please contact [authorsupport@elsevier.com](mailto:authorsupport@elsevier.com) who will be happy to deal with any questions. Please note Elsevier neither endorses nor takes responsibility for any products, goods or services offered by outside vendors through our services or in any advertising. For more information please refer to (<http://www.elsevier.com/authors>).

### **Offprints**

Twenty-five offprints will be supplied free of charge. Additional offprints and copies of the issue can be ordered at specially reduced rate using the order form sent to the corresponding author after the manuscript has been accepted. Orders for reprints (produced after publication of an article) will incur a 50% surcharge.

### **Checklist**

Please check your typescript carefully before you send it off to the Editorial Office, both for correct content and typographical errors, as it is not possible to change the content of accepted typescripts during the production process.

- One copy of typescript and illustrations
- Referenced list in correct style
- Written Permission from original publishers and authors to reproduce any borrowed any borrowed material

Appendix I: Permission to reproduce figure (Newell and Kumar, 2005).

-----Original Message-----

**From:** Steward, Laura (ELS-OXF) [mailto:L.Steward@elsevier.com]

**Sent:** Monday, January 14, 2008 10:37 PM

**To:** mattstewart@clear.net.nz

**Subject:** RE: Permission Request from Elsevier Health



**ELSEVIER**

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