

**Cavitation of the cervical spine using rotational high
velocity/low amplitude thrusts: finding consistency,
relationships and beliefs**

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Background: There is limited evidence to validate many of the techniques that osteopaths and other manual therapists use. Many techniques are performed by manual therapists without complete understanding of the mechanical and physiological mechanisms involved. The high velocity/low amplitude (HVLA) thrusts that are frequently used in osteopathic practice are one such example. Several authors suggest that accuracy (cavitating only the *dysfunctional* spinal segment) of the thrust is important for a successful clinical outcome (Meal & Scott, 1986). However, there is a division within the profession as to how accurate these thrusts need to be to create clinically relevant outcomes (Beffa & Mathews, 2004; Meal & Scott, 1986; Ross, Bereznick, & McGill, 2004). Recent research suggests that the accuracy of HVLA thrusts in both the thoracic and lumbar spine may be limited (Ross, Bereznick, & McGill, 2004).

Objectives: The first aim of this study was to determine how consistently an experienced osteopathic practitioner could target a side of the cervical spine using one rotational HVLA technique in multiple sessions. This study will also help determine which side of the cervical spine produces a cavitation sound during a primary lever left rotation HVLA thrust. The second part of this research surveys osteopaths registered to practice in New Zealand on their beliefs regarding sites of cavitation during cervical spine HVLA thrusts.

Design: Part 1: Observational study

Part 2: Survey

Methods: Part 1: Thirty-three (17 male and 16 female) participants aged between 18 and 40 volunteered for this study. One experienced osteopathic practitioner performed a single primary lever left rotational thrust to C3/4 segments of the cervical spine to each volunteer on three separate occasions over a four week period. Cavitation sounds were recorded via sensitive microphones attached to the postero-lateral aspects of each volunteer's neck at the level of C2. Analysis of the

recorded wave forms indicate the side where the cavitation of the cervical facets has occurred.

Part 2: A web-based survey was designed and emailed to 164 osteopaths within New Zealand. Demographic questions sought details on age, gender, schooling and the like, and also asked participants to watch four videos of commonly applied cervical spine manipulations. Osteopaths were asked to indicate on the survey which side of the cervical spine they believed the cavitation occurred during each of the thrusts.

Results: The findings from Part 1 of the study suggest that this osteopath can cavitate, with reasonable consistency, the right side cervical facets using a left rotational HVLA thrust. The findings also show that this type of thrust is most likely to produce cavitations ipsilateral to the practitioner's applicator hand.

The findings from Part 2 of this research show that there is consensus amongst osteopaths registered to practice osteopathy in New Zealand regarding the side where cavitation should occur during various HVLA manipulations of the cervical spine. There is more agreement from these osteopaths regarding the rotational style thrusts than the side-bending thrusts.

Conclusions: The results of this study show that this practitioner was able to cavitate zygapophyseal joints on the right side of the cervical spine in 75 out of 86 successful manipulations (87%). Out of the 86 thrusts 53 cavitations were purely on the right side while on 22 occasions bilateral events occurred that contain right side cavitations. This study confirmed that a left rotational HVLA thrust is more likely to cavitate the right side facets of the cervical spine. This finding is in agreement with the current anecdotal evidence and clinical biomechanical principles and with the *accepted theories* taught in many osteopathic colleges, but is in contrast to the findings of Bolton *et al.* (2007) and Reggars and Pollard (1995).

The experimental findings in Chapter Two were consistent with the reported beliefs from the surveyed osteopaths. These osteopaths mostly agreed regarding side of cavitation during cervical HVLA thrusts. There was 78% agreement that a left

rotational HVLA thrust will cavitate the right side facets of a patient's cervical spine. There was 70% consensus that right rotational thrusts will cavitate the left side facets. There was approximately 60% agreement on side of cavitation associated with both left and right side-bending thrusts which was lower than for rotational thrusts.

Declaration

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

I, Nic Naysmith, declare that this project is all my own work. Supervisor contribution was consistent with the Unitec Code of Supervision. All research conducted for this thesis was conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled all requirements set by said committee.

Nicholas R. Naysmith

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Introduction and Literature Review

1.1 Introduction

Manipulation of the human spine is one of the oldest treatment methods of manual medicine and one of the most frequently used techniques amongst osteopaths, chiropractors and physiotherapists (Greenman, 1996). The high velocity low amplitude (HVLA) thrusts are the best known of these manipulative techniques (DiGiovanna, Dowling, & Sciowitz, 2005). As the name suggests they are techniques defined by application of fast (high-velocity), controlled (low-amplitude) forces to joints that are typically exhibiting decreased range of motion. They are a group of techniques that employ the therapist's palpatory skills to identify and then alleviate restrictions of the spine.

These manipulative thrust techniques have been passed on between generations of manipulators (Weise & Callender, 2005), evolving over time to what we see today, by a culmination of repetitive demonstration and imitation (Evans, 2009). Until relatively recently, very little research has been conducted on the effect of these techniques. Positive clinical outcomes of spinal manipulation have been demonstrated in some studies (Assendelft, Morton, Yu, Suttorp, & Shekelle, 2003; Bronfort, Haas, Evans, Kawchuck, & Dagenais, 2008; Bronfort, Haas, Evans, & Bouter, 2004) but for the most part, the mechanisms for any reported effects are not fully understood and require further study. Recently several studies have shown that cavitation is not necessary for clinical outcomes (Cleland, Flynn, Childs & Eberhart, 2007; Flynn, Fritz, Wainner & Whitman, 2003).

Osteopaths and other manual therapists base their claims on clinical experience and anecdotal observation. Manual therapists often claim to understand the physiological effects that various treatments produce, but without the evidence to support these claims. Likewise the mechanisms and effects of HVLA thrust manipulations remain unclear. Consequently, professional opinion varies widely

regarding the very basics of these manipulations. In particular, there is controversy about the need for accuracy (side) of HVLA cavitations and whether or not cavitation is necessary for therapeutic benefit. Accuracy of HVLA thrusts has been defined as cavitation emanating solely from the target joint (segment specificity), this being the joint which has been diagnosed as being dysfunctional (Meal & Scott, 1986).

HVLA thrusts are said to increase the range of motion of dysfunctional joints (Brodeur, 1995; Bruckner & Khan, 1994; Kappler & Jones, 2003; Kenna & Murtagh, 1989; Kuchera & Kuchera, 1992; Lewit, 1991; Maigne, 1995; Sandoz, 1976), reduce the *hypertonicity* (in a state of abnormally high passive tension) of muscles (Brodeur, 1995; Kenna & Murtagh, 1989; Kuchera & Kuchera, 1992), release entrapped meniscoids and synovial folds (Bogduk & Jull, 1985; Indahl, Kaigle, Reikeras, & Holm, 1997; Kenna & Murtagh, 1989; Lewit, 1991; Shekelle, 1994), disrupt adhesions (Akeson, Amiel, & Mechanic, 1977), reset aberrant neurological pathways (Maigne & Vautravers, 2003; Maigne, 1995; Vernon, Dhimi, Howley, & Annett, 1986) and increase blood and lymph flow (Sucher, 1990). There are many theories as to how these effects might happen, and these will be discussed below; however the basic premise is that these thrusts produce local and specific effects to targeted tissues, which somehow lead to a reduction of symptoms. The thrusts themselves are meant to deliver energetic force in a very specific manner to the target joint that is thought to be responsible for the patient's current symptoms. In order for these techniques to be effective it has been suggested that they only target the dysfunctional spinal segment (Beffa & Mathews, 2004; Meal & Scott, 1986). However, for the most part it is difficult to know for certain how accurate these thrusts are, or indeed how accurate they need to be to produce desired clinical outcomes.

There are two popular and generally accepted HVLA techniques used for manipulating the cervical spine, commonly termed, rotational and side-bending thrusts. These refer to the direction of the primary thrust that is applied to create the cavitation. At Unitec New Zealand, during this researcher's undergraduate study, the general principal taught for HVLA thrusts of the cervical spine was that; rotational thrusts produce cavitations in zygapophyseal joints on the same side where contact is made with the practitioners thrust hand; and side-bending thrusts cause cavitation

on the opposite side to the practitioner's thrust hand. Thus the practitioner can use either technique to target a cervical joint depending on the restriction identified. These theories are largely based upon the understanding of the clinical biomechanics of the cervical spine but also upon anecdotal or individual opinions reflective of practitioner personal styles and beliefs.

This current study builds upon the results of a similar study by Bolton, Moran, & Standen (2007) who experimentally determined the side of cavitation using rotational and side-bending thrusts of the cervical spine. Bolton *et al.* (2007) concluded that HVLA thrusts produced cavitation on the opposite side to the generally held opinion. Following an extensive on-line search of the relevant literature, and to the best of the author's knowledge, only two studies (Bolton, Moran, & Standen, 2007; Reggars & Pollard, 1995) exist which investigate the side where cavitations occur in the cervical spine during HVLA thrust manipulations. The Reggars and Pollard (1995) study showed that the practitioner in their study was more likely to cavitate the cervical spine in a manner contrary to the biomechanical models also.

Review of the research literature follows. Firstly this review will describe the basic anatomy of the cervical spine and outline why HVLA thrusts are thought to be useful in correcting joint dysfunction in the neck. This is followed by detailed descriptions of the anatomical and biomechanical factors that are important in the rotational HVLA thrust employed in the study described in Chapter Two. The next section reviews the current theories attempting to explain mechanisms and effects of these thrusts. Finally, accuracy of manipulation of the spine with particular emphasis on the cervical region will be discussed.

1.2 Somatic Dysfunction

Within osteopathy HVLA techniques are typically used where 'somatic dysfunction' is diagnosed. Somatic dysfunction is identified on the basis of a number of palpatory findings relating to tissue texture, asymmetry of motion, range of motion and tissue tenderness. According to the Glossary of Osteopathic Terminology (Ward, 2003) somatic dysfunction is defined as "impaired or altered function of related components of the somatic (body framework) system: including skeletal, arthroal, and myofascial structures and related vascular, neural and lymphatic elements". There

are positional aspects of somatic dysfunction which are described using several parameters: (1) the position of the body part as determined by palpation and referenced to its adjacent defined structures, (2) the direction in which motion is freer, and (3) the direction in which motion is restricted.

Physiologist Irvin Korr (1979) postulated that in areas of somatic dysfunction the local efferent nerves exist in a heightened state close to the point of depolarisation. This makes the neurons more sensitive and more likely to produce an action potential. In osteopathy this sensitivity to depolarisation is termed facilitation or the facilitated segment (Korr, 1979). It is postulated that the facilitated state leads to alterations in local muscle tone, connective tissue stiffness, contracture and nociception causing a decrease in mobility of the affected spinal segments (Korr, 1979).

Korr (1979) suggests that the nociceptors produce muscular guarding reactions, as well as autonomic activation, when musculoskeletal tissue is under stress or has been damaged. This guarding in turn causes abnormal musculoskeletal range of motion due to altered positioning of skeletal components. Consequent localised inflammatory responses and autonomic reflexes further strengthen the nociceptive activity, thus increasing the restriction. Korr also suggests that the nociceptive autonomic reflexes change immunologic function. Eventually, sustained malfunction of muscles, joints, and related tissues in abnormal positions causes changes in the connective tissues which results in further attenuation of the normal position and motion (Korr, 1979). Korr's model emphasizes the nociceptor and its reflexes as a source of the changes seen in somatic dysfunction.

It has been postulated that repeated and prolonged stimulation will elicit a detrimental response in most neural receptors (Burgess & Perl, 1973), particularly in nociceptors. It is for this reason that the nociceptive neurons are thought to play a major role in the facilitated segment (Burgess & Perl, 1973; Korr, 1979). Nociceptors have been identified that respond to all sorts of stimuli, and for the most part their description goes beyond what is needed for this review. However, there are nociceptors that are quite relevant to this discussion. The British neurologist Barry Wyke (Wyke, 1979) discovered and described articular neural receptors responsive

to noxious mechanical stimuli. Subsequent to this, mechanical nociceptors have been described in the zygapophyseal joints of all the regions of the human spine (McLain, 1994; McLain & Pickar, 1998). It is thought that these articular nociceptive neurons play a major role in the decreasing movement of spinal vertebrae due to the process of facilitation described above.

The neurological events that occur in response to facilitation, the changes in local tissues surrounding the facilitated segment and the responses that occur with HVLA manipulations will be discussed in further detail in Section 1.5 Mechanisms and Effects of HVLA.

1.3 The Cervical Spine

The human neck is an extraordinary anatomical structure. It possesses a large range of mobility in almost all planes and at the same time acts as a protective conduit for major soft tissue elements including nerves and blood vessels. The cervical spine provides the platform for the skull, orientates the head in 3-dimensional space, and balances the cranium upon a relatively immobile thorax. The neck flexes, extends, side-bends, circumducts and rotates the head and positions the special senses. The neck contains skeletal, muscular, ligamentous, neural and vascular components all of which are susceptible to dysfunction, immobility and pain. The movement of the cervical spine is dictated by the unique shapes of the vertebrae and the muscles of the region. And like many parts of the human body the cervical spine can be susceptible to somatic dysfunction.

According to Bogduk and Mercer (2000) the cervical spine can be divided, for descriptive purposes, into four units which all contribute to the overall function of the neck determined by their unique morphology. The four functional units are the occipito-atlantal (OA) joint, the atlanto-axial (AA) joint, the articulation of the second and third cervical vertebrae (C2/C3) and the articulations of the remaining *typical* vertebrae C3-C7. Of the seven cervical vertebrae three are readily distinguished by their morphological distinctiveness: the atlas (C1), the axis (C2) and the seventh vertebrae (C7), known as *vertebra prominens*, because of its large spinous process. The atlas cradles the occiput and allows for nodding movements of the head (Platzer, 2004). The atlas lacks a true vertebral body and has a large vertebral

foramen with lateral masses either side which possess the superior and inferior articular processes. The superior facets articulate with the occiput while the lower facets articulate with the second cervical vertebrae (Platzer, 2004). C1 sits upon the axis and weight bears via the laterally placed atlanto-axial joints. The articulation of C1 on C2 allows rotational motion of the head. The axis differs from the other cervical vertebrae because of the odontoid process, a superior projection on the cranial surface of the vertebral body (Platzer, 2004). The poorly developed lateral masses of C2 contain foramina for the passage of the vertebral arteries. More often than not the large spinous process is bifurcated. The spinous process of the axis is an important anatomical landmark for manual therapists to palpate and is often used to determine which level of the neck they are manipulating.

The articulation of C2 on C3 is the commencement of the *typical* cervical spine where common morphological and kinematic features are shared (Platzer, 2004). These vertebrae have larger bodies, smaller vertebral foramen than C1 and C2 and more developed transverse processes, which like C1 and C2, contain foramina for the passage of the vertebral arteries. The C3-C7 vertebrae, like the rest of the vertebrae in the human spine, articulate upon the intervertebral discs and the lateral articular processes, known as zygapophyseal joints, but unlike the thoracic and lumbar vertebrae they also have modified synovial joints found laterally on the vertebral bodies which are known as uncovertebral joints (Platzer, 2004).

The zygapophyseal joints are small synovial joints that lie between the adjacent vertebrae of the spine that allow for movement (Platzer, 2004). They are true diarthrodial joints complete with capsule and synovial lining (Platzer, 2004). Their articular surfaces are covered in hyaline cartilage, which transmits loads and allows for repetitive joint motion. Zygapophyseal joints have a fibrous joint capsule that is relatively lax and allows for this movement. The capsule is poorly vascularised and subsequently heals slowly following damage (Barnett, Davies, & MacConahill, 1961). The synovial membrane that lines the capsule allows for the exchange of nutrients and waste products between blood and the joint contents (Barnett, Davies, & MacConahill, 1961). The membrane synthesises and excretes synovial fluids that are essential for joint movement and health. The zygapophyseal joints are innervated by posterior primary rami from at least two levels (Bogduk, 1976) and

contain mechanoreceptors that are responsive to noxious mechanical stimuli which are considered likely sources of nociception (McLain, 1994).

The bony and soft tissue components of the zygapophyseal joint are susceptible to the same disorders that affect joints elsewhere in the human body. The clinical presentations of patients with neck pain are many, and are beyond the scope of this review; suffice it to say however, that many of these presentations are treatable with osteopathic HVLA manipulation. With detailed knowledge of the anatomy and biomechanics of the cervical spine, therapists have been able to theorise how HVLA manipulations might behave. The mechanisms and effects of these manipulations and the instances in which they are used in the spine are discussed in the following sections.

1.4 HVLA Thrusts of the Cervical Spine

High velocity low amplitude thrust manipulations are techniques used to provide biomechanical, neurophysiological and psychological effects to patients suffering from symptoms (Heilig, 1986; Nyberg, 1985; Schneider, Dvorak, Dvorak, & Tritschler, 1988; Van Buskirk, 1990). Historically they have been divided into either direct or indirect techniques. The direct techniques apply force directly over the target segment whilst the latter delivers force to the target segment through its contiguous neighbours. In both cases there is deformation of superficial and restraining tissues (Evans, 2009) with the joint being thrust towards the restricted barrier thus reestablishing proper physiologic function (Kappler & Jones, 2003). Greenman (1989) refers to the thrust as an 'impulse' of force to the joint that results in an audible 'click' or 'pop', known as a cavitation, that can lead to an immediate increase in the mobility and provide significant pain relief.

Diagnosis of dysfunction of a vertebral segment, that usually includes positional or motion changes, usually precludes the thrust (Ward, 1997). The therapist then uses primary levers of rotation or side-bending coupled with local flexion or extension of adjacent vertebral segments to "lock-up" target facets so that further motion will be limited to the target segment. This "lock-up" has been investigated by several authors (Herzog, Conway, Zhang, Gal, & Guimaraes, 1993; Herzog, Kats, & Symons, 2001) and has been variously described as "joint pre-load" and "pre-thrust

tension". The practitioner creates a palpatory feeling of "density" and "tension" within the target joint which is a "physiological resistance of all of the stabilising components of the target joint" (Byfield, 2005). This pre-thrust tension is applied prior to the thrust and determines the amount of force and energy required by the practitioner to cavitate the target joint (Byfield, 2005; Herzog *et al.*, 1993; Herzog *et al.*, 2001).

A biomechanical model for HVLA manipulations has been proposed (Evans & Breen, 2006) which predicts that this pre-thrust tension allows delivery of an HVLA "impulse" to the target joint whilst the joint is itself held in a neutral zone. This neutral zone is the region in which the joint lies within its normal physiological range whilst the manipulation is performed (Evans & Breen, 2006). Thus, the precise mechanical positioning of the joint prior to the thrust will result in an efficient transfer of kinetic energy to the peri-articular tissues. There is, however, debate surrounding the true nature of vertebral movement through the spine, and so this theory remains to be validated.

The target spinal segment (diagnosed to be dysfunctional) is moved passively by the practitioner to its end of range motion (or barrier) so that slack is removed from the system. Then a brief, specific and controlled thrust, of most commonly either a rotational or side-bending manner, is applied in the direction that is perceived to have restricted motion, resulting in a small amount of movement against the barrier (Stone, 1999; Ward, 1997). The operator delivers the "impulse" of force toward the target joints creating a small amplitude of movement between the articular surfaces of the zygapophyseal joints (Cramer *et al.*, 2002a).

The two commonly practiced HVLA techniques (the rotational cervical spine HVLA and the side-bending cervical spine HVLA) are named for the primary lever that is performed to take the joint to end of range. For instance, the rotational HVLA uses combined movements of flexion, extension and shear to produce the "lock-up" described above, however, the final thrust is rotational in manner (see Figure 1.1a). The side-bending HVLA uses a similar "lock-up" utilizing flexion, extension and shear also but the final thrust is of a side-bending nature (see Figure 1.1b).

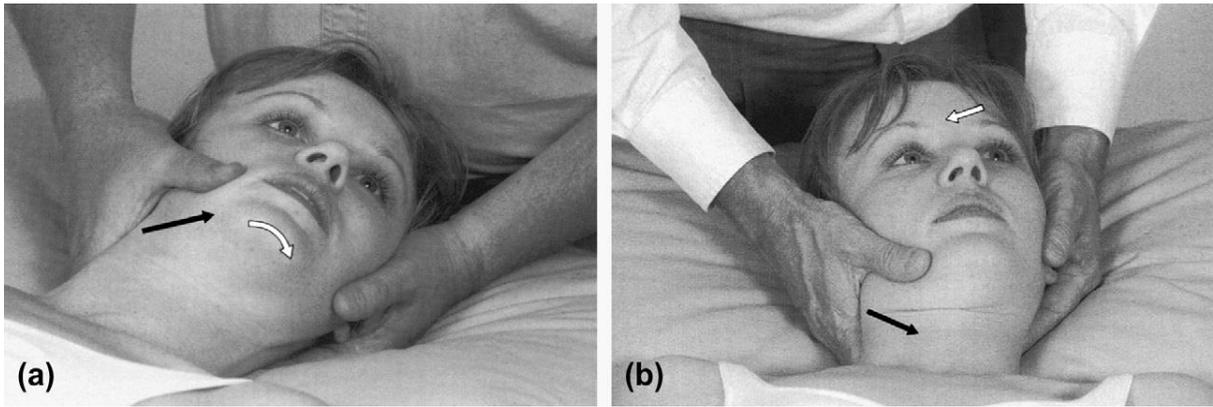


Figure 1.1: (a) Primary lever rotation HVLA manipulation of the cervical spine (after Gibbons and Tehan, 2000). Anecdotal opinion and biomechanical reasoning suggests that the cavitation should take place on the right facet of the patient's neck during this type of thrust. (b) Primary lever side-bending HVLA manipulation (after Gibbons and Tehan, 2000). Conventional opinion suggests that cavitation should occur from the patient's left sided facet joint during this type of cavitation. Note: black arrow indicates the plane of the thrust; white arrow indicates direction of patient head movement. Reprinted from Gibbons and Tehan (2000) with permission from Elsevier.

A brief description of the techniques will give an idea of the biomechanics involved with these thrusts and will show how accuracy to the target joint is obtained and will also reveal the differences between the rotational and side-bending thrusts.

For manipulating the typical cervical vertebrae (C3-C7) with a left rotational focus the set-up is as follows (adapted from Gibbons & Tehan, 2000):

1. With the patient supine the practitioner stands slightly over the right shoulder.
2. The practitioner's left hand contacts the patient's head just behind the left ear, on the occipital region and acts as a stabilizer.
3. The lateral aspect of the proximal phalanx of the 2nd digit of the right (applicator) hand contacts the postolateral aspect of the articular pillar.
4. The neck is flexed down to the target segment before a small amount of local extension is produced at the target segment.
5. The practitioner rotates the patients head and neck left down to the target segment to provide facet lock.
6. The practitioner applies a high-velocity/low-amplitude left rotational thrust in the plane of the facet of the target joint to produce a cavitation sound.
7. The segment is retested for normal motion.

According to convention and the properties of intervertebral motion this type of thrust should produce a lock-up and subsequent cavitation on the same side as the practitioner's applicator hand. This is known as an ipsilateral cavitation. A right rotational thrust, named for the direction that the patients head rotates during the maneuver, is performed opposite to the setup above and should produce a lock-up and cavitation on the patients left side.

For manipulating the typical cervical vertebrae (C3-C7) with a right side-bending focus the set-up is as follows (adapted from Gibbons & Tehan, 2000):

1. With the patient supine the practitioner stands slightly over the right shoulder.
2. The practitioner's left hand contacts the patient's head just behind the left ear, on the occipital region and acts as a stabilizer.
3. The lateral aspect of the proximal phalanx of the 2nd digit of the right (applicator) hand contacts the postolateral aspect of the articular pillar
4. The neck is flexed down to the target segment before a small amount of local extension is produced at the target segment.
5. The practitioner side-bends the patients head and neck to the right until it localises at the target segment.
6. The head is rotated to the left down to the target segment so that facet lock is obtained.
7. The practitioner applies a high-velocity/low-amplitude right side-bending thrust in the plane of the facet of the target joint to produce a cavitation sound.
8. The segment is retested for normal motion.

Clinical biomechanical reasoning predicts that this type of thrust produces lock-up and cavitates facets on the patients left side. This is known as a contralateral cavitation because cavitation occurs on the opposite side to the applicator hand. A left side-bending thrust is performed opposite to this and is theorised to produce lock-up and cavitation on the patient's right side.

1.5 Mechanisms and Effects of HVLA Manipulation

Currently, the accepted theory is that cavitation sounds originate from within the zygapophyseal joints in the human spine during HVLA thrusts (Unsworth, Dowson, & Wright, 1971). Cavitation is a well documented engineering phenomenon that describes the collapse of gas bubbles in a fluid (Brodeur, 1995). In the human body cavitation sounds are thought to be the result of a sudden decrease in intra-articular pressure as joint surfaces are distracted from each other producing the release of (mainly) CO₂ from within the synovial fluid (Brodeur, 1995). Unsworth *et al.* (1971) agree that the sound emanates from the synovial fluid. They suggested that as the joint is tractioned during an HVLA the volume of the joint increases with a subsequent reduction in the partial pressure of the articular fluid. Tractioning of the joint is said to draw intra-articular gases out of solution creating a gas bubble within the synovial fluid. Radiographic (Mierau, Cassidy, Bowen, Dupuis, & Notfall, 1988) and cineradiographic (Watson, Kernohan, & Mollan, 1989; Watson & Mollan, 1990) imaging has shown a dense area within the joint, assumed to be this bubble, lending weight to this hypothesis. Unsworth *et al.* (1971) have suggested that the resultant net flow of fluid back into the space created by the bubble of gas produces the cracking (cavitation) sound. Not all researchers agree with this theory. Recently, Cascioli, Corr and Till (2003) showed that there is no evidence of gas in the joint space following HVLA thrusts. However, as Unsworth *et al.* (1971) hypothesised, the articular fluid flows back in to the space created by the gas bubble during the cavitation, so absence of a bubble after cavitation would not be expected. The most recent MRI investigation into the phenomenon confirms that the source of the sound was the zygapophyseal joints (Cramer *et al.*, 2002b), as opposed to any other anatomical structure related to the vertebral segment, but did not go as far as suggesting the exact mechanism of the audible crack.

It is not clear whether the cavitation sound itself is indicative of success in these techniques and/or whether it will ensure greater therapeutic benefit to the patient. Cleland, *et al.* (2007), Flynn *et al.* (2003) and Grieve (1988) contest the clinical significance of the cavitation sound while Lewit (1978) and Sandoz (1976) insist that the cavitation sound is necessary for the success of the treatment. Mierau *et al.* (1988) showed that manipulation of the metacarpophalangeal joint accompanied by

a cavitation sound produced a greater range of flexion than a manipulation to the same joint that had no audible crack. Despite this evidence, others (DiGiovanna *et al.*, 2005; Greenman, 1996) place little significance in the cavitation sound and suggest that simply taking the joint to its end-of-range barriers is effective enough in producing a greater range of motion (Grieve, 1988).

The mechanism by which the HVLA thrust might influence spinal joint mobility and alleviate pain is not fully understood either. The “impulse” that the operator introduces, and the subsequent cavitation of the zygapophyseal joint, restores maximal pain-free range of motion via a number of mechanisms, that are thought to include: (1) reducing hypertonic muscles (in a state of abnormally high passive tension) surrounding the joint (Brodeur, 1995; Kenna & Murtagh, 1989; Kuchera & Kuchera, 1992; Reggars, 1998), by lengthening locally shortened connective tissues and by increasing fluid movement to the area (DiGiovanna *et al.*, 2005; Lederman, 2005; Reggars, 1998); (2) releasing trapped intra-articular material such as meniscoids and synovial folds (Bogduk & Jull, 1985; Indahl *et al.*, 1997; Kenna & Murtagh, 1989; Lewit, 1991;Shekelle, 1994); (3) the disruption of articular and peri-articular adhesions (Akeson, Amiel, & Mechanic, 1977; Indahl *et al.*, 1997); and (4) unbuckling of motion segments that have undergone displacement (Shekelle, 1994). Reggars (1998) proposes that the HVLA thrust initiates a reflex relaxation of the peri-articular musculature and there is a suggestion that the thrusts reset local aberrant neurological pathways present within the dysfunctional segment allowing normal input to return.

Hypertonic muscles

According to Schiowitz (DiGiovanna *et al.*, 2005) it is probable that most decreases in spinal segmental mobility diagnosed as somatic dysfunction are due to hypertonicity of the deep intrinsic musculature of the spine. A hypertonic muscle displays extreme tension, is resistant to movement and exists in a protective state thus reducing spinal segment mobility. This hypertonic state can be caused by numerous factors including injury, poor posture and illness. Fatigue usually ensues, which impairs the muscular efficiency and co-ordination and can alter neurological firing of the muscle. It has been assumed that direct HVLA thrusts stretch and

elongate these shortened tissues and in doing so rapidly lengthen the hypertonic muscle in a passive manner and produce relaxation by increasing Golgi tendon organ discharge and reflex inhibition (Bogduk & Jull, 1985). It has long been assumed that the proprioceptors, mechanoreceptors and nociceptors of the joint capsule and the surrounding musculotendinous tissues were the probable mechanisms that would influence the nervous system during the HVLA thus reducing muscular tone (Brodeur, 1995; Herzog, 2000; Korr, 1975). It was thought that the stretch produced an increase in the γ -afferent discharge which in turn elicits brainstem descending inhibition which provides muscle relaxation. According to some research (Bogduk & Jull, 1985) stretching the joint capsule is known to blunt the action potential of the paraspinal muscles reducing the likelihood of inappropriate firing and pain.

However, Lederman's (Lederman, 1997) opinion is that "this is highly unlikely as sudden stretch produced by this form of manipulation will excite rather than inhibit the motor neuron". Observations by Herzog *et al.* (Herzog, 1994, 1995, 1996, 2000; Herzog *et al.*, 1993) confirmed this, showing that HVLA caused excitatory reflexes in neck musculature. Thus it has been hypothesised that the effect of the HVLA is not to relax hypertonic muscles but rather create hypoalgesia (Vernon, 2000) and an increase in pain thresholds to noxious stimuli (Terrett & Vernon, 1984).

Meniscoids and synovial folds

Zygapophyseal joints are innervated structures containing both nociceptive and mechanosensitive receptors and are therefore potential sources of nociception (Giles & Taylor, 1987). Synovial folds and meniscoids have the potential to become entrapped between the opposing surfaces of the joint and are thought to produce changes in the normal mechanics of the joint, possibly resulting in pain (Indahl *et al.*, 1997).

Bogduk and Jull (1985) have addressed the issues of entrapment of these structures and have concluded that there are indeed potentials for pain and immobility. They suggest that distension of the joint capsule that occurs with meniscoid and synovial pinching is a sufficient stimulus for depolarisation of nociceptors. It is thought that

HVLA thrusts may pull articular surfaces apart releasing entrapped soft tissues, reducing joint distension and pain which returns the joint to its normal anatomic position (Shekelle, 1994).

Unbuckling motion segments

The idea that HVLA manipulations realign dysfunctional joints is one of the oldest theories of spinal manipulation. The HVLA thrust is applied directly to the spinous process of the patient's vertebrae, and for the most part the energy is absorbed by the paraspinal muscles, however energy is also absorbed by and mobilises the vertebrae on one another (Triano, 1992). The movement that this induces is complex and can target more than one vertebra and produce displacements outside of the normal physiological range (Maigne & Guillon, 2000). The net effect is an increase in motion of segments displaying less than normal range of motion.

Resetting aberrant neurological pathways

Stretching of the local paraspinal muscles along with joint capsules, ligaments and intervertebral discs, which has been demonstrated in manipulation experiments (Maigne, 1995), has been hypothesised to activate or reset the pain inhibitory system (Maigne & Vautravers, 2003). Forceful manipulation is known to induce presynaptic inhibition of afferent impulses thus increasing pain thresholds (Vernon *et al.*, 1986). It has also been shown that following HVLA thrusts there is a moderate increase in the local levels of plasma beta endorphins which are known to reduce pain intensity (Maigne & Vautravers, 2003).

Disruption of adhesions

The normal range of motion of any synovial joint is known as its physiological range. It is possible that following injury to a zygapophyseal joint, such as a capsular tear, that fibrosis can occur leading to immobilisation (Mercer & Bogduk, 1993). It has been postulated that one of the mechanisms of effect of the HVLA thrust may include the alteration of these adhesions (Akeson *et al.*, 1977). Thus it is possible that the thrusts disrupt the connective tissue adhesions and by improving the soft tissue

texture also improve the flow of lymph and blood, thus furthering the effect of the technique (Sucher, 1990).

While it is accepted that the cavitation sounds produced during the HVLA thrusts are common phenomena (DiGiovanna *et al.*, 2005), and that more needs to be done to elucidate the source, there is little data regarding the relationship between the type of thrust used and the site of the cavitation. Similarly there is little data about whether there are differences between practitioners, for example, idiosyncrasies of technique due to theory taught during training or whether levels of experience and handedness affect outcomes. This is discussed in the next section.

1.6 Previous Research on HVLA Manipulation

The first investigations into the recording of cavitation phenomenon were conducted in 1947 by Roston and Haines on the metacarpophalangeal (MCP) joints of the hand, which were chosen because of their accessibility. Their research showed that a radiolucent cavity appeared in the joint following an HVLA and that there were changes in overall mechanical behavior. The source of the noise and the mechanisms of its production have been researched by several authors since this time (Mierau *et al.*, 1988; Roston & Wheeler-Haines, 1947; Unsworth *et al.*, 1971). Collectively, their research on MCP cavitation advanced the theory of an intra-articular gas bubble being produced. Unsworth, Dowson and Wright (Unsworth *et al.*, 1971) in a study of MCP joint distraction demonstrated a CO₂ gas bubble forming as joint volume increased and intra-articular pressure dropped. It was concluded that the net movement of the synovial fluid back in to the space created by the gas bubble created the crack sound. Later, Mierau *et al.* (1988) confirmed the theory with radiographic evidence of a gas bubble in MCP joints after manipulation. Further research (Mierau *et al.*, 1988; Sandoz, 1969) has demonstrated significant changes in joint mobility following HVLA.

Woods and West (1986) recorded cavitation sounds from within the temporomandibular joint (TMJ) of the jaw. This study showed distinct changes in the biomechanical behavior of the joint following HVLA. Woods and West also conducted the first research on the cavitation phenomenon of cervical, thoracic and

lumbar joints of the human vertebral column (Woods and West 1986). They concluded that there were distinct differences between the sound signals from the TMJ and the vertebral cavitations.

In that same year Meal and Scott (1986) recorded MCP cavitation sounds and concluded that the cavitation sound is an essential indication that the joint has been taken to its physiological end range and that the articular surfaces have been separated.

In 1993 Herzog *et al.* (Herzog *et al.*, 1993) studied the characteristics of the recorded wave sounds produced by an HVLA of the fourth thoracic (T4) segment of the spine. Unlike previous research they used accelerometers rather than audio recording equipment and compared the findings with practitioner perception of cavitation. Their study showed 100% agreement between the practitioner's perception of the occurrence of cavitation and actual cavitation showing that a practitioner can consistently determine by palpation whether cavitation has occurred during HVLA. This study also shows that cavitation sounds can be captured using accelerometers; however, the accuracy of this method is yet to be properly studied.

Three subsequent literature reviews (Evans, 2002; Protapapas & Cymet, 2002; Reggars, 1998) and two studies (Cleland, *et al.*, 2007; Flynn *et al.*, 2003) on HVLA thrust manipulations and cavitation phenomenon dispute the therapeutic benefit of the audible release and suggest that it may not be an absolute requirement for beneficial mechanical effects.

Typically the study of the effects of spinal manipulation on the mobility of the spine has entailed radiological and goniometric studies. Several studies have analysed changes in cervical range of motion following cavitation using active and passive ranges of motion (Cassidy, Lopes, & Yong-Hink, 1992; Clements, Gibbons, & McLaughlin, 2001; Nansel, Peneff, Cremata, & Carlson, 1990; Schalkwyk & Parkin-Smith, 2000) but only one recent study (Fernandez-de-las-Penas, Downey, & Miangolarra-Page, 2005) has shown evidence of increased intervertebral motion as measured by functional radiography following a supine cervical spine rotation manipulation. These researchers suggest that spinal manipulation might affect the

mobility of an inter-vertebral joint, as well as zygapophyseal joints, in the cervical spine in a clinically desirable manner.

1.7 Accuracy of Cavitation during Spinal HVLA Manipulation

When a joint is identified by palpation as being restricted because it displays abnormal biomechanical behavior, an osteopathic practitioner may choose an appropriate manipulative technique with the aim of restoring normal function. Keeping in mind though that diagnosis of dysfunction of a segment is a subjective finding that may differ between practitioners. In addition, accuracy with which a practitioner can target a segment has not been determined. Each segment of the spine has four articular surfaces, any one or all of these may cavitate during articulation. Yet, accuracy (Meal & Scott, 1986). in targeting this joint with a cavitation is considered essential by some (Beffa & Mathews, 2004). Meal and Scott (1986) state that “one of the skills of the manipulation is to be able to isolate the effect on the one joint that needs to be adjusted”.

Why the HVLA thrust needs to be so accurate is open to debate. Some authors suggest that a “shotgun” approach that manipulates several joints over multiple segments of the spine around the restricted joint would be just as effective as an approach that targets the dysfunctional joint only (Ross *et al.*, 2004). Indeed few studies have even managed to establish the location of cavitation with respect to the various HVLA thrusts that are available to the practitioner let alone whether accuracy is necessary for positive clinical change to occur. There are four studies that have investigated the location of cavitation sounds in the human spine that are related to a few of the many HVLA techniques that are used (Beffa & Mathews, 2004; Bolton *et al.*, 2007; Reggars & Pollard, 1995; Ross *et al.*, 2004).

In 1995 Reggars and Pollard performed an experiment designed to determine the relationship between the direction of head rotation and the side of joint cavitation using what they termed “diversified” rotary manipulations in the cervical spine. According to Gitelman and Fligg (Gitelman & Fligg, 1992) the “diversified” technique refers not to the manipulation itself but the entire technique of patient care that chiropractors use. Thus, the “diversified” manipulation is similar to that used by

osteopaths and other manual therapists. Reggars and Pollard (1995) fixed skin mounted microphones to 50 participant's cervical spines overlying the transverse processes of the second cervical segment (C2). All the subjects received a manipulation targeted at the C3/4 zygapophyseal joint using either a "diversified" left or a right rotational thrust. The joint cavitation sounds were analysed and results showed that zygapophyseal joint cavitation occurred on the ipsilateral side to head rotation (i.e. on the side opposite to the applicator hand) in 94% of the subjects (95% CI). In the three subjects who had had previous neck trauma, the cavitation occurred in what they call a manner contralateral to the head rotation (i.e. on the same side as the contact hand). One of these subjects had a pure contralateral cavitation whilst the other two had bilateral cavitations. There was significantly less exclusively ipsilateral cavitations in subjects with previous neck injury ($p=0.023$). However, the low numbers of participants with previous cervical injury make this finding difficult to generalise. In general, this study suggests that a "diversified" rotary manipulation of the cervical spine is more likely to result in zygapophyseal joint cavitation ipsilateral to the direction of head rotation. This is contrary to conventional opinion and clinical biomechanical reasoning but they laid the foundation for further investigations on the accuracy of cervical spine cavitations.

There were several limitations to this study. Primarily, they used only one practitioner to perform all cavitations, which means their results are difficult to generalise because idiosyncrasies of the practitioner's technique may account for these findings. It has long been suspected that determination of side and site of cavitation (accuracy) is dependent on the practitioner's individual style as well as the set-up used (Good, 1992) and the type of technique employed (Cassidy, Thiel, & Kirkaldy-Willis, 1993). Reggars and Pollard (1995) note that the external validity of their study is limited due to the use of only one practitioner. This effects style of the HVLA technique which may also affect the clinical outcome of the treatment. This study also suggests that a prior history of neck dysfunction changes the side of cavitation, but this requires further study. It is entirely plausible that biomechanics of the cervical spine can be altered by neck trauma. They did not, however, describe the degree of dysfunction, for instance, the type of neck trauma, the duration, the level of pain etc of each of the three subjects that had previous cervical spine injuries. Two further studies have shown that in the presence of discogenic

spondylosis (Good & Mikkelsen, 1992) and pain (Amevo, April, & Bogduk, 1992) the joint cracking phenomenon changes highlighting the need to study symptomatic subjects.

In 2004, Beffa and Mathews conducted research with the purpose of locating the cavitation sounds produced during lumbar and sacroiliac HVLA thrusts using two commonly practiced chiropractic manipulations. The differences in location relative to the two different techniques used were analysed. With 30 asymptomatic volunteers divided into two groups, one for each technique, they recorded cavitation sounds using eight skin-mounted microphones. Radiographic images were used to ensure the optimal positioning of recording devices. The sounds that were produced were recorded, digitized and analysed statistically. The Wilcoxon signed rank test resulted in acceptance of the null hypothesis for both groups (Lumbar: $P=0.188$; lower sacroiliac: $P=0.355$), indicating that no particular joint was cavitated frequently enough to signify accuracy of the 2 adjustments.. In contradiction to reported theories (Lewit, 1978; Sandoz, 1976; Schafer & Faye, 1989) about the importance of obtaining cavitation sounds during manipulation, in this study cavitation sounds were frequently detected from non-target joints. This study was limited by its small sample size where only 15 subjects were allocated to each group. In addition, similar to the Reggars and Pollard (1995) study they only used one practitioner to perform all the manipulations also reducing the external validity. They suggested that better recording equipment with a greater range of frequency and amplitude might have improved the study because they felt that some sounds might have not been recorded with the equipment they used.

Ross, Bereznick and McGill (2004) investigated the location of cavitations in lumbar and thoracic vertebrae in order to determine the accuracy of HVLA manipulations. Twenty eight practitioners with varying levels of experience (1-43 years) manipulated a range of levels of the spine and recorded cavitation sounds using accelerometers. All the practitioners used in this study were faculty members of the Canadian Memorial Chiropractic College limiting the study's generalisability. There were a total of 64 volunteers, 59 of which received one cavitation, five of whom received two. The practitioners had a choice of four lumbar techniques and two thoracic techniques to choose from. Practitioners located a joint exhibiting tenderness and/or

restricted motion for manipulation. Comparisons were made between the attempted target segment and the actual segment that cavitated. Within the lumbar region the practitioners were accurate only about 50% of the time, i.e. they were unable to contain the cavitation phenomenon to only the joint they were targeting in 50% of the manipulations. The mean discrepancy between the calculated location of the cavitation and the target joint was 5.29 cm, which was at least one vertebrae away from the target segment, with a range of 0-14 cm. Within the thoracic spine, cavitations were only slightly more accurate compared to the lumbar spine (54%). Of the total 54 thoracic cavitations that were performed only 29 were considered to have originated from the target joint. The mean discrepancy from the target joint in the thoracic spine was 3.5 cm, with a range of 0-9.5cm. In most cases, in both the lumbar and thoracic spine, multiple cavitations were recorded. This is interesting because it is considered the skill of the practitioner to cavitate the target joint, yet practitioners, albeit of varying experience, were more likely to produce multiple cavitations rather than the sought after single cavitation of the target joint. They concluded that in the lumbar spine the HVLA techniques they employed were accurate in single cavitations at the target joint in only 50% of cases. However, as many of manipulations resulted in multiple cavitations, many actually included the target segment, and thus they may be considered successful. In the thoracic spine they concluded that the techniques they employed were slightly more accurate. They suggest that the clinical response to manipulations relies on the fact that, in the majority of cases, multiple cavitations occur during a single HVLA. Thus whilst the “shotgun” approach is not particularly accurate it cavitates the target joint, along with neighbouring joints, which still results in positive clinical outcomes for patients.

Recently Bolton *et al.* (2007) conducted a study to identify side of cavitation resulting from cervical spine manipulations. Their research had two objectives; the primary goal was to determine whether there was a correlation between the side of cavitation of the cervical spine and the type of technique used. And secondly, the researchers wished to compare the subjects’ perceived side of cavitation with actual side of cavitation. Twenty asymptomatic subjects each received two mid-cervical HVLA thrusts of both a rotational and side-bending manner. One registered osteopath of six years clinical experience performed all the manipulations. Using skin mounted microphones they recorded a total of 40 cavitations, 20 for each technique.

Statistical analysis (two-tailed Fisher's exact test) revealed that cavitation was significantly more likely to occur on the contralateral side to the applicator ($P=0.02$) for rotational HVLA thrusts. These findings agree with those of Reggars and Pollard (1995), but again are contrary to conventional opinion and clinical biomechanical reasoning. For side-bending thrusts these researchers found that the practitioner employed in the study was no more likely to produce a cavitation sound on the ipsilateral (same) or contralateral (opposite) side as the point of contact of the applicator hand ($p=0.350$). Both these findings are in contrast to what is commonly taught at osteopathic schools. Kappa values showed that there was fair to moderate correlation between the recorded side of cavitation and the patients' perceived side of cavitation for rotation ($k=0.49$) and side-bending ($k=0.30$) thrusts.

There were several limitations to the work of Bolton *et al.* (2007). One of the limitations of the research was the frequency with which they recorded the cavitations. They reported that the recorded wave form peaks were sometimes open to subjective interpretation; *i.e.* it was not always clear whether the sound recorded was from the left or right side of the neck. Research (Reggars & Pollard, 1995) suggested that a recording frequency of 44,000Hz is much more sensitive than the 2200Hz used by Bolton *et al.* (2007) and decreases subjective analysis of results. Also, only a single practitioner was used for all manipulations and this limits the applicability of the findings to a general practitioner population. The low number of participants involved and the small number of data points collected reduces the statistical significance of their findings.

Conclusion: Anecdotally there is an assumption amongst practitioners using HVLA thrust manipulation that cavitation of cervical vertebrae occurs on the same side as the applicator hand during primary lever rotational HVLA thrusts and on the opposite side during primary lever side-bending HVLA thrusts. Also there is osteopathic professional opinion that success of these techniques is attributed to accuracy in targeting the dysfunctional joint only. However, the few studies so far investigating this phenomenon suggest that joints in the cervical spine can cavitate in a manner contrary to current biomechanical modeling and professional opinion, and that accuracy is more difficult to obtain than previously thought.

The research conducted by Reggars and Pollard (1995) and Bolton *et al.* (2007) has shown that cervical manipulation using HVLA techniques can result in cavitations that do not fit the current biomechanical models nor agree with clinical reasoning and previous anecdotal evidence. These findings suggest that several factors, including personal practitioner style and a patient's individual neck biomechanics may play a role in the side where cavitation sounds will be produced. Similarly Ross *et al.* (2004) have shown that targeting the dysfunctional segment with HVLA thrusts is not as accurate as once thought.

It is clear that these issues need to be addressed because practitioners commonly apply these techniques in clinical settings with possibly little understanding of the accuracy of the techniques they are employing. They also claim importance of the cavitation sound itself, although some researchers dispute the need for this for positive clinical outcomes to occur. Essentially, spinal HVLA manipulations have been passed down through the generations as a diverse assortment of techniques without an empirical base, and with little unity. Thus practitioners are teaching techniques based on anecdotal rather than evidence based findings to future generations. Further research into the phenomenon associated with HVLA thrust techniques will provide a unified theoretical model based on research that provides real answers to many of the grey areas still clouding these techniques.

1.8 Aims and Objectives of this Study

1) The primary aim of this project was to determine how consistently a single experienced practitioner could cavitate a target side of the cervical spine on different occasions. A practitioner's ability to cavitate a target joint has relevance to the industry because this is considered important in producing clinical outcomes for neck and back pain (Beffa & Mathews, 2004; Meal & Scott, 1986). This study will also attempt to determine if there is a relationship between the type of HVLA thrust and the side of cavitation within the cervical spine.

2) The second part of this dissertation is a pilot study which aims to determine what the general opinion of qualified New Zealand osteopaths is with regard to the side and site of cavitation in the cervical spine during HVLA thrust manipulations. This was achieved by showing osteopaths videos of rotational and side-bending cervical spine manipulations and asking them to indicate which side of the spine they believe cavitated during each manipulation.

Manipulation of the cervical spine: can a single practitioner consistently cavitate a target side using a rotational HVLA thrust?

2.1 Introduction

High velocity low amplitude (HVLA) thrusts are frequently used by osteopaths, chiropractors and physiotherapists in order to increase the range of motion of restricted joints of the spine (Greenman, 1996). As the name suggests they are techniques characterised by application of high-velocity/low-amplitude forces to joints that are typically exhibiting decreased range of motion. Some authors (Beffa & Mathews, 2004; Meal & Scott, 1986) suggest that in order to be successful (that is, increase joint mobility and ease pain) these thrusts need to be very accurate in their application, in other words, only cavitate the joint displaying reduced motion. In fact Meal and Scott (1986) went as far as saying that "...one of the skills of the manipulation is to be able to isolate the effect on the one joint that needs to be adjusted". However, Ross, Bereznick and McGill (2004) suggest that an HVLA thrust that cavitates many joints over various segments of the spine in the region of the joint whose mobility is reduced will be just as effective. This has tentatively been coined the "shotgun" approach. Recent research has suggested that there is no significant relationship between the cavitation and positive outcomes for patients (Cleland, *et al.*, 2007; Flynn *et al.*, 2003).

There are a number of theories that predict which zygapophyseal joint (left or right side) will cavitate during HVLA thrusts of the spine. For the most part these theories are based on current biomechanical models of the spine but also frequently draw upon historical and anecdotal evidence. Several authors have suggested that the side of cavitation is dependent upon the type of manipulation employed and the exact set-up of the thrust (Cassidy, Quon, LaFrance, & Yong-Hing, 1992; Grieve, 1988). Others theorise that location of the cavitation is dependent upon personal idiosyncrasies and the position of the practitioner's applicator hand (Good, 1992). These theories are yet to be validated by research.

One recent study has examined the accuracy of delivery of the HVLA thrust in both the lumbar and thoracic spine concluding that these manipulations can be quite inaccurate (Ross *et al.*, 2004). That is, the cavitations originate from more than just the target segment. Based on data recorded from 124 cavitations of the lumbar spine Ross *et al.* (2004) calculated that on average, the cavitation occurred 5.3cm (approximately one vertebral level) from the target joint, with a range of 0 to 14cm. They concluded that only 57 (46%) of these were deemed to be accurate (cavitated the target joint). They also performed 54 HVLA thrusts on the thoracic spine and elicited 54 cavitations of which 29 were deemed accurate (54%). The average error from the target in the thoracic spine was 3.5cm, with a range of 0 to 9cm. They also showed that in most cases individual procedures produced multiple cavitations. They did not investigate accuracy of cavitations in the cervical spine.

Only two attempts have thus far been made to verify the relationship between technique and side of cavitation in the cervical spine. In 1995 Reggars and Pollard performed an experiment designed to determine the relationship between the direction of head rotation and the side of joint cavitation using what they termed “diversified” rotary manipulations in the cervical spine. Using skin mounted microphones attached to the skin overlying the upper posterior neck they were able to capture cavitation sounds from the cervical zygapophyseal joints. Their research showed that when using a “diversified” rotary manipulation of the cervical spine there is more likely to be zygapophyseal joint cavitations ipsilateral to the direction of head rotation. In fact 94% of the cavitations were from the side of the neck opposite to the applicator hand. This is fairly conclusive evidence that the practitioner in that study consistently induced cavitations in a manner contrary to the clinical biomechanical reasoning. Anecdotal evidence and biomechanical theory suggests that rotational HVLA thrusts cavitate joints under the practitioner’s applicator hand (Cassidy *et al.*, 1992; Grieve, 1988; Maigne, 1972; Schafer & Faye, 1989).

In 2007, research in the field of cervical spine manipulations was conducted by Bolton, Moran and Standen (Bolton, Moran & Standen, 2007). The primary goal of their research was to determine whether there was a correlation between side of cavitation of the cervical spine and the type of technique used. With skin mounted microphones they captured cavitation sounds produced during rotational and side-

bending HVLA thrusts. They showed that a primary lever rotational HVLA thrust was most likely ($P=0.02$) to produce cavitations contralateral to the applicator hand while side-bending HVLA thrusts were no more likely ($p=0.350$) to produce cavitations contralateral to the applicator hand than ipsilateral to it.

Again, these findings are contrary to current opinion and clinical biomechanical models and also contradict what was taught in the Unitec undergraduate course in osteopathy (Course documents, 2004). It is commonly taught that rotational thrusts produce ipsilateral cavitations and that side-bending thrusts produce contralateral cavitations within the cervical spine. These teachings are probably based upon several published readings (Cassidy *et al.*, 1992; Grieve, 1988; Maigne, 1972; Schafer & Faye, 1989) but also seem to have their origins in anecdotal evidence. Personal communication with tutors within the osteopathic school showed that there was definitely some disagreement regarding side of cavitation during HVLA thrusts to the cervical spine. There appears to be no text that explicitly describes side of expected cavitations, although they do describe the predicted side of lock-up, and thus it could be concluded that the rules-of-thumb that are currently taught about cavitations are merely anecdotal and that there is no published evidence to support the current beliefs.

It is clear that current knowledge of the accuracy of cervical thrusts is indeed limited. If accuracy is deemed to be an important component of the therapeutic effect that is derived from the HVLA then there are obvious benefits in determining the side that these sounds emanate from during HVLA thrusts. This current study expands upon research conducted by Reggars and Pollard (1995) and Bolton *et al.* (2007) by investigating the side from which cavitation sounds are produced during a primary lever left rotational HVLA thrust to the cervical spine.

The primary purpose of this research is to determine how consistently an experienced osteopathic practitioner can cavitate a target side of the cervical spine over multiple HVLA thrusts.

The secondary purpose of this study was to determine which side (left or right) of the cervical spine produces a cavitation sound during a primary lever left rotation HVLA thrust of the cervical spine.

2.2 Methods

2.2.1 Subjects and Practitioner

Thirty-three subjects (17 Males and 16 females) who were all students in either the undergraduate or post-graduate programmes in osteopathy at Unitec, with a mean age of 25.3 years (SD 7.5; range: 18-40 years) participated in this study. All were asymptomatic for neck pain and did not report a history of cervical trauma, pain, or any known cervical spine instability.

Prior to any data collection all participants completed a medical history form based on the Australian Physiotherapy Association Clinical Guidelines of Pre-manipulative Procedures for the Cervical Spine (2000) which is intended to exclude people at risk of vertebrobasilar insufficiency. Exclusion from participation was based upon the absolute and relative contraindications (Gibbons & Tehan, 2000) as reported in the medical history questionnaire that all participants read, answered and signed (see appendix A). Additionally, a physical examination was performed upon all subjects by the researcher. The physical examination included a cervical spine nerve root compromise test, vertebrobasilar insufficiency (VBI) screening (Gibbons & Tehan, 2000) and bilateral blood pressure measurements. Positive VBI and upper cervical spine instability were grounds for exclusion.

All participants were presented with an information sheet and a consent form to sign prior to data collection. All participants were given the right to withdraw their data up until two weeks after the conclusion of the entire data gathering process was completed.

One single practitioner who is currently a member of Unitec staff, and who has over 20 years of experience practicing Osteopathy in both New Zealand and the United Kingdom, performed the same technique on all participants. This practitioner

regularly uses cervical spinal HVLA manipulation techniques as a treatment modality within the clinic setting.

This study was approved by the Unitec Research Ethics Committee.

2.2.2 Materials

The cavitation of the cervical joints was recorded with two microphones (MLT201 Cardio Microphones, ADInstruments Pty Ltd, Vic.) affixed to the postolateral aspect of each participant's neck (see Figure 2.1) over the region of the articular pillars at the level of C2. The cavitation wave forms were recorded by the digital data acquisition system (ML785 PowerLab8 SP, ADInstruments Pty Ltd, Vic.) which allows visual display of wave forms for statistical analysis on the Chart5 for Windows software (v5.01 ADInstruments Pty Ltd, Vic.). The system allows recording of multiple inputs at a maximum sampling frequency of 44,000Hz.

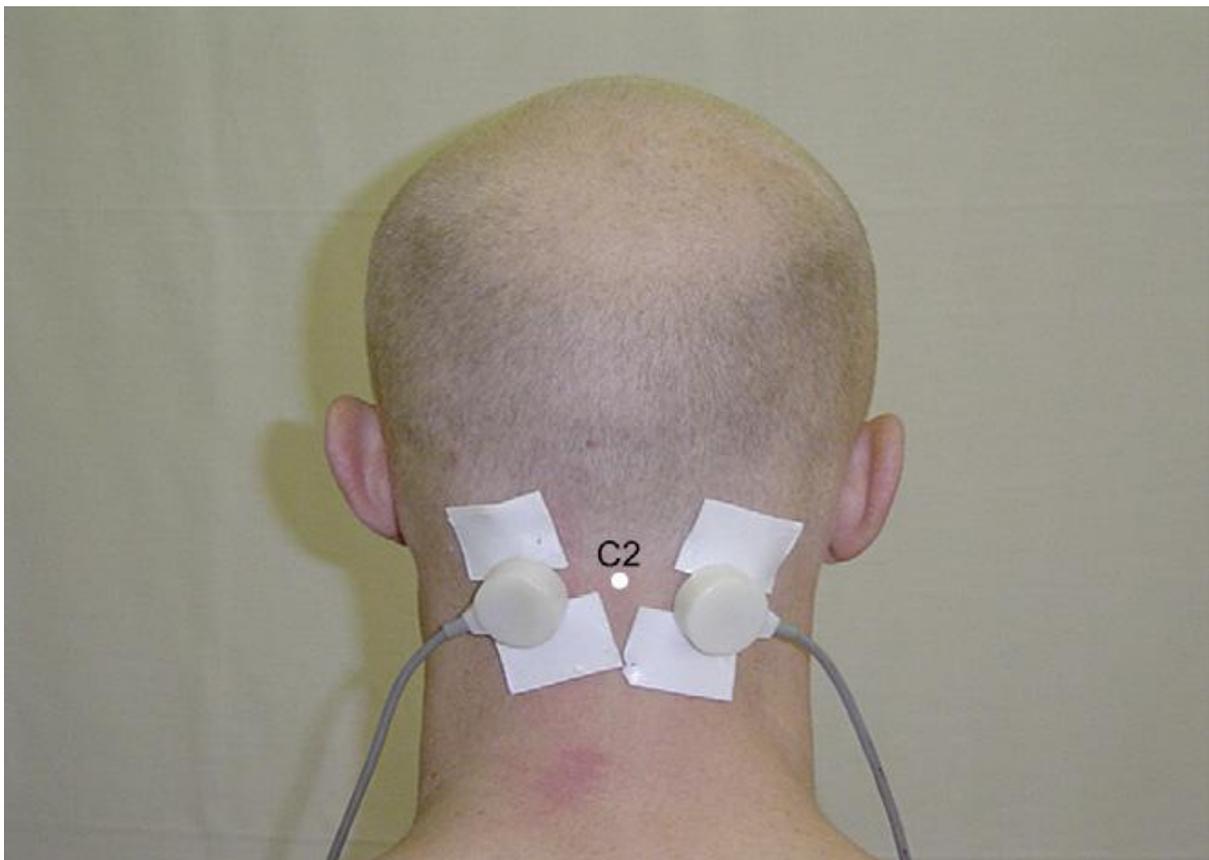


Figure 2.1: View of microphones mounted on the skin over the articular pillars of the second cervical segment (C2). (image used with permission from Bolton *et al.* 2007).

2.2.3 Procedure

The participants initially sat upright on the treatment table whilst the spinous process of C2 was located. Using this bony landmark the two microphones were then attached over the lateral masses of this segment using industrial strength double-sided adhesive tape.

After assuming a supine position the participants were then manipulated using a left rotational HVLA thrust applied to C3/4 (see Figure 2.2). Data collection for each participant was conducted on three separate occasions over a four week period. Thus there was at least one week period between consecutive thrusts.

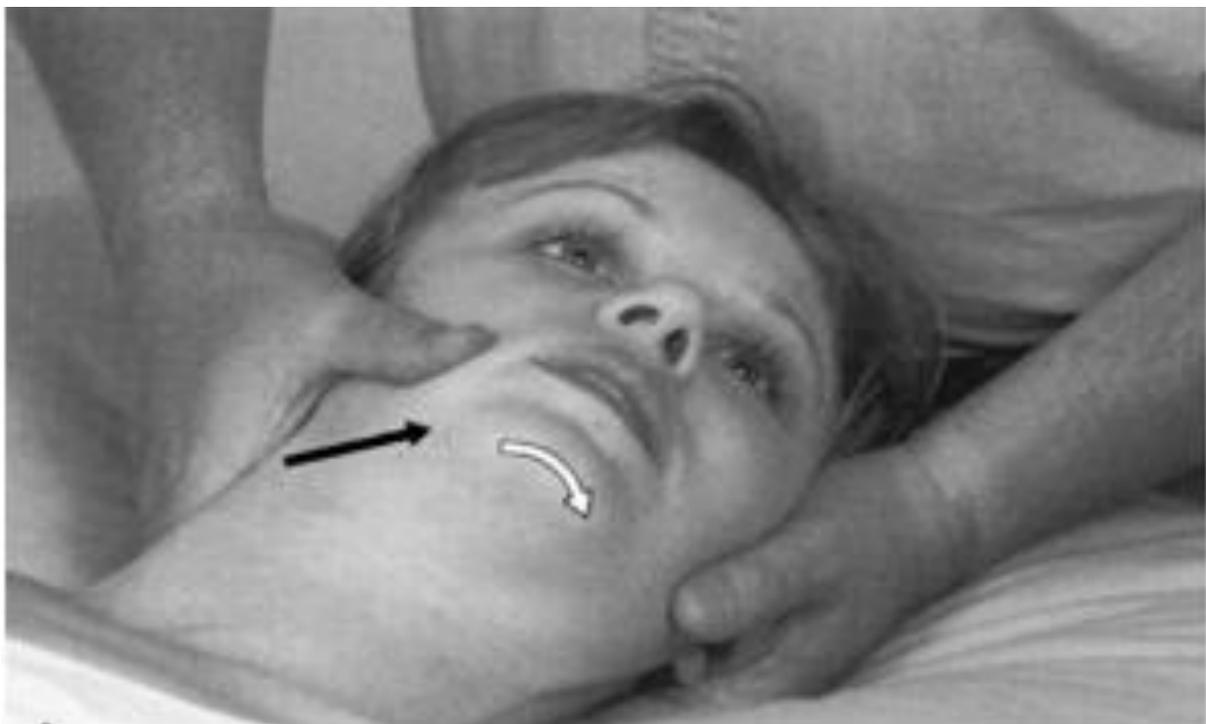


Figure 2.2: Primary lever left rotation HVLA manipulation of the cervical spine (after Gibbons and Tehan, 2000). Note: black arrow indicates the plane of the thrust; white arrow indicates direction of patient head movement. Reprinted from Gibbons and Tehan (2000) with permission from Elsevier.

The practitioner stood behind and slightly over the right shoulder of each of the participants. The lateral aspect of the proximal phalanx of the 2nd digit of the right hand (the applicator) contacted the postolateral aspect of the articular pillar at the level of the C3 (third cervical) facet joint. The practitioner's left hand (the stabiliser) contacted the head postolaterally on the opposite side to the applicator. The

manipulation consisted of lateral bending toward the applicator hand with rotation away. The practitioner applied the left rotational thrust as softly as possible and with limited force. If needed, several attempts, with a maximum of three, were made to elicit an audible cavitation of the facet joint that also displayed on the recording equipment as a visible waveform. After the manipulation the practitioner returned the head to the neutral position. The participants sat up and the microphones were removed.

For manipulation of the last 10 subjects the left tagged and right tagged microphones were switched to the opposite side of the spine to ensure that no phase error occurred within the recording equipment.

2.2.4 Data analysis

The sound wave data resulting from the manipulations was captured and displayed in a graphical format (see Figure 2.3). Deviations in the graph along the x-axis indicated that a cavitation had occurred. These deviations were also coincident with audible cavitation sounds. The cavitation was assessed to start at the first deviation from the x-axis and concluded when the signal returned to zero on this axis. The difference in amplitude in sound waves recorded between the left and right microphones was used to indicate which side of the cervical spine cavitated.

Because determining the side of cavitation from the recorded wave forms involves some operator judgement, it was necessary to conduct a blinded reliability evaluation test prior to data analysis. To do this, a randomly generated and anonymous sample of 20 waveform plots was presented to the researcher on two separate occasions. The randomisation was achieved using the online tools published at www.random.org. A Kappa score of 1.0 indicated perfect reliability for the judge over the two consecutive viewings that were held 10 minutes apart. With consistency of plot evaluation established the full set of wave form data was viewed and were characterised as belonging to one of several cavitation outcomes. These outcomes were classified as: ipsilateral cavitation, contralateral cavitation, bilateral cavitations, and unsuccessful attempts.

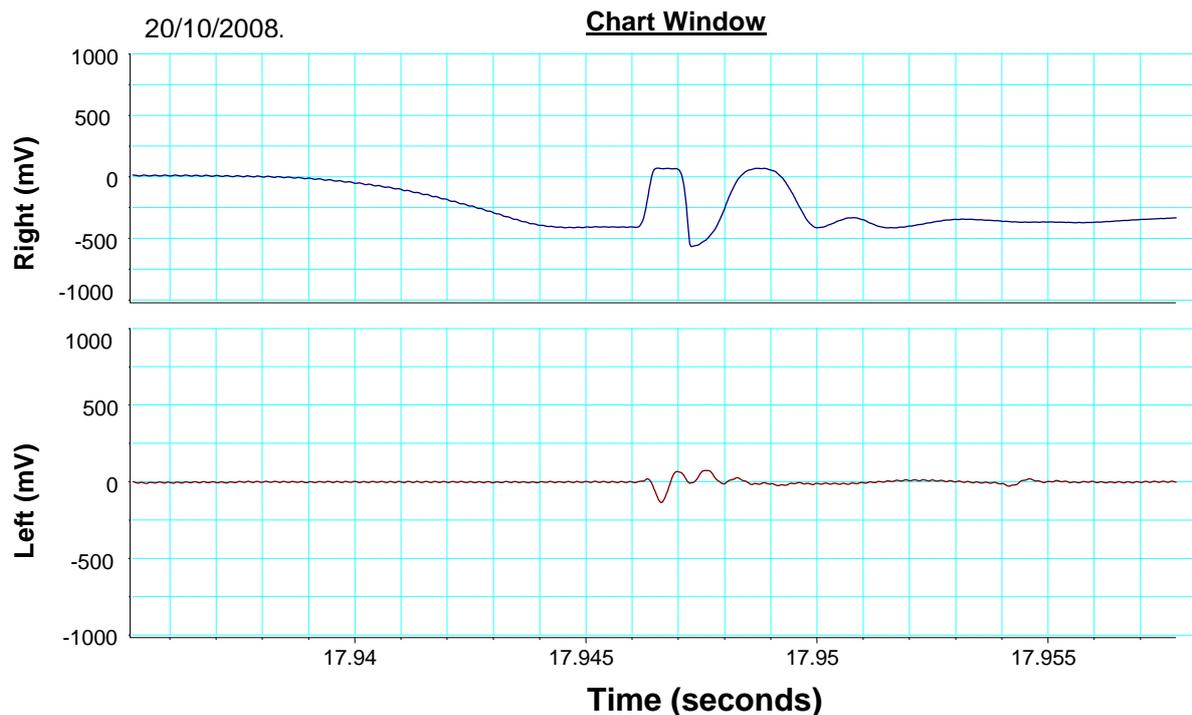


Figure 2.3: Typical wave form with large depolarization captured in right microphone indicating cavitation emanated from volunteer's right side z-joint. The assumption of this analysis is that the cavitation sound will be of largest magnitude in the microphone nearest the sound source.

2.2.5 Pilot study

A pilot study with two participants was conducted in order to trial the methodology of the study. Neither of these participants was used in the main study. The pilot study also provided an opportunity for the researcher to practise using the recording equipment and to trial the procedure for data collection.

In addition, the recording equipment was checked prior to the main study. This involved affixing the microphones to the under surface of a wooden desk at various distances ranging from 10cm to 3cm (the latter being the approximate distance the microphones are apart when attached to the cervical spine) and dropping a small ball bearing on to the top surface of the table from a height of 10cm. This procedure allowed the researcher to be certain that the microphones were detecting sound at equal levels.

2.3 Results

One osteopath and 33 volunteers were recruited by convenience sampling from the Department of Health Sciences at Unitec, New Zealand. Following screening for any

contraindications to manipulation the volunteers were subjected to the manipulative and recording protocol. The osteopath performed the same left rotational HVLA thrust to the C3/4 segment of each volunteer’s cervical spine on three separate occasions with at least one week period between manipulations. The cavitation sounds were recorded by sensitive microphones adhered to the skin over the lateral masses of C2. Several participants failed to attend some of the sessions so a total of 91 of a possible 99 manipulations were attempted and a total of 86 cavitation events were recorded (see Table 2.1).

Table 2.1: Total number and side of cavitations.

	Recorded cavitation side			
	Ipsilateral	Contralateral	Bilateral	Unsuccessful
Total successful events (86)	53 (61.6%)	11 (12.8%)	22 (25.6%)	5 (5.5%)*

*Unsuccessful events calculated from the total 91 attempted manipulations. (All other results calculated from the 86 successful HVLA manipulations).

In only five out of 91 occasions the practitioner was unsuccessful in producing cavitation sounds detectable by the equipment used. Approximately 62% of the cavitations recorded were purely ipsilateral, meaning that they came from facets on the same side as the applicator hand. These events were more than twice as likely to occur as any other cavitation event suggesting that there is a strong relationship between the right side cavitation and the primary lever left rotational HVLA thrust. Bilateral cavitations (both the ipsilateral and contralateral zygapophyseal joints) were the second most common events. Combining pure ipsilateral and bilateral cavitations (see Table 2.2) shows that this practitioner was successful at inducing cavitations on the ipsilateral side 75 times in 86 successful attempts (87.2%). Again, this result confirms a relationship between the left rotational thrust and the right sided cavitation. In approximately 13% of successful attempts pure contralateral cavitations resulted. Contralateral cavitations refer to sounds that are derived from zygapophyseal joints on the opposite side of the patient’s neck to the practitioner’s applicator hand.

When the bilateral cavitations are added to the total contralateral sounds (see Table 2.2) the sum total is 33. These events account for 38.4% of the total cavitation sounds that were recorded.

Table 2.2: Total number of combined ipsilateral and contralateral with bilateral events.

	Recorded cavitation side	
	Ipsilateral + bilateral	Contralateral + bilateral
Total successful events (86)	75 (87.2%)	33 (38.4%)

There were differences in the numbers of recorded cavitation sounds between sessions indicating that this practitioner is capable of having varied success (see Table 2.3). In week two the practitioner was able to produce purely ipsilateral cavitations approximately 78% of the time. However, in the weeks one and three pure ipsilateral cavitations occurred in less than 50% of attempts. In these weeks contralateral cavitations either occurred with ipsilateral cavitations (bilateral cavitations) or occurred alone accounting for up to 50% of attempts (compared to less than 20% in week two). However, in each of the three weeks, ipsilateral cavitations outnumber other events. In week one, 22 events contained ipsilateral cavitations while 12 were contralateral. In week two 30 manipulations contained ipsilateral cavitations while six were contralateral. In the final week, 23 were in favour of ipsilateral to only 15 contralateral events.

Table 2.3: Total and percent of type of cavitation recorded per week.

	Recorded cavitation side			
	Ipsilateral	Contralateral	Bilateral	Unsuccessful
Week 1 (30)	14 (46.7%)	4 (13.3%)	8 (26.7%)	4 (13.3%)
Week 2 (32)	25 (78.1%)	1 (3.1%)	5 (15.6%)	1 (3.1%)
Week 3 (29)	14 (48.3%)	6 (20.7%)	9 (31.0%)	0 (0.0%)

Multiple cavitations appear to be a common phenomenon associated with a singular HVLA thrust (see Table 2.4). Of the 86 manipulations that resulted in cavitations being recorded 42 contained multiple cavitations from ipsilateral, contralateral and bilateral joints. This accounted for almost 49% of the total recorded outcomes showing that for this practitioner multiple cavitations are indeed frequent results of cervical manipulations.

Table 2.4: Total number of singular and multiple cavitation events.

	Recorded cavitations				
	Single ipsilateral	Multi ipsilateral	Single contralateral	Multi contralateral	Bilateral
Total Events	38/86 (44.2%)	15/86 (17.4%)	6/86 (7.0%)	5/86 (5.8%)	22/86 (25.6%)

Of the total cavitations 38 contained a single cavitation sound that emanated from the ipsilateral side of the cervical spine. This accounted for 44.2% of the total outcomes. Fifteen further cavitations of purely ipsilateral origin were recorded, however, these contained more than one waveform and were considered to be multiple in their nature. Singular contralateral sounds were recorded in six of the 86 events and thus accounted for only 7% of the total. Only five multiple contralateral events were recorded. Sounds that emanated simultaneously from both the ipsilateral and contralateral zygapophyseal joints, which are thus deemed multiple

events by their very nature, accounted for 22 of the 86 recorded events. These events were the second most frequent event to be recorded and accounted for 25.6% of the total recorded sounds. As stated earlier, because these cavitation events contain ipsilateral sounds, they can be deemed as “successful”.

Consistency of side of cavitation was variable within individual participants between recording sessions (see Appendix 5). Of the 33 subjects that were enrolled only five consistently recorded cavitations on one side (ipsilateral) at all three sessions. None of the subjects had contralateral cavitations for all three manipulations, although one subject had two contralateral and one bilateral cavitation whilst another had two contralateral and one ipsilateral cavitation. Several subjects had an ipsilateral, a bilateral and a contralateral cavitation at the three sessions and therefore showed no consistency with time. One participant had bilateral cavitations at all three sessions.

2.4 Discussion

The primary aim of this study was to determine whether an experienced osteopath was able to consistently produce a cavitation on a targeted side of the cervical spine between sessions using a single commonly practiced HVLA technique. The results indicate that the osteopathic practitioner used in this study was able to cavitate the target zygapophyseal joints with reasonable consistency. Almost two thirds of thrusts produced purely ipsilateral cavitations. When ipsilateral and bilateral cavitations (where bilateral events contain ipsilateral cavitations also), are combined we see that the practitioner is able to cavitate the right side facets in almost nine out of ten thrusts.

This study also aimed to build upon other studies (Bolton *et al.*, 2007; Reggars & Pollard, 1995) to confirm whether or not there is a relationship between type of HVLA thrust performed and the side where cavitation occurs in the cervical spine. The results of this current study showed that cavitation was more likely to occur from zygapophyseal joints under the practitioner’s applicator hand using a left rotational HVLA thrust than the contralateral side which was the result that both Reggars and Pollard (1995) and Bolton *et al.* (2007) gained. This current study is limited however because only one practitioner was tested and more expansive studies are necessary to verify the repeatability of this finding.

Many clinicians claim to be very accurate with their thrusts and that they are able to isolate the cavitation to one joint. This current research was able to record singular and multiple cavitation events that occurred during each single manipulation, and therefore were able to, in part, determine the accuracy of the dynamic thrust performed by the practitioner used in this study. Accuracy in the context of this research is the cavitation of the facets ipsilateral to the applicator hand, and may or may not include multiple cavitations from that side. The definition of accuracy varies amongst researchers. According to Meal and Scott (1986), the skill of the manipulative therapist is in isolating the effect to the one joint that needs to be adjusted. However, previous research (Ross *et al.* 2004) indicates that multiple cavitations are common during manipulation of the spine, thus accuracy is limited, but can be defined by manipulation that includes the target joint, plus neighbouring joints also. This study shows that most of the time the side that did cavitate was the side that the practitioner intended to cavitate, *i.e.* the facets beneath the applicator hand. For a primary lever left rotational HVLA thrust the target facets are expected to lie beneath the applicator hand (Nicholas & Nicholas, 2007). These findings are in accordance with clinical biomechanical reasoning, conventional opinion and what is assumed to be the teachings at osteopathic institutions. However they are contrary to the findings of both Reggars and Pollard (1995) and Bolton *et al.* (2007).

Reggars and Pollard (1995) performed an experiment designed to determine the relationship between the direction of head rotation and the side of joint cavitation using rotational manipulations in the cervical spine. The joint cavitation sounds were analysed and results showed that zygapophyseal joint cavitation occurred on the ipsilateral side to head rotation (*i.e.* on the side opposite to the applicator hand) in 94% of the subjects (95% confidence interval). In subjects who had previous neck trauma (3 subjects), the cavitation occurred in what these researchers call a manner contralateral to the head rotation (*i.e.* on the same side as the practitioner's contact hand). There was a significantly lower rate of exclusively ipsilateral cavitations in subjects with previous neck injury ($p=0.023$). Their research suggests that when using a rotational HVLA manipulation of the cervical spine there is more likely to be zygapophyseal joint cavitations ipsilateral to the direction of head rotation (contralateral to the applicator hand).

Bolton *et al.* (2007) confirmed the work of Reggars and Pollard (1995) showing that cavitation was more likely to be contralateral to the contact hand using a rotational style HVLA. They also found that when using a side-bending thrust, cavitation was no more likely to occur contralaterally than ipsilaterally.

This current study did not evaluate the correlation between sides of cavitation with side-bending thrusts and so can make no comparison with their findings. However, it needs to be stated that again, at least anecdotally, their findings do not support the current hypothesis that side-bending thrusts are intended to produce cavitations contralateral to the practitioner's applicator hand. Their findings are however in agreement with those of Ross *et al.* (2004) who showed that accuracy of cavitations is rather limited and that for the most part joints other than the target are likely to cavitate during HVLA thrusts.

The research conducted by Ross *et al.* (2004) concentrated upon thoracic and lumbar vertebrae but not cervical. It would be tempting to assume that the accuracy in the cervical spine would be similar to the other regions of the spine so far investigated. Ross *et al.* (2004) found that thoracic manipulations were more accurate than lumbar and suggested that this was due to variation in the two techniques used in the two regions of the spine. They suggest that the long-lever lumbar techniques are not surprisingly less accurate than the thoracic techniques where the practitioners' applicators are close to the target segments. With this in mind it could be assumed that cervical thrusts would be at least as accurate as thoracic thrusts and more accurate than lumbar thrusts because the practitioners' hands are in close proximity to the target segment therefore the thrust through the joint should be more controlled. This conjecture needs to be backed with some solid clinical data and would be a good piece of research to conduct. This could be achieved with the use of more sophisticated hardware such as accelerometers that have the ability to determine both side and site of cavitation (Ross *et al.*, 2004).

During this study approximately half of the total successful HVLA thrusts performed produced more than one cavitation sound. This supports the claim made by Ross *et al.* (1995) that practitioners are likely to cavitate more than just the target joint.

Because so many multiple cavitations were recorded we could conclude that HVLA manipulation of the cervical spine, like the lumbar and thoracic spine (Ross *et al.*, 2004), is not very accurate. This study is unable to determine whether accuracy of the thrusts we performed affected clinical outcomes because all volunteers were asymptomatic. However, previous research has shown that manual techniques directed at dysfunctional segments were no more beneficial in reducing the patient's symptoms than those that cavitate random segments (Chiradejnant, Maher, Latimer, & Stepkovitch, 2003; Haas *et al.*, 2003). This suggests that accuracy is not necessarily the key to successful clinical outcomes.

There was marked variation in side of cavitation between and within individuals over the three sessions of this study. It is unclear whether variation is determined by individual spinal mechanics, practitioner idiosyncrasies or by some other factors. Reggars and Pollard (1995) report that patients with a previous history of cervical spine trauma displayed different outcomes to manipulations than those with no history of trauma. In fact those volunteers that did report a history of cervical trauma were more likely to have cavitations from zygapophyseal joints beneath the practitioners' applicator hand, which is the pattern that is expected. They did not report the extent of the trauma in any of the cases. This current study excluded all volunteers with history of cervical trauma or current neck pain, but without any knowledge of how major or minor trauma needs to be to produce changes in biomechanics, we cannot be completely sure that the differences we saw in cavitation phenomena was not due to prior traumas.

Analysis of data cannot rule out the possibility that biomechanically (anatomically) the subjects differ in ways that affect side of cavitation, or that side of cavitation is affected by previous HVLA induced cavitations. In this study, the observed data is consistent with the hypothesis that the practitioner can affect pure ipsilateral cavitations two thirds of the time, and combined ipsilateral and bilateral cavitations on nine out ten occasions and the different combinations observed for each subject can be fully explained by this hypothesis.

2.4.1 Study limitations

This study used skin mounted microphones to amplify cavitation sounds rather than use accelerometers that allow for more precise determination (Ross *et al.*, 2004) of the site of cavitation sounds. Thus this study was only able to report *side* of cavitation and not the *site* of cavitation. Future studies should be designed to identify the site of cavitations produced by cervical spinal manipulations.

With the use of sound amplification equipment to detect cavitation an assumption is made that the sound waves produced by the cavitation of the joints travels through tissues in such a manner that the largest magnitude does indeed come from the nearest joint. Care was taken to position the microphones as close as possible to the zygapophyseal joints on each side of the neck to minimise the chances of recording sounds from the opposite joints.

Only one practitioner was used to perform all HVLA thrusts for this research and so the results may simply reflect the unique qualities with which the practitioner used in this study administers his manipulations thus making any results impossible to generalise. This research shows that there is the possibility for great variation in generation of cavitation phenomenon between practitioners' even using techniques of similar description as shown by comparison of these results with those of previous studies (Bolton *et al.*, 2007; Reggars & Pollard, 1995). This in itself is valuable to know and it could be suggested that students graduating from osteopathic schools have their techniques analysed by use of skin mounted microphones, or accelerometers, so that they are made aware of their tendencies for cavitation side and site. This may be important to know considering some practitioners' suggest that accuracy of HVLA thrusts are paramount for clinical outcomes (Beffa & Mathews, 2004; Meal & Scott, 1986).

2.4.2 Recommendations for further research

Before more work is conducted upon determining the accuracy of cavitations in relation to the various HVLA thrusts it would be advisable to conduct studies to determine if cavitation is even important in providing clinical outcomes for neck pain. All participants in this current research were asymptomatic for neck pain so data

pertaining to clinical outcomes was not possible. However, recent research has shown that no relationship exists between the number of audible pops and improvements in pain and disability associated with either thoracic manipulations (Cleland, Flynn, Childs & Eberhart, 2007) or lumbar manipulations (Flynn, Fritz, Wainner, & Whitman, 2003). Future studies at Unitec could utilize cervical spine thrust procedures on symptomatic patients to determine whether clinical outcomes are associated with cervical manipulations.

It would be valuable to recruit those volunteers that had ipsilateral cavitations at all three sessions for further cervical manipulation research. It would be interesting to see if these participants continued to cavitate consistently with other techniques and with other practitioners. This could provide some valuable data on what role an individual's neck biomechanics or a practitioner's idiosyncrasies play in the cavitation phenomenon.

2.5 Conclusion

This research shows that the experienced osteopathic practitioner that performed all the manipulations for this study is capable of reasonable consistency in cavitating the ipsilateral (right side facet joint under the applicator hand) zygapophyseal joints of the cervical spine using a left rotational type HVLA thrust. When considering the findings of Bolton *et al.* (2007) and Reggars and Pollard (1995) this research also indicates that personal style may play a role in the cavitation phenomenon in cervical HVLA manipulations.

In this study there is a strong relationship between the type of thrust described in this study and the side of cavitation. This study showed that a left rotational HVLA thrust was more likely to produce a cavitation from the right side facet joints than left side facets which occurred during the studies of both Bolton *et al.* (2007) and Reggars and Pollard (1995). This result is consistent with the anecdotal evidence that rotational thrusts produce cavitations ipsilateral to the practitioner's applicator hand.

Results of this research also show that while success in targeting side of cavitation can occur frequently that cavitating a single target segment is limited, as evidenced by the production of multiple cavitations in a large proportion of the HVLA thrusts.

A web-based investigation into registered Osteopaths' understanding of cervical manipulations: a pilot study

3.1 Introduction

Spinal manipulations are a very popular treatment modality practised by osteopaths, chiropractors, physiotherapists and other manual therapists to treat a range of musculoskeletal problems. The manipulation requires an externally applied force perpendicular to a target spinal segment that creates rotational torque and deformation of surrounding tissues (Evans, 2009). The thrust carries the joint beyond its normal physiological limits, without compromising anatomical integrity, and is typically applied to increase range of motion of a dysfunctional motion segment.

There are several commonly practiced HVLA thrusts that osteopaths use for mobilising dysfunctional cervical spine segments. These are generally referred to as rotational thrusts and side-bending thrusts. Anecdotally they are thought to cavitate different sides of the cervical spine when applied. According to conventional opinion and clinical biomechanical reasoning it is thought that the rotational thrusts produce cavitation of the zygapophyseal joints on the same side as the practitioners applicator hand in what is known as an ipsilateral manner (Cassidy *et al.*, 1992; Grieve, 1988; Maigne, 1972; Nicholas & Nicholas, 2007; Schafer & Faye, 1989). For example, during a left rotational thrust the practitioner's hand contacts the right side of the patient's neck. The primary thrust is in a rotatory manner to the left and the cavitation is said to occur on the right side under the practitioner's hand. Conversely, application of side-bending thrusts is thought to cavitate facets on the opposite side of the cervical spine to the applicator hand in what is known as a contralateral manner (Nicholas & Nicholas, 2007).

The advantage of having two different thrusts is that theoretically the practitioner can be more accurate about delivery of the HVLA to the desired segment. Accuracy of

delivery is considered particularly important within the cervical spine because of the sensitive anatomical structures found there (Beffa & Mathews, 2004; Meal & Scott, 1986). There have been several reports of adverse reactions to cervical manipulations, including vertebral artery dissection (Ernst, 2002), that make accuracy of delivery, among other factors, particularly important.

Many clinicians claim to be very accurate with the delivery of their manipulative thrusts. However, there is debate regarding the necessity for accuracy of HVLA thrusts in producing positive clinical outcomes for patients (Beffa & Mathews, 2004; Cleland *et al.*, 2007; Flynn *et al.*, 2003; Meal & Scott, 1986;). Meal and Scott (1986) suggest that targeting only the joint that is diagnosed as being dysfunctional (possibly displaying reduced mobility), is important for successful treatment. However Ross, Bereznick and McGill (2004) suggest that a “shotgun” approach that cavitates multiple joints increases the chance of cavitating the target joint works equally as well.

Practitioners often take the cavitation sound and palpatory vibration in the applicator hand as evidence that the target segment has cavitated. However, there is research to suggest that there is little accuracy in many of the common manipulative techniques performed by manual therapists (Ross *et al.*, 2004).

Two recent research papers (Bolton *et al.*, 2007; Reggars & Pollard, 1995) both conclude that cavitation is most likely to occur in the facets opposite the applicator hand during rotational HVLA thrusts. These findings are contrary to clinical biomechanical reasoning, current conventional opinions (Cassidy *et al.*, 1992; Grieve, 1988; Maigne, 1972; Nicholas & Nicholas, 2007; Schafer & Faye, 1989) and what is taught at Unitec New Zealand. The results reported in Chapter Two of this dissertation are contrary to the findings of both Bolton *et al.* (2007) and Reggars and Pollard (1995) and indicated that a rotational style HVLA thrust was most likely to produce an ipsilateral cavitation *i.e.* a cavitation on the same side as the applicator hand.

The discrepancy between the results of Chapter Two and the findings of Bolton *et al.* (2007) and Reggars and Pollard (1995) and the theory being taught raises the

question; is there a unified belief amongst osteopaths regarding the side of cavitation during these common HVLA techniques?

Thus the aim of this research was to survey the attitudes and beliefs of osteopaths with respect to the side that cavitations occur during HVLA thrusts of the cervical spine.

3.2 Methods

The survey was delivered on the web site SurveyMonkey and contained fourteen questions (see Appendix 4). The first ten questions were designed to gather demographic information including age, gender, handedness, school of osteopathic training, number of years spent practicing and whether or not they have taught osteopathic technique. The last four questions were pertaining to videos that were specifically produced and designed to gather information regarding osteopaths' beliefs about the side that cavitation occurs during cervical manipulations.

The videos (view at <http://vimeo.com/user677232/videos>) were recorded using a Sony cybershot 6.0 megapixel camera. A single experienced practitioner performed all the HVLA thrusts recorded in the videos. The four cervical manipulations were: primary lever rotation right, primary lever rotation left, primary lever side-bending right and primary lever side-bending left. The two volunteers lay supine on the table. The osteopath positioned himself at the head of the table and performed all the manipulations from this point.

Descriptions of the HVLA thrusts that were performed are set out below:

For manipulating the typical cervical vertebrae (C3-C7) with a left rotational focus the set-up should go like this (adapted from Gibbons & Tehan, 2000):

1. With the patient supine the practitioner stands slightly over the right shoulder.
2. The practitioner's left hand contacts the patient's head just behind the left ear, on the occipital region and acts as a stabilizer.

3. The lateral aspect of the proximal phalanx of the 2nd digit of the right (applicator) hand contacts the right postolateral aspect of the articular pillar.
4. The neck is flexed down to the target segment before a small amount of local extension is produced at the target segment.
5. The practitioner rotates the patients head and neck left down to the target segment to provide facet lock.
6. The practitioner applies a high-velocity/low-amplitude left rotational thrust in the plane of the facet of the target joint to produce a cavitation sound.
7. The segment is retested for normal motion.

According to Nicholas and Nicholas (2007) this procedure will produce lock-up of the right side facets. For a right rotational thrust set-up is in the opposite manner to the above.

For manipulating the typical cervical vertebrae (C3-C7) with a right side-bending focus the set-up should go like this (adapted from Gibbons & Tehan, 2000):

1. With the patient supine the practitioner stands slightly over the right shoulder.
2. The practitioner's left hand contacts the patient's head just behind the left ear, on the occipital region and acts as a stabilizer.
3. The lateral aspect of the proximal phalanx of the 2nd digit of the right (applicator) hand contacts the right postolateral aspect of the articular pillar.
4. The neck is flexed down to the target segment before a small amount of local extension is produced at the target segment.
5. The practitioner side-bends the patients head and neck to the right until it localises at the target segment.
6. The head is rotated to the left down to the target segment so that facet lock is obtained.
7. The practitioner applies a high-velocity/low-amplitude right side-bending thrust in the plane of the facet of the target joint to produce a cavitation sound.
8. The segment is retested for normal motion.

According to Nicholas and Nicholas (2007) this procedure will produce lock-up of the left side facets. For a left side-bending thrust the set-up is in the opposite manner than above.

3.2.1 Data analysis

For statistical analysis all respondents were bracketed into five-year groups according to years since graduating. It was intended to correlate age, gender, handedness, school of training, whether they have taught osteopathic technique since graduating, and the number of cervical cavitations performed on a weekly basis with *correct* prediction of side of cavitation (according to anecdotal evidence) using Spearman’s correlation (which correlates nonparametric relationship between two variables), however, the small number of respondents prevented this analysis.

All data recorded on the SurveyMonkey web site is automatically plotted. The participant’s beliefs about side of cavitation addressed in the survey regarding the videos are presented in the results section.

3.3 Results

The survey was emailed to the 164 recipients who have their email addresses registered in the public domain. Respondents were asked to read and respond to the questionnaire and watch the four videos of cervical spine HVLA thrusts and indicate which side of the patients’ spine cavitated during each thrust. Of the 164 osteopaths that received the survey 42 answered and returned it. Twenty six of the respondents were male and 16 were female with an average age of 42.9 years (S.D.=10.9).

Table 3.1 Subject characteristics.

Sex	<i>n</i>	Mean Age (yrs)	Handedness		Years since graduating
			R	L	
Male	26	43.3	23	3	12.8
Female	16	42.1	15	1	13.9

The respondents represented 12 osteopathic schools from New Zealand, Australia and England (see Appendix 6). On average the 42 respondents have worked in the industry for 13 years (S.D.=10.27) and approximately 79% report working 41-50 weeks per year in the clinic setting.

When asked to estimate the average numbers of patients that receive cervical spine manipulations per week in their clinics the results amongst the respondents was highly variable. Twenty two of the respondents claim that they include cervical spine HVLA manipulations in somewhere between 0-30% of their treatments per week. Fourteen respondents include cervical manipulations on between 30-60% of their patients in an average week. Six of the osteopaths report that they perform cervical manipulations on greater than 60% of their patients. Of the latter, one respondent reported performing cervical HVLA thrusts on more than 90% of patients.

There seemed to be some general agreement among respondents regarding their understanding of the cavitation phenomenon presented in the four videos. There were also some vastly differing opinions. These are presented in the following sections.

3.3.1 Rotational HVLA

After viewing video one the majority of respondents (78%) support the belief that cavitation would occur on the side ipsilateral to the practitioner's applicator hand after a left rotation HVLA thrust (see Figure 3.1). In other words, they believe that the patient's right side facets would cavitate during this type of manipulation. Approximately 12% of respondents expressed that they "did not know" which facet would cavitate. Only a little over 7% of the respondents said that the left side facets would cavitate while less than 3% said that bilateral cavitations would occur.

When asked which side they thought was more likely to cavitate during a primary lever right rotation HVLA thrust around 70% of respondents felt that the left side facets were the target joints (see Figure 3.2). Around 15% of respondents felt that the right side should cavitate while about 5% felt that the cervical spine would

cavitate bilaterally. Almost 10% of the respondents in this survey “did not know” which side of the spine would cavitate during this type of thrust.

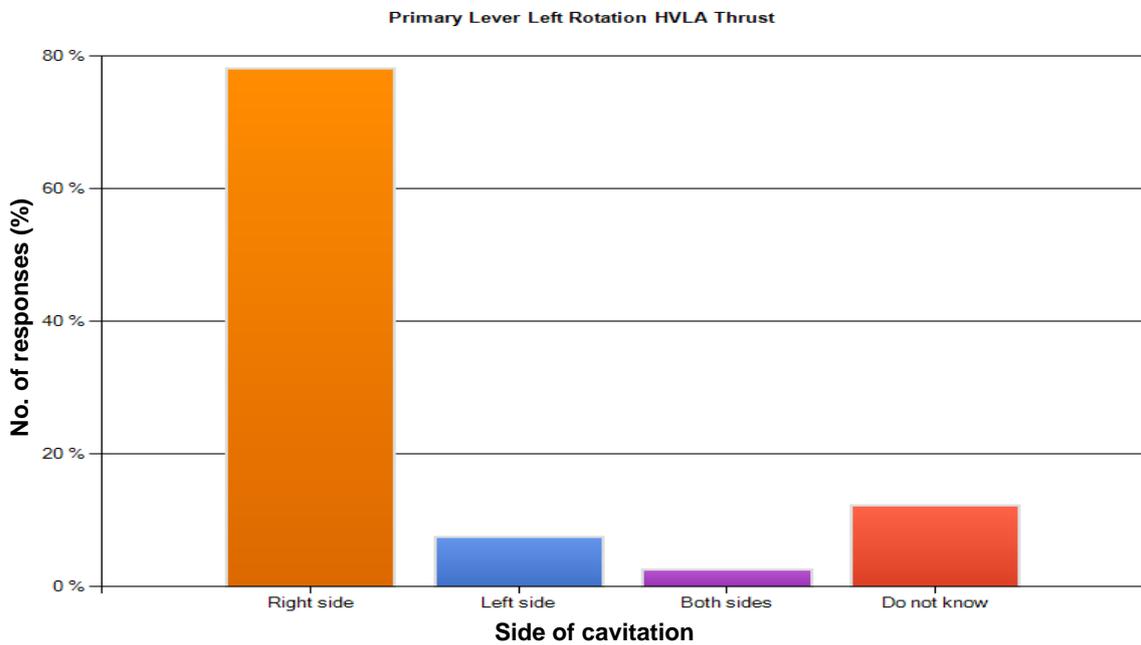


Figure 3.1: Graph showing respondents opinion regarding side of cavitation during primary lever left rotational HVLA thrust.

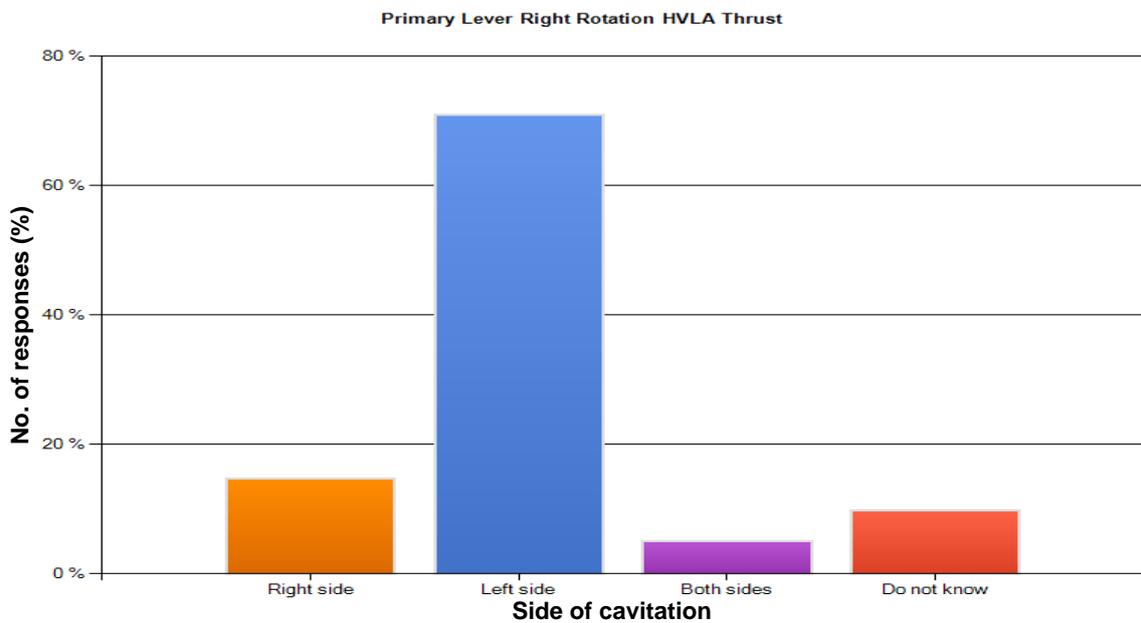


Figure 3.2: Graph showing respondents opinion regarding side of cavitation during primary lever right rotational HVLA thrust.

3.3.2 Side-bending HVLA

There was less agreement amongst the respondents surveyed regarding cavitation of facets during side-bending thrusts (see Figures 3.3 and 3.4) than for the rotational thrusts.

During a primary lever left side-bending thrust (see Figure 3.3) a little more than 60% of respondents believed that the right side would cavitate while around 30% reported it should be the left side. None of the respondents replied that the cavitation would be bilateral but almost 10% said that they “did not know” which facets would cavitate.

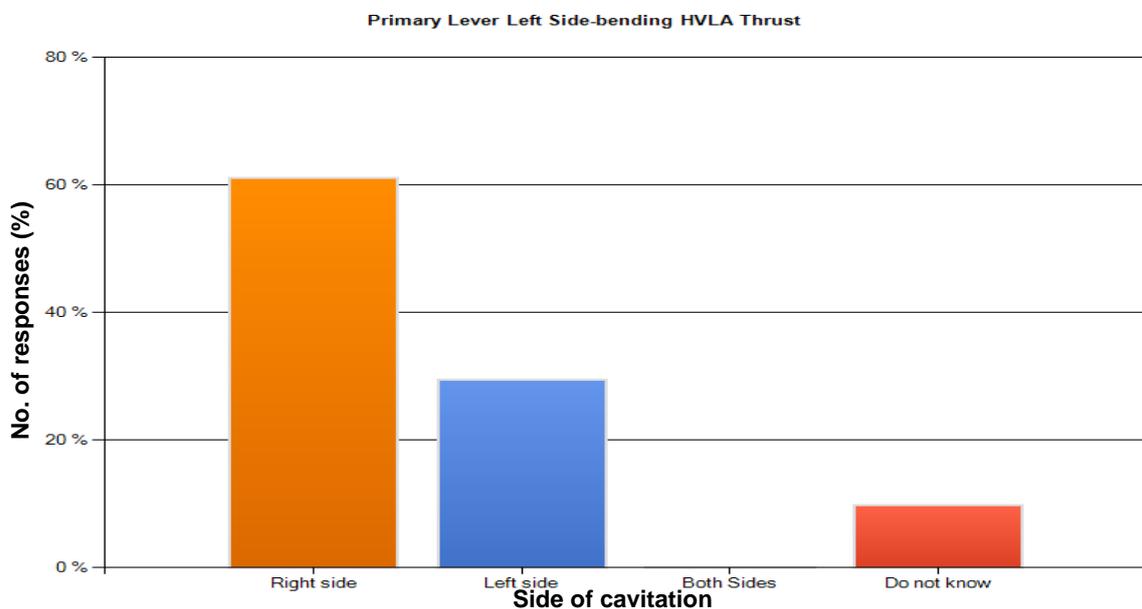


Figure 3.3: Graph showing respondents opinion regarding side of cavitation during primary lever left side-bending HVLA thrust.

The results for the primary lever right side-bending thrusts (see Figure 3.4) were similar to the above with about 60% again suggesting that the cavitations would be contralateral to the operator’s applicator hand, in other words left-sided cavitations. Just over 20% believed that the patient’s right side facets would cavitate during this type of thrust. Almost 15% of respondents did not know which side would cavitate while less than 3% said that bilateral cavitations would occur during a right side-bending thrust.

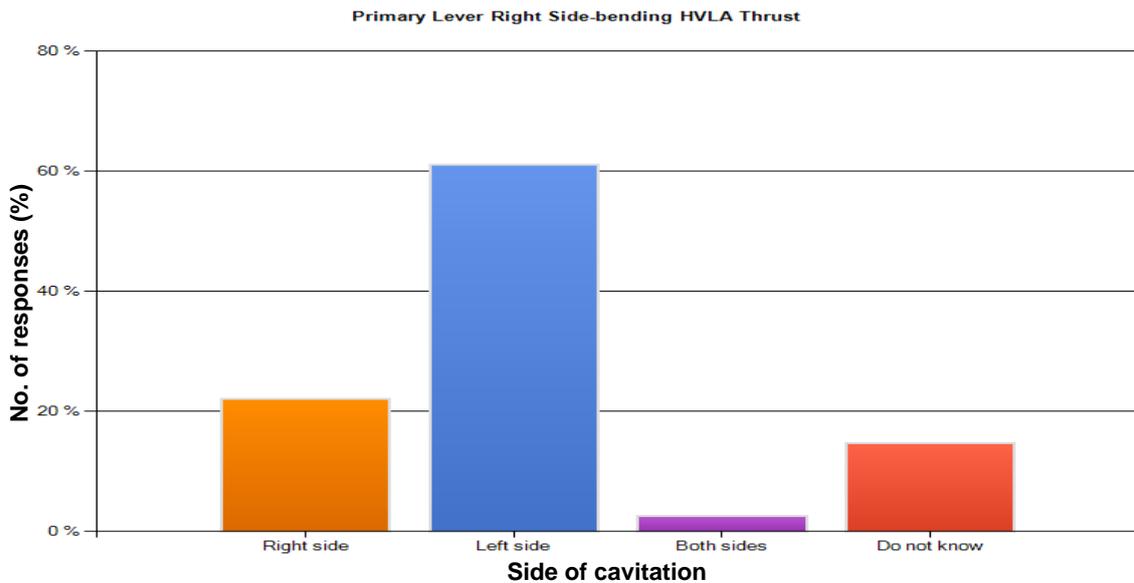


Figure 3.4: Graph showing respondents opinion regarding side of cavitation during primary lever right side-bending HVLA thrust.

Twenty one (50%) of the respondents that completed the survey reported that they have taught osteopathic techniques to students since themselves graduating. Of these, only nine reported the side of cavitation in all four videos in agreement with the predicted biomechanical models and conventional opinion. Thirteen of the 21 that have not taught osteopathic technique reported cavitations in the predicted manner. In other words those that have not taught osteopathic technique were more *accurate* than those that have in correctly predicting side of cavitation.

Four of the six respondents who answered that they “did not know” where cavitation would occur did so for all four thrusts shown in the videos. One of these was a recent graduate from Unitec New Zealand who has aided in teaching osteopathic technique. The three others were all graduates of the British College of Naturopathy and Osteopathy (BCNO) and all reported that they have taught osteopathic technique. One of these respondents reported that performing cervical HVLA techniques on approximately 90-100% of patients on a weekly basis.

Two osteopaths, who predicted side of cavitation (in all 4 situations) contrary to the predicted outcomes, reported that they perform cervical thrusts on more than 80% of their patients.

3.4 Discussion

The primary aim of this pilot study was to investigate whether there was agreement among osteopaths registered to practice in New Zealand regarding side of cavitation when using various commonly practiced HVLA thrusts to the C3/4 segment of the cervical spine. The results suggest that there is reasonable agreement overall, but that there is more agreement with regard to rotational thrusts than with side-bending thrusts.

Almost four fifths of participants agreed that during a primary lever left rotational HVLA thrust the patient's right cervical facets should cavitate. This outcome is in agreement with conventional opinion and anecdotal evidence and was the predicted outcome for this survey question (based on said opinion and anecdotal evidence). For the primary lever right rotation thrust there was less agreement with just under three quarters of respondents predicting that the left side facets should cavitate. There was less general agreement with regard to the side bending thrusts. Approximately only two thirds of respondents are in agreement over the side of cavitation for both the right and left thrusts.

The differences in belief may be reflective of the variations in training that each respondent received and could be related to the opinions of those that taught them osteopathic technique (further research required). It is possible that there is less emphasis placed on teaching of side-bending thrusts of the cervical spine and this could explain the differences in agreement (again, further research is required).

In spite of the low number of responses, two schools, Unitec New Zealand and British School of Osteopathy (BSO), showed considerable agreement in regard to side of cavitation which was in accordance with the predicted outcomes. This suggests that the theory taught at both these schools could be similar and may also be reflective of the fact that BSO graduates have taught osteopathic technique at Unitec in recent years.

Three of the four respondents from the British College of Osteopathy and Naturopathy reported that they "did not know" which side would cavitate during any

of the thrusts in any of the thrust situations. This could suggest that this school does not place huge emphasis upon the importance of side of cavitation when teaching these techniques (more research required).

This study does not specify why there is variation in the consensus between the two rotational thrusts. Given that there was strong agreement for a left rotational thrust producing cavitation of the right side facets in a predictable manner then it would be reasonable (biomechanically) to assume that a right rotational thrust would cavitate the left side facets similarly. This was not the case. There was some variation in agreement, but given the small response size, this result may not necessarily be significant and may only represent measurement error. The reasons for there being less agreement regarding the side-bending thrusts remains were not clarified by this research.

This survey supports previous reports that high velocity low amplitude manipulations of the cervical spine are commonly practiced by osteopaths (Greenman, 1996). The current respondents reportedly manipulate on average about one third of their patients' cervical spines in practice. This claim is made with caution of course because of the low number of responses. Either way this may or may not be representative of the population presenting with neck pain because not all osteopaths will use HVLA thrusts to correct neck dysfunction.

We can conclude that the use of cervical HVLA thrusts accounts for a considerable proportion of the treatment techniques (on 30% of patients presenting to osteopathic clinics) performed by the survey respondents. Given that so many cervical manipulations are performed, it is interesting that there is not total agreement regarding cavitation side, considering that it has been suggested by some that accuracy of delivery is important to clinical success (Beffa & Mathews, 2004; Meal & Scott, 1986).

It was not possible to produce correlation statistics for the other variables of this study due to low respondent numbers.

These findings will be discussed in light of findings from Chapter 2 in the final Discussion Chapter (Chapter 4).

3.4.1 Study limitations

This study was limited by the low number of respondents. For more definite patterns to come from research of this manner the response rate needs to be a lot higher. However, this research was designed to be a pilot study and further study is obviously necessary before conclusions can be made.

There is a possibility that the angle from which the videos were taken may have affected the ability of the practitioners to determine the primary thrust. Videos that captured the HVLA procedures from directly above the patient may be more useful or perhaps displaying a video from more than one angle may solve this potential problem.

3.5 Conclusion

This pilot study indicates that there is reasonable agreement amongst respondents regarding the side of cavitation produced by cervical spine HVLA manipulations. There is greater agreement regarding rotational style thrusts than side-bending thrusts. The reasons for this are unknown. For the most part, these results agree with the anecdotal evidence for side of cavitation produced by the various cervical spine HVLA thrusts commonly in use.

General Discussion

Spinal high velocity low amplitude (HVLA) thrusts are commonly used manipulative techniques (DiGiovanna *et al.*, 2005). They are often applied to alleviate identifiable restrictions of the spine (and other joints) by application of a fast, controlled thrust aimed typically to restore normal joint motion. The technique is often accompanied by an audible cracking sound, known as a cavitation. The generally accepted theory is that the sound relates to cavitation of intra-articular gases (Meal & Scott, 1986; Mierau *et al.*, 1988; Sandoz, 1969; Unsworth *et al.*, 1971). Some authors suggest that the cavitation sound is essential for the success of the treatment (Lewit, 1978; Sandoz, 1976) while others place no significance upon it (Cleland, *et al.*, 2007; DiGiovanna *et al.*, 2005; Flynn *et al.*, 2003; Grieve, 1988).

Furthermore, several authors suggest that accuracy (cavitating only the *dysfunctional* spinal segment) of the thrust is essential for successful clinical outcomes (Meal & Scott, 1986). However, recent research suggests that the accuracy of HVLA thrusts in both the thoracic and lumbar spine may be limited (Ross *et al.*, 2004) and that there is no significant relationship between the cavitation and positive outcomes for patients (Cleland, *et al.*, 2007; Flynn *et al.*, 2003). Currently there are only a few studies which examine the accuracy of cervical HVLA manipulations. Two recent studies (Bolton *et al.*, 2007; Reggars & Pollard, 1995) have shown that cavitations in the neck can occur in ways that are contrary to popular opinion (Chapter Three).

Anecdotal evidence and clinical biomechanical principles suggest that HVLA thrust manipulations of the cervical spine would cavitate the zygapophyseal joints as follows; rotational thrusts will produce cavitation of joints on the same side as the practitioner's applicator hand and side-bending thrusts will produce cavitations on the opposite side of the neck to the practitioner's applicator hand (Cassidy, Quon *et al.*, 1992; Grieve, 1988; Maigne, 1972; Schafer & Faye, 1989). A survey study

(reported in Chapter Three) confirms that these theories are widely accepted by New Zealand registered osteopaths. This survey showed that there was substantial agreement amongst respondents that a left rotational HVLA thrust should cavitate the right side facets of a patient's cervical spine. There was similar agreement that right rotational thrusts will cavitate the left side facets. Approximately two thirds of respondents agree on side of cavitation associated with both left and right side-bending thrusts.

In Chapter Two of this dissertation we discovered that this experienced practitioner could consistently cavitate the targeted side of the cervical spine using a single left rotation HVLA thrust technique. The results show that under these experimental conditions, this practitioner was able to cavitate zygapophyseal joints on the target side of the cervical spine, ipsilateral to the applicator hand, in almost nine out of ten occasions. Thus, this study also confirmed that a left rotational HVLA thrust is more likely to cavitate the right side facets of the cervical spine. This finding is in agreement with the current anecdotal evidence and clinical biomechanical principles but is in contrast to the findings of Bolton *et al.* (2007) and Reggars and Pollard (1995). Surprisingly, these latter studies provide evidence contrary to expectations, suggesting that the practitioners they used were more likely to cavitate facet joints opposite the applicator hand when performing rotational HVLA thrusts on the cervical spine. Their results are contradictory to the findings reported in this manipulation study (Chapter Two) and disagree with the opinions of the New Zealand registered osteopaths who responded to the survey reported here (Chapter Three). In contrast, the findings of this current study are in agreement with the *accepted theories*.

In this current study (Chapter Two), of the total cavitations that were recorded just under fifty percent were singular cavitations from the right side facets. This indicates that in theory this practitioner could be capable of segment specificity, but this cannot be confirmed with the recording equipment used. Additionally, this practitioner was able to cavitate the right side facets, albeit inclusive of multiple cavitations from single thrusts, in a considerable fashion, indicating that accuracy in cavitating the targeted *side* is possible.

The many multiple cavitations recorded in this research suggest that in actual fact segment specificity is more difficult to achieve than previously thought. This agrees

with research by Ross *et al.* (2004) who showed that accuracy of manipulation in both the thoracic and lumbar spines is limited.

The practitioner who performed all the thrusts reported in Chapter Two was evidently capable of reasonable variation in the side of cavitation whilst performing the same thrust on multiple occasions. Cavitations from joints contralateral to the applicator hand were recorded in two fifths of manipulations. This finding in conjunction with the findings of Bolton *et al.* (2007) and Reggars and Pollard (1995) indicate that there can be considerable variation in the side of cavitation obtained by these procedures, described as similar thrusts, amongst practitioners. There is reason to believe that this is due to personal style and idiosyncrasies developed over time (Good, 1992) and the effect of a patient's individual neck biomechanics (Reggars & Pollard, 1995).

Conclusion

Currently, there is conflicting evidence regarding the side of cavitations occurring in the cervical spine resulting from rotational HVLA thrusts. This is not helped by the fact that only a modest amount of research has thus far been conducted on the techniques readily used by osteopaths, chiropractors and physiotherapists alike. General opinion, anecdotal evidence and biomechanical principles currently explain the cavitation phenomenon but more clinical evidence needs to be produced. Future research could investigate methods for clarifying the role that the individual practitioner, the techniques themselves and other factors play in the cavitation phenomenon seen in this research. Future study should verify the significance of the cavitation phenomenon on patient outcomes.

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Appendices

Appendix 1: Subject Information Sheet



An investigation into the consistency of side of joint cavitation associated with a primary lever rotational HVLA manipulation of the cervical spine.

Information Sheet

You are invited to take part in a research project being undertaken as a part of the Masters of Osteopathy Degree. The research involves investigating the consistency of side of cavitation of the cervical spine using a primary lever rotational HVLA thrust. This information sheet is designed to provide information regarding the nature of the research, and what will happen should you decide to participate. We currently need people who are asymptomatic for neck pain aged between 18 to 40 years. Unfortunately, if you have neck pain or diseases such as cancer or obvious medical conditions you cannot be included.

The Researchers

The researcher is Nic Naysmith, with supervision from Dr Craig Hilton Associate Professor Clive Standen, and Rob Moran. Graeme Saxby will perform all the manipulations. Graeme has a BSc Hons. in Human Biology and a Diploma in Osteopathy from the British School of Osteopathy. He has 17 years experience as an osteopath and is registered to practice in both New Zealand and the U.K. He currently teaches osteopathic technique and tutors in the Unitec Osteopathic Clinic.

What will participation involve?

Attending a brief initial appointment to ensure that you are eligible for this project. Discussing the procedures, and being informed of what happens in the research. After you have had time to consider participating you will be invited to sign the consent form. Being available for three weeks during the trial, involving one 10 minute contact sessions at Unitec each week. The study process will last for 3 weeks and is fairly simple. At each session you will be fitted with recording equipment to the back of your

neck, and then the practitioner will perform one rapid, gentle rotational lever HVLA to your cervical spine.

What is the nature of the intervention and outcome measure?

The intervention is a commonly used osteopathic technique employed to decrease pain and increase range of motion of a restricted cervical spine segment. The technique has been found very effective by manual therapists all over the world, however only limited research on the side and site of cavitations associated with various HVLA techniques has been done yet.

For this interventional study the outcome measures will be the side of cavitation during each thrust.

Potential Risks to Research Participants

Possible adverse events from cervical spine manipulation are the main ethical issues in this study, however, these are very uncommon (in order of between 1/400,000 and 1/10,000,000 manipulations (Coulter et al 1996)). Recent research investigating neck manipulation still does not provide conclusive evidence of any risk of adverse events (Rothwell, Bondy & Williams 2001). An extract from the Journal of Bodywork and Movement Therapies states that while there are potential risks from the use of HVLA thrust techniques (manipulation), the risks are low providing the patients are thoroughly assessed and treatment is given by appropriately trained practitioners.

To further minimise the chance of these events occurring several measures are in place for this research: firstly, appropriate pre-treatment case history and full neck examination will be performed. This will include special tests to rule out preconditions for adverse events. Questions regarding medical history will be made, including a family history of disease and a systemic enquiry including questioning on cardiovascular and respiratory health, history of illness, accidents and surgery, current or long term medication and alcohol/tobacco use. Secondly, the manipulations will be performed by a very experienced osteopathic practitioner with a long and successful career in this industry both in New Zealand and abroad.

The Health and Disabilities Commissioner considers the risks of adverse events from these types of manipulations to be extremely low. Thus osteopaths, chiropractors and

physiotherapists regularly and confidently perform these manipulations with successful clinical outcomes.

Confidentiality

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

All consent forms and completed questionnaires will be seen only by the researchers.

All hard copies and information will be stored in a locked file in a secured room. Only the researchers will have access to this file.

Only anonymous data will be presented in reports related to this research.

Electronic files will be protected with an electronic password.

Information gathered during this research will be held for 5 years before being destroyed.

You have the right not to participate, or to withdraw from this research project within two weeks of your final data collection. This can be done by contacting Nic Naysmith or Dr Craig Hilton by telephone or email, or by verbally informing either of them upon contact that you no longer wish to participate.

A final report containing the information from this study will be available at the Unitec Main Library upon completion.

Information and Concerns

For further information or concerns please contact the researchers by phone or email:

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Appendix 2: Subject Medical History Questionnaire



Medical History Questionnaire

Name:

Contact phone no:

Absolute contraindications to HVLA manipulative techniques (Gibbons & Tehan, 2000):

Have you ever experienced any of the following conditions or pathologies? (please tick).

Bone – any pathology that has lead to significant bone weakening:

tumour, e.g. metastatic deposits

infection, e.g. tuberculosis

metabolic, e.g. osteomalacia

congenital, e.g. dysplasia's

iatrogenic, e.g. long-term corticosteroid medication

inflammation, e.g. rheumatoid arthritis

traumatic, e.g. fracture

Neurological

cervical myelopathy

cord compression

cauda equina compression

nerve root compression with increasing neurological deficit

Vascular

diagnosed vertebrobasilar insufficiency

aortic aneurysm

bleeding diastheses, e.g. haemophilia

Instability

incompetence of the odontoid process

incompetence of the transverse atlantal ligament

Relative contraindications to HVLA manipulative techniques (Gibbons & Tehan, 2000):

adverse reactions to previous manual therapy

disc herniation or proplase

inflammatory arthritides

pregnancy
women post-partum
spondylolysis
spondylolisthesis
osteoporosis
advanced degenerative joint disease and spondylosis
arterial calcification
non active Schurmann's disease
abdominal hernia
psychological dependence on HVLA technique

The signs and symptoms of vertebrobasilar insufficiency (VBI) and upper cervical instability.

Have you ever experienced any of the following? (please tick)

Signs of VBI (Gibbons & Tehan, 2000)

nystagmus (abnormal eye movements consisting of repetitive jerks)
gait disturbances
Horner's syndrome (consists of drooping upper eyelid, constricted pupil and endophthalmus-impression that eye is sunk in compared to opposite eye)

Symptoms VBI (Gibbons & Tehan, 2000)

dizziness/vertigo
diplopia
tinnitus
nausea
drop attacks
dysarthria or disruption in speech
dysphagia or difficulty swallowing
occipital headaches
facial paraesthesia
tingling in upper limbs
blurred vision
fainting/blackouts

Signs and symptoms of upper cervical instability (Gibbons & Tehan, 2000):

overt loss of balance in relation to head movements
facial lip paraesthesia, reproduced by passive and active neck movements

bilateral or quadrilateral limb paraesthesia, either constant or reproduced by neck movements

nystagmus produced by active and passive neck movements

Signature:

Date:

Findings of physical examination (practitioner to fill in):

Appendix 3: Subject Consent Form



An investigation into the consistency of side of joint cavitation associated with a primary lever rotational HVLA manipulation of the cervical spine.

Consent Form

This research is being undertaken by Nicholas Naysmith from Unitec New Zealand, with supervision from Dr Craig Hilton, Associate Professor Clive Standen and Rob Moran.

Name of Participant:.....

I have seen the Information Sheet dated / /2008 for people taking part in the research project that is investigating the consistency of side of cavitation of the cervical spine. I have had the opportunity to read the contents of the information sheet and to discuss the project with the project team, and I am satisfied with the explanations I have been given. I agree that raw data from this research project can be held for 5 years for the purposes of future analysis and research. I understand that taking part in this project is voluntary (my choice) and that I may withdraw from the project if necessary.

I understand that I can withdraw from the project at any time up until a fortnight following the termination of the trial, for any reason.

I understand that my participation in this project is confidential and that no material from which I might be identified will be used in any reports on this project.

swl 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:

Nicholas Naysmith

Master of Osteopathy student

Can be contacted:

40 Fontenoy St, Mt Albert, Auckland

(09) 845 6058

(021) 492 060

nic.naysmith@gmail.com

Signature.....participant(date)

Project explained by.....

Signature.....(date)

This study has been approved by the Unitec Research Ethics Committee from Sept 1st 2008 to Feb 28th 2009. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the Secretary (ph: 09 815-4321 ext 8041). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

Appendix 4: Copy of Survey



An investigation into the consistency of side of joint cavitation associated with HVLA manipulation of the cervical spine.

1. In which year were you born?

2. Gender?

- Male
- Female

3. Are you left or right handed?

- L
- R

4. Which osteopathic school did you train at?

5. In which year did you graduate with your osteopathic degree?

6. Since graduating, how many years have you worked at least part time as an osteopath?

7. Have you ever taught osteopathic technique?

- Yes
- No

8. If your answer to Q7 was yes, did you teach technique in the classroom, as a tutor in clinic, or both?

- Classroom
- Clinic
- Both

9. In a typical week approximately what proportion of your patients receive cervical spine thrust manipulations (HVLA, HVT, HVA)?

- 0-10%
- 10-20%
- 20-30%
- 30-40%
- 40-50%
- 50-60%
- 60-70%
- 70-80%
- 80-90%
- 90-100%

10. In 2008, how many weeks did you work in an osteopathic practice?

11. Please click on the following link to access videos:

<http://vimeo.com/user677232/videos>

Once the video link is open click on and watch the four videos of cervical spine manipulations.

After viewing Video One, please make your best guess as to whether you believe the patient's right facet, left facet or both facets would typically cavitate during this type of thrust. Alternatively, please indicate if you do not know which facets cavitated.

- Right side
- Left side
- Both sides
- Do not know

12. After viewing Video Two, please make your best guess as to whether you believe the patient's right facet, left facet or both facets would typically cavitate during this type of thrust. Alternatively, please indicate if you do not know which facets cavitated.

- Right side
- Left side
- Both sides
- Do not know

13. After viewing Video Three, please make your best guess as to whether you believe the patient's right facet, left facet or both facets would typically cavitate during this type of thrust. Alternatively, please indicate if you do not know which facets cavitated.

- Right side
- Left side
- Both Sides
- Do not know

14. After viewing Video Four, please make your best guess as to whether you believe the patient's right facet, left facet or both facets would typically cavitate during this type of thrust. Alternatively, please indicate if you do not know which facets cavitated.

- Right side
- Left side
- Both sides
- Do not know

Appendix 5: Table shows side of cavitation for each volunteer during each manipulation. Also shows calculation of proportion of cavitation showing actual versus chance occurrence of sounds. Calculations are based on the hypothesis that the practitioner cavitates ipsilaterally 61.6%, contralaterally 12.8%, bilaterally 25.6% and unsuccessfully 5.5% of attempts.

<u>actual</u>	<u>chance</u>	<u>Volunteer</u>	<u>week 1</u>	<u>week 2</u>	<u>week3</u>
18.52%	8.20%	1	ipsilateral	ipsilateral	bilateral
18.52%	19.75%	2	ipsilateral	ipsilateral	ipsilateral
18.52%	19.75%	3	ipsilateral	ipsilateral	ipsilateral
		4	no show	ipsilateral	bilateral
7.41%	8.20%	5	bilateral	ipsilateral	ipsilateral
		6	unsuccessful	ipsilateral	no show
7.41%	3.40%	7	bilateral	ipsilateral	bilateral
3.70%	1.41%	8	bilateral	bilateral	bilateral
7.41%	8.20%	9	bilateral	ipsilateral	ipsilateral
3.70%	8.20%	10	ipsilateral	bilateral	ipsilateral
		11	no show	ipsilateral	ipsilateral
18.52%	8.20%	12	ipsilateral	ipsilateral	bilateral
18.52%	8.20%	13	ipsilateral	ipsilateral	bilateral
18.52%	8.20%	14	ipsilateral	ipsilateral	bilateral
3.70%	1.70%	15	contralateral	ipsilateral	bilateral
3.70%	4.10%	16	ipsilateral	contralateral	ipsilateral
7.41%	1.70%	17	bilateral	ipsilateral	contralateral
		18	no show	ipsilateral	ipsilateral
3.70%	1.70%	19	ipsilateral	bilateral	contralateral
18.52%	19.75%	20	ipsilateral	ipsilateral	ipsilateral
		21	contralateral	no show	no show
7.41%	1.86%	22	unsuccessful	ipsilateral	ipsilateral
3.70%	0.77%	23	bilateral	unsuccessful	ipsilateral
3.70%	1.86%	24	unsuccessful	ipsilateral	ipsilateral
		25	bilateral	ipsilateral	no show
18.52%	19.75%	26	ipsilateral	ipsilateral	ipsilateral
3.70%	0.85%	27	contralateral	ipsilateral	contralateral
3.70%	0.39%	28	unsuccessful	ipsilateral	contralateral
		29	ipsilateral	bilateral	no show
3.70%	0.35%	30	contralateral	bilateral	contralateral
3.70%	1.70%	31	bilateral	ipsilateral	contralateral
18.52%	8.20%	32	ipsilateral	ipsilateral	bilateral
18.52%	19.75%	33	ipsilateral	ipsilateral	ipsilateral

Appendix 6: Demographic data attained from survey

<u>Age</u>	<u>Gender</u>	<u>Handedness</u>	<u>School</u>	<u>Graduated</u>	<u>Taught</u>	<u>Manips.</u>	<u>Wks/yr</u>	<u>L Rotn.</u>	<u>R Rotn.</u>	<u>L S.B.</u>	<u>R S.B.</u>
36	M	R	BCNO	1998	Y	21-30%	41-50	DNN	DNN	DNN	DNN
49	F	R	BSO	1990	N	11-20%	41-50	R	L	R	L
35	M	R	Unitec	2007	N	11-20%	41-50	R	L	R	L
73	M	R	BSO	1964	Y	11-20%	41-50	DNN	B	R	DNN
30	M	R	Unitec	2004	N	21-30%	31-40	R	L	R	L
55	F	R	BSO	1976	Y	51-60%	41-50	R	L	R	L
52	M	R	ESO	1989	N	21-30%	41-50	L	B	R	L
53	M	R	OCNZ	1998	N	0-10%	41-50	R	L	R	L
31	M	R	Unitec	2007	Y	31-40%	41-50	R	L	R	L
30	F	R	ESO	2003	N	51-60%	31-40	B	R	L	R
50	M	R	BSO	1983	N	0-10%	31-40	R	L	L	DNN
48	M	L	BSO	1992	N	51-60%	41-50	R	L	L	R
32	F	R	Unitec	2007	N	0-10%	41-50	R	L	R	L
34	F	R	Unitec	2007	N	0-10%	41-50	R	L	R	L
39	M	R	Unitec	2003	Y	71-80%	41-50	R	L	R	L
42	F	R	BSO	1988	N	51-60%	41-50	R	L	R	L
48	F	R	RMIT	1989	Y	41-50%	41-50	L	R	L	L
38	M	R	Vic Uni	2006	Y	0-10%	41-50	R	L	L	R
27	M	R	Vic Uni	2006	N	21-30%	41-50	R	L	L	L
39	M	R	ESO	1992	Y	51-60%	41-50	R	L	L	R
37	M	R	BSO	2004	N	31-40%	41-50	R	L	R	L
58	F	L	BSO	1990	Y	0-10%	41-50	R	L	L	L
41	F	R	ESO	2002	Y	0-10%	11-20	R	L	R	L
37	F	R	BSO	1994	N	0-10%	21-30	R	R	R	B
46	M	R	ESO	1996	Y	11-20%	41-50	R	L	R	L
29	M	R	Unitec	2007	Y	51-60%	41-50	R	R	R	R
26	M	R	Unitec	2007	Y	11-20%	31-40	DNN	DNN	DNN	DNN
29	F	R	Unitec	2004	N	31-40%	41-50	R	L	R	L
30	F	R	UWS	2004	N	81-90%	11-20	R	L	R	L
55	M	R	OCNZ	1998	N	51-60%	41-50	R	L	L	R
55	M	R	ICO	1988	Y	0-10%	41-50	R	L	R	L
57	M	R	BCNO	1976	Y	91-100%	41-50	DNN	DNN	DNN	DNN
37	M	L	Unitec	2008	Y	81-90%	11-20	L	R	L	R
52	M	R	COET	1998	N	81-90%	41-50	R	R	R	R
50	M	R	BCNO	1981	N	41-50%	41-50	R	L	L	R
52	M	L	BCNO	1983	Y	11-20%	41-50	DNN	DNN	DNN	DNN
48	F	R	BSO	1986	Y	61-70%	41-50	R	L	R	L
29	M	R	Unitec	2003	Y	41-50%	41-50	R	L	R	L
53	F	R	RMIT	1990	Y	0-10%	41-50	R	L	L	L
52	F	R	TCOUK	1992	N	21-30%	41-50				
36	F	R	BSO	2000	Y	51-60%	31-40	R	L	R	L
51	M	R	LSO	2004	N	21-30%	41-50	R	L	R	L