The effect of thoracolumbar high velocity low amplitude manipulation on gross trunk rotational range of motion: Is the position of the technique important?

School of Health Sciences

Victoria University

Patrick John-James Mudge B.Sc.(Clinical Science)

Supervisor: Dr Gary Fryer B.App.Sc.(Osteopathy), N.D.

ABSTRACT

Background and objectives: High velocity low amplitude (HVLA) thrust manipulation is commonly used by manual therapists to treat motion restrictions in the spine. In the thoracolumbar spine, there are two ways that the manipulation is usually carried out: one with the patient lying on their side and another with the patient lying on their back. The aim of this controlled, single blinded study was to investigate the effect of these two thrust manipulations on the gross trunk rotational range of motion (GTR) of the spine in an asymptomatic population.

Methods: Ninety subjects (57 female, 33 male) aged 18 to 40 years (μ=22 years) were randomly allocated into three intervention groups; receiving either a HVLA manipulation in the side-lying position, a HVLA manipulation in the supine position, or a sham treatment (control) allegedly consisting of functional technique. GTR measurements were made with the Axial Rotation Measuring Device No.3, utilising three-dimensional magnetometry. Measurements were recorded immediately before, immediately after and 30 minutes after treatment intervention.

Results: Both side-lying and supine HVLA manipulations of the thoracolumbar spine were found to produce statistically significant increases in GTR towards the restricted direction immediately following intervention (2.76° p=0.012, and 2.16° p=0.041, respectively) and 30 minutes following intervention (3.42° p=0.005, and 2.67° p=0.039, respectively). The ‘sham’ treatment also produced statistically significant increases in GTR towards the restricted direction immediately following intervention (3.01°, p=0.011) and 30 minutes following intervention (4.77°, p=0.001). Analysis of between-subjects effects revealed that there was no significant difference between the three groups ($F_{2,87}$=0.31, p=0.73, for restricted direction; $F_{2,87}$=0.50, p=0.61, for non-restricted direction).

Conclusion: HVLA manipulation of the thoracolumbar spine produces significant increases in GTR in asymptomatic subjects. The positioning of the HVLA manipulation does not significantly affect the changes seen in GTR following intervention.

Keywords: manipulation, thoracolumbar spine, gross trunk rotational range of motion, magnetometry

INTRODUCTION

Full, active axial rotation of the trunk, or gross trunk rotational range of motion (GTR), is accomplished by both the thoracic and lumbar spines, working synchronously with the rib-cage and pelvis. The thoracolumbar spine comprises the upper lumbar segments and the lower thoracic segments, and includes the junction of the thoracic and lumbar spines, namely the thoracolumbar junction. Kapandji[1] states that 37 degrees of axial rotation occurs bilaterally in the thoracic spine, attributing approximately three degrees to each thoracic level. The rotational biomechanics of the upper lumbar segments are similar to the rotational biomechanics of the lower thoracic segments,[2] and thus the thoracolumbar spine plays a significant role GTR.

Adequate mobility of the spine is a prerequisite for activities of daily living,[3] and as such, many authors advocate range of motion (ROM) assessment in neuromusculoskeletal examination of the spine.[4,5,6,7] Practitioners use ROM measurements to determine disability, to guide therapeutic intervention and to supply the patient with feedback when restoring function.[3]

Authors of osteopathic texts have claimed that discrepancies in ROM measurements, or *restrictions*, can be ameliorated with various forms of manipulative intervention.[5,8,9,10] One such intervention is the high velocity low amplitude (HVLA) thrust, where a joint is moved suddenly beyond its normal physiological range of motion, but within anatomical limits. The aim of HVLA techniques is to achieve joint cavitation that is accompanied by a 'popping' or 'cracking' sound.[8] Brodeur[11] suggests that the audible release is produced by the sudden 'snap back' of the synovial capsule, in association with formation of a gas bubble within the joint.[12] HVLA manipulation is primarily utilised to maintain or restore ranges of motion.[13] In the context of this article, therefore, the term *manipulation* refers to a single, localised, HVLA thrust directed at a joint articulation,[9,14] accompanied by an audible cavitation.

Manipulations to the thoracolumbar spine are commonly carried out by practitioners in one of two different positions: one in which the patient lays on their side and another which has the patient lying on their back. Both techniques are commonly described by many osteopathic authors.[5,8,9,15]

There is, however, a paucity of research to justify the use of manipulation for thoracolumbar ROM restrictions. Research conducted to date on the effects of spinal manipulation on ROM has been primarily focused on the cervical spine,[16,17,18,19,20,21,22,23,24] with little research into ROM changes following thoracolumbar manipulation.[3]

Changes in active cervical ROM immediately after manipulation were studied by Cassidy and co-workers.[21] They examined symptomatic participants with cervical paraspinal tenderness and unilateral neck pain aggravated by movement. Using goniometric measurements, they found mean increases in rotational ROM following manipulation (5.0° for ipsilateral rotation, 3.6° for contralateral rotation), however they were not significantly different to the increases achieved by muscle energy technique (4.2° for ipsilateral rotation, 2.4° for contralateral rotation; p=0.67 and p=0.36, respectively). Changes in passive lateral-flexion ROM asymmetry immediately after manipulation have been extensively researched by Nansel and co-workers.[22-24] Their studies were blinded and controlled, and their results consistently indicated an increase in lateral-flexion ROM by at least 8° ($p<0.05$ level or better) immediately after manipulation. More recent research by Clements *et al.*[17] and Surkitt *et al.*[18] demonstrates immediate mean increases in atlanto-axial rotation following HVLA manipulation ($p<0.02$ and $p<0.01$, respectively). Both studies utilised the same cervical goniometric device (cervicorotometer), and only included asymptomatic subjects who displayed a unilateral passive atlanto-axial rotation asymmetry of 8° or more (n=40 and n=12, respectively). The study by Surkitt *et al.* also found that manipulation of the atlanto-axial joint reduced mean total cervical rotation asymmetry by more than half immediately post-manipulation ($p<0.02$). The immediate improvements in rotation range displayed by Surkitt *et al.* were neither augmented nor maintained by time, however, with mean asymmetries in atlanto-axial and total cervical rotation ranges one hour after the manipulative procedure (10.91° and 10.64°, respectively) almost returning to the original pre-manipulation mean ranges of asymmetry (11.18° and 14.91°, respectively).

Gavin[3] explored the effects of manipulation to the mid-thoracic spine on active flexion and left and right side-bending of the mid-thoracic spine. Seventy-eight asymptomatic subjects were pre-tested for active range of motion of T3-T8, divided then into three intervention groups – Group 1 was rested, Group 2 received mobility tests, and Group 3 received mobility testing and joint manipulation to a restricted segment – and then immediately retested. The electronic inclinometer used by Gavin to gain range of motion measurements of the spine, the EDI 320 by Cybex, has been previously found by Koes & Mameren[25] to be a reliable device for assessing range of motion of the spine, with a coefficient of variance no greater than 6-16% (r=0.84-1.96). However, Gavin only found statistical significance in the modest mean increase of 1.9° (p=0.012) in left side-bending, an increase that is considered likely to fall within the non-stated error range of his measurement procedure.

There is currently no literature that has examined the effect of thoracolumbar manipulation on spinal ROM. Review of related literature suggests that manipulation of the cervical spine is associated with immediate increases in ROM. The aims of this study, therefore, were firstly to determine the effects of thoracolumbar manipulation on GTR, including changes over time, and secondly to determine which of the two more commonly used thoracolumbar manipulations has the greatest positive influence on GTR – be that the greatest increase in GTR or the least decrease in GTR. It is hoped that such evidence will be useful in guiding practitioners toward the most appropriate method of therapeutic intervention in manipulative treatment of the thoracolumbar spine.

METHODS

Subjects

Ninety asymptomatic volunteers (N=90; 57 female; 33 male; age range 18 to 40 years; μ=22 years) were recruited from the student body at Victoria University's City Flinders Campus, upon completion of a consent form and a questionnaire to exclude thoracic and lumbar pathology. Volunteers were excluded from the study if they were suffering from a thoracic or lumbar condition or pathology, if they were experiencing spinal pain or pain, numbness or weakness in the leg or foot, if they had been a long-term corticosteroid user, or if they had been diagnosed with osteoporosis.

Testing and intervention procedures were performed in the Victoria University Osteopathic Medicine Clinic. All participants had the procedures explained to them prior to their participation and were supplied an information sheet to read before signing the consent form. The Victoria University Human Research Ethics Committee granted ethical approval for the study.

Range of motion measurements

Pre-, post- and half hour post-intervention active range of motion measurements were made using a simple device called the Axial Rotation Measuring Device No.3 (ARMDno3) (Figure 1).

Figure 1. The Axial Rotation Measuring Device No.3

The ARMDno3 was modelled on a similar design by Lenehan *et al.*[26] called the ARMDno2. Unlike its precursor, which required visual estimation of GTR gauged from a ruler and paper copy of a protractor bearing 180 degrees at the base of the device, the ARMDno3 utilised a three-dimensional magnetometer (3DM®, Solid State 3-axis Pitch, Roll and Yaw Sensor, Microstrain, USA) to measure GTR. Studied by Daly & Fryer,[27] the ARMDno3 was found to be reliable (ICC=0.99) and had an error range of 5.02°.

Participant positioning

Seated on the treatment table in front of the device, participants were positioned on the ARMDno3 in a manner similar to the procedure described by Lenehan *et al.*,[26] placing their arms over the horizontal bar, referred to as the *scapula beam*. The table height was adjusted to ensure the scapula beam was level with the *interscapular line* (Figure 2).

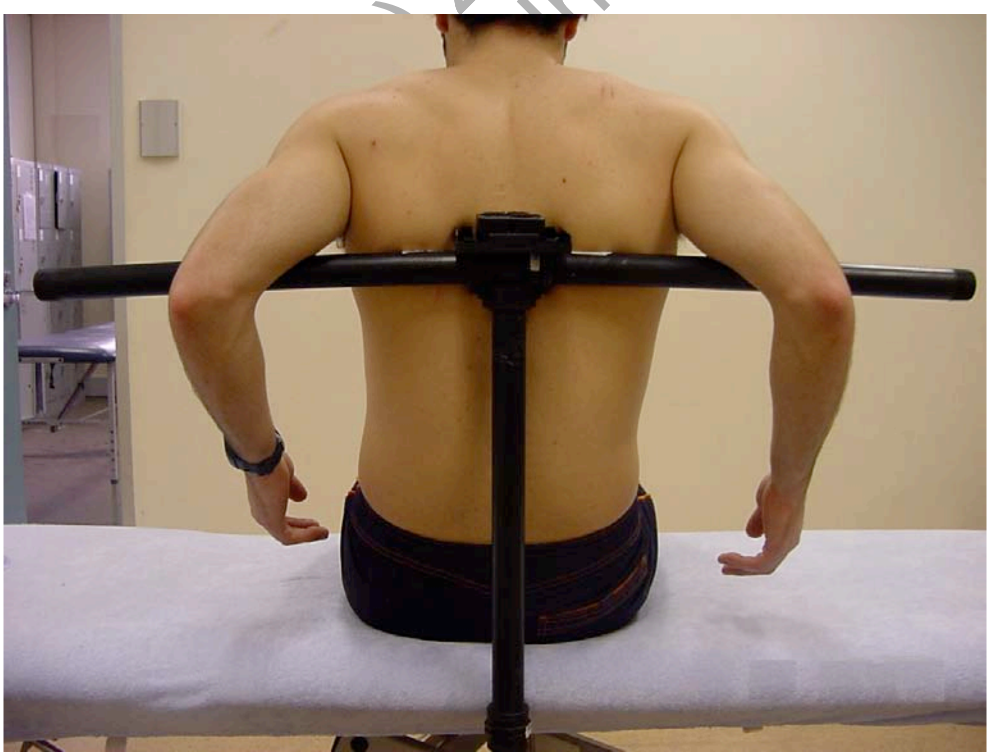

Figure 2. Participant positioning for measurement of GTR

The 'interscapular line' refers to the imaginary line between the infero-medial angles of the scapulae. Sitting freely on the table, each subject was instructed to sit in an upright posture and adjust their seating position to approximate the vertical bar and their own sacrum as much as possible, thereby bringing the vertical bar as close as possible to the spine. An examiner blinded to the group allocations of all participants stabilised the pelvis of each participant as they actively turned as far as possible to the right. The subsequent range of motion measured by the ARMDno3 was recorded by another examiner, also blinded to the treatment allocation of participants, to the nearest degree. The participant then returned to the neutral position for a latent period of three seconds before the procedure was repeated to the left side. 'Neutral' was monitored from the computer output of the magnetometer, such that the subject's rotation about the vertical axis equalled or very closely approached zero degrees. Each participant completed the left and right rotation measures three times, and the mean values were calculated for analysis. The direction to which GTR was the least was deemed the restricted direction.

Procedure

Following the measurement of the pre-intervention GTR, participants were informed that they would now receive treatment in the form of a manipulation, a functional technique, or a control intervention with no treatment. They were handed a card indicating the direction of their restricted GTR, which was folded to blind the subjects, and directed into an adjacent room where they handed the card to the treating examiner. Participants were randomly and equally assigned to either the control (C), side roll HVLA (ROLL), or supine "dog" HVLA (DOG) groups, by way of a hat draw. The C group (n=30) received a 'sham' treatment intervention, which they were informed was functional technique, and underwent no manipulation of any kind, whilst the ROLL group (n=30) and DOG group (n=30) received the respective thoracolumbar HVLA manipulations. The treating examiner was a qualified osteopath with 13 years experience in thoracolumbar manipulation.

Interventions

1. HVLA manipulation (ROLL)

The manipulation used in the ROLL group was performed with the patient side-lying in a neutral position. The subject's lower leg was straightened such that the leg and spine were in a straight line, whilst the upper leg was flexed at the hip and knee and placed just anterior to the lower leg. The treating examiner then rotated the subject's upper body towards the direction of the restricted GTR until they could palpate motion at the thoracolumbar spine. The examiner's leading forearm rested on the subject's upper pectoral and rib cage region to control upper body rotation whilst the other forearm was applied to the buttock region between the area of the gluteus medius and maximus, thereby controlling lower body rotation (Figure 3).

Minor adjustments in holds and patient positioning were made to achieve appropriate pre-thrust tension at the thoracolumbar segment. The HVLA thrust was then delivered through the forearm controlling lower body rotation in a slight amplification of thoracolumbar rotation towards the examiner, in the direction of the GTR restriction.

Figure 3. Side-lying ROLL manipulation intervention

2. HVLA manipulation (DOG)

The manipulation used in the DOG group was carried out with the participant supine with their arms crossed over their chest and their hands clasped firmly around their shoulders. The examiner rolled the subject towards himself and made contact over the transverse process of a given thoracolumbar segment with his opposite hand to that of the direction of the patients restricted GTR: i.e. right GTR restriction, left hand application; left GTR restriction, right hand application. Maintaining the contact, the patient was then rolled back towards the supine position. The examiner engaged flexion of the thoracic spine by cradling the patient's head and neck with his other hand and forearm. Appropriate pre-thrust tension was achieved by applying contact of his upper abdomen and sternum with the subject's elbows and forearms and making minor adjustments in flexion, extension, rotation and side-bending (Figure 4). The thrust was delivered in a rotation gliding fashion, also in the direction of the GTR restriction.

Figure 4. Supine DOG manipulation intervention

Although the precise level of the joint cavitation could not be determined, both manipulations were directed to the thoracolumbar spine and were performed in a manner consistent with the appropriate protocols prescribed by Gibbons & Tehan.[28]

3. 'Sham' functional treatment (control)

A 'sham' functional treatment was used for the control group (Figure 5) rather than no intervention to minimise differences in expectation bias between the manipulation and control groups, which could potentially motivate subjects to perform differently when performing their active GTR.

Figure 5. 'Sham' control intervention

All subjects in this group were informed that they were receiving a functional technique that would attempt to restore coordinated activity between the segments of the vertebral column and the related soft tissues.[9] This was done to give the impression that they were receiving a genuine therapeutic technique, when in fact they received no form of therapeutic treatment at all, a so-called 'sham'.

Post-intervention testing

Post-intervention GTR measurements were recorded consistent with pre-intervention measurement procedures for C, ROLL, and DOG groups immediately following intervention. All participants returned 30 minutes later for half hour post-intervention testing procedures, also conducted in an identical manner to that of the pre-intervention procedures. Throughout the pre-, post- and half hour post-intervention testing procedures, the position of all equipment used was monitored and maintained with the aid of floor markings made by adhesive tape. The positioning of the participants in the post- and half our post-intervention testing was more difficult to monitor, but consistent instructions on positioning (see *Participant positioning*, pp8-9) were given to participants throughout testing procedures in an attempt to minimise possible changes in position from pre-intervention testing to post-intervention testing.

Statistical methods

All pre-, post- and half hour post-intervention data from the C, ROLL and DOG groups were collated and analysed using the statistical package SPSS version 12. A SPANOVA was conducted for both the restricted and non-restricted GTR measurements to determine if differences existed between the changes produced by the three interventions, and to determine whether the treatment groups were more effective than the control group over time. Post-hoc analysis was carried out in the form of repeated measures *t*-tests to determine where the significant findings lay. Statistical significance was set at the alpha <0.05 level.

RESULTS

Before intervention, subjects displayed mean GTRs of 45.47° (10.09°) in the restricted direction and 52.25° (11.10°) in the non-restricted direction, and both pre-intervention mean measurements were slightly greater in the control group than the manipulation groups. All groups made small increases in GTR immediately post- and 30 minutes post-intervention in the direction of the restriction (Table 1 & Table 2). Whilst the control group also experienced a mean increase in GTR in the *non-restricted* direction immediately post- and 30 minutes post-intervention, the two manipulation groups experienced slight *decreases* in the non-restricted direction immediately post-intervention and further decreases 30 minutes post-intervention (Table 1 & Table 2).

Table1. Group GTR Means (SD): Pre-intervention Versus Immediately Post-intervention

	Control Restricted	DOG Restricted	ROLL Restricted	Control NRestricted	DOG NRestricted	ROLL NRestricted
Pre	45.98(10.47)	45.01(11.26)	45.41(8.70)	52.93(12.57)	51.90(12.10)	51.90(8.53)
Post	48.98(9.84)	47.17(10.37)	48.17(9.99)	52.97(12.77)	51.48(12.45)	50.36(9.74)
Difference	3.01(6.02)	2.16(5.51)	2.76(5.64)	0.04(4.24)	-0.42(4.84)	-1.54(4.89)

Table2. Group GTR Means (SD): Pre-intervention Versus 30 Minutes Post-intervention

	Control Restricted	DOG Restricted	ROLL Restricted	Control NRestricted	DOG NRestricted	ROLL NRestricted
Pre	45.98(10.47)	45.01(11.26)	45.41(8.70)	52.93(12.57)	51.90(12.10)	51.90(8.53)
30minPost	50.75(10.74)	47.68(9.73)	48.84(10.03)	53.64(12.63)	48.96(11.04)	49.95(9.40)
Difference	4.77(6.88)	2.67(6.75)	3.42(6.15)	0.71(6.94)	-2.95(7.74)	-1.95(4.86)

Table 1 and Table 2 display the mean GTR measurements and the differences between them for each of the three intervention groups in both restricted and non-restricted directions, for results immediately post- and 30 minutes post-intervention, respectively. They demonstrate a small mean improvement in GTR towards the direction of restriction in the C, DOG and ROLL groups (3.01°(6.02), 2.16°(5.51) and 2.76°(5.64), respectively) immediately following intervention (p=0.011 for C, p=0.041 for DOG, p=0.012 for ROLL) and further mean improvement on pre-intervention measurements (4.77°(6.88), 2.67°(6.75) and 3.42°(6.15), respectively) half an hour after intervention (p=0.001 for C, p=0.039 for DOG, p=0.005 for ROLL). In the opposite, 'non-restricted' direction, there were only very slight mean improvements in GTR in the C group immediately after intervention (0.04°(4.24), p=0.959) and decreases in the DOG and ROLL groups (-0.42° (4.84), p=0.636; and -1.54°(4.89), p=0.094; respectively) immediately after intervention, with similar results half an hour after intervention (0.71°(6.94), p=0.581; -2.95°(7.74), p=0.046; and –1.95°(4.86), p=0.036; for C, DOG and ROLL groups, respectively).

A SPANOVA showed that the main effect for time was significant for the restricted direction ($p<0.01$), however Mauchly's statistic was also significant ($p<0.05$), which indicated that a violation of the sphericity assumption for interaction between the groups had occurred and thus unequal variances of population differences of the treatment and control groups existed. Because sphericity could not be assumed, the Greenhouse-Geisser adjustment was made, allowing the main effect for time to be accepted as being significant for the restricted direction ($F_{1.9}$=18.24, $p<0.001$). The main effect for time in the non-restricted direction was not found to be significant (p=0.142).

Post-hoc analysis using repeated measures t-tests found significance in the increases in GTR towards the restricted direction immediately following intervention in both the DOG and ROLL manipulations (2.16° p=0.041, and 2.76° p=0.012, respectively) and 30 minutes following intervention (2.67° p=0.039, and 3.42° p=0.005, respectively). The 'sham' treatment also produced statistically significant increases in GTR towards the restricted direction immediately following intervention (3.01°, p=0.011) and 30 minutes following intervention (4.77°, p=0.001).

Analysis of between-subjects effects revealed that there was no significant difference between the effects of the DOG manipulation and the effects of the ROLL manipulation in either the restricted or the non-restricted directions ($F_{2,87}$=0.31, p=0.73, and $F_{2,87}$=0.50, p=0.61, respectively).

Audible joint cavitation was noted for all participants in the DOG and ROLL groups during the administration of the manipulation interventions.

DISCUSSION

In clinical practice, manipulation is generally considered to be a useful tool in improving motion restrictions in the spine, and has been shown by a number of researchers[3,15-23] to significantly increase spinal ranges of motion. The modest increases in range of motion found by this study are similar to the findings made by Gavin[3], who only found small statistically significant increases in left side-bending following manipulation of the thoracic spine. Improvements were certainly not as vast as those seen in the cervical spine (at least 8°, p<0.05 level or better) as reported by Nansel *et al.*[22-24], although the differences in biomechanics and expected ranges of motion that exist between the cervical and thoracolumbar spines[1,2] are appreciated.

In contrast to findings by Surkitt *et al.*[18], time appeared to augment the immediate gains seen in range of motion towards the restricted side following manipulation. GTR increases in the restricted direction immediately after intervention slightly improved half an hour after intervention in all groups, including the ‘sham’ treatment.

However, significant mean improvements seen in GTR in the restricted direction immediately after intervention were modest at best, with the greatest mean increase being 3.01°(6.02) in the group receiving the ‘sham’ functional treatment ($p<0.01$). The procedure used to measure GTR, described by Daly & Fryer[27], required subjects to fully turn to the left and then the right, three times over, with mean ranges of motion calculated and identified as the GTR. Participants were not strapped down in any way and were only restrained from ‘impure GTR movements’ by verbal instruction and an examiner holding the pelvis. Monitoring the precise position of participants from one measurement to the next also proved challenging, with consistent verbal instruction from examiners being the only controlling factor. It was therefore difficult to make absolutely sure participants were performing their active GTR exactly the same way in all three measurement procedures (pre-, post- and half hour post-intervention). Daly & Fryer[27] reported an error range of 5.02° for the ARMDno3, and thus it is possible that the improvements seen in GTR following intervention were due to the existing error in the pre- and post-intervention measurements, rather than the interventions themselves.

One of the major limitations encountered by the authors in this study was the reliability of the ARMDno3 used in the generation of all pre-, post-, and half hour post-intervention GTR measurements. Descriptive statistics from the study by Lenehan *et al.*[26] revealed that pre-intervention mean GTRs when measured by the ARMDno2 were 25.39° in the restricted direction and 34.40° in the non-restricted direction. Examining a similar asymptomatic population, data gained from the ARMDno3 in the present study reveals substantially higher pre-intervention mean GTRs of 45.47° in the restricted direction and 52.25° in the non-restricted direction. Whilst Daly & Fryer[27] found the ARMDno3 measurement procedure had acceptable test-retest reliability (ICC=0.99, error range of 5.02°), it is noted that this is only a measure of *repeatability*, and in this author's view the *reliability* of the ARMDno3 is not well established. It is therefore possible that the equipment design was subject to errors, from a variety of sources. ARMDno3 has a number of different aspects distinguishing it from its predecessor upon which it is modelled, the ARMDno2, which incidentally has also demonstrated high test-retest reliability.[26] It utilises three dimensional magnetometry to detect changes in degrees of axial motion to two decimal places, replacing visual estimation utilised by the ARMDno2 that was gauged from a ruler and enlarged paper copy of a protractor bearing 180 degrees at the base of the device. The apparent sensitivity of the magnetic field generated by the magnetometer meant that the designers of the ARMDno3 could not use any metals as part of the construction, due to their interfering with the magnetic field. As a result, designers had to forgo the use of sturdy metallic components and instead use less rigid plastic materials that included threaded junctions that rotated about the same axis as the GTR. The designers also noted difficulty in fixing and stabilising the magnetometer to the rest of the ARMDno3, ultimately resorting to adhesive glue and heavy duty gaffer tape to provide attachment.[27] In this author's view, these factors combined left the device vulnerable to absorbing some of, or exaggerating, the true GTR produced by the subjects and in turn formulating inaccurate GTR measurements of unknown magnitudes, which may then have affected results.

Subjects involved in the study were drawn from across all year levels of the student body of the osteopathy course at Victoria University. The testing examiners felt that during the post- and half hour post-intervention testing procedures, some of the subjects may have been influenced by the desire to improve on their pre-intervention GTR and as a consequence 'try harder' in the following post- and half hour-post intervention tests, despite careful instruction from the testing examiners not to do so. This would explain the slight mean increases in GTR in the restricted and non-restricted direction immediately after (3.01°(6.00), p=0.011, and 0.04°(4.24), p=0.959, respectively) and half an hour after (4.77°(6.88), p=0.001, and 0.71°(6.94), p=0.581, respectively) the 'sham' treatment, but doesn't explain the modest and relatively insignificant results of the manipulation treatments. Whilst it is possible that these modest increases in mean GTR measurements in the control group may be due to conscious efforts from subjects or even a placebo effect, the ability of the ARMDno3 to reliably and irrefutably measure GTR whilst being unaffected by external influences remains questionable.

The authors noted that the GTR measurements to each side obtained in the pre-intervention procedures were frequently separated by just a few degrees or less, meaning the designated 'restricted' direction was not always much different to the 'non-restricted' direction, and, given the ARMDno3's error range of 5.02°, may not have been the 'restricted' direction at all. Reasons for this trend could include the testing of an asymptomatic population or aberrations in the reliability of the ARMDno3. Future research could therefore exclude subjects with minor or negligible ROM asymmetries and only include those subjects with more substantial restrictions, such as 8° or more – as was done by Clements *et al.*[17] and Surkitt *et al.*[18] in their cervical spine studies – thereby also overcoming the error range of the ARMDno3 (5.02°).

In general, the so-called 'sham' functional treatment used as a 'control' provided greater improvements (small as they were) in GTR than the manipulations which may suggest that the effect of the 'sham' functional technique was greater than the effect of the manipulations on improving GTR. The fact that asymptomatic subjects responded better to a 'sham' functional technique than manipulation, moreover, may indicate that manipulation does not improve GTR in asymptomatic subjects. This raises a new hypothesis that improvements in GTR following manipulation would be greater in symptomatic subjects than in asymptomatic subjects. This notion is something that could also be explored further in future research. At this point in time, therefore, results of this study shouldn't discourage the present wide use of manipulation in the clinical setting where it is used predominantly on the symptomatic population.

Analysis of between-subjects effects revealed that there was no significant difference between the effects of the DOG manipulation and the effects of the ROLL manipulation on either the restricted direction or the non-restricted direction ($F_{2,87}$=0.31, p=0.73, and $F_{2,87}$=0.50, p=0.61, respectively), suggesting that the position of the technique is not important when manipulating the thoracolumbar spine of asymptomatic subjects.

The present study compared and examined the immediate and short-term effects of two different thoracolumbar manipulations on GTR in asymptomatic subjects. Future studies could also examine the effect of thoracolumbar manipulation on symptomatic individuals, with criteria to exclude subjects with less than 8° asymmetry in GTR. Measuring procedures should be modified such that pure GTR can be easily and reliably performed by participants, totally eliminating involvement of the pelvis and ensuring reliable positioning of participants. Possible modifications could include strapping down the lower limbs and pelvis, and using a specially designed chair or table (such as a Biodex Chair) to properly position participants during measuring procedures. It is also recommended that the ARMDno3 retain the use of magnetometry as its measuring device but is reconstructed with more rigid materials and without threaded junctions that permit rotation about the GTR axis.

CONCLUSIONS

Manipulation of the thoracolumbar spine produces a statistically significant modest increase in restricted directions of GTR in asymptomatic subjects, but no more than a 'sham' treatment. The positioning of the thoracolumbar manipulation is not important when used on an asymptomatic population.

Increases in GTR in the restricted direction are augmented by time for at least half an hour in asymptomatic subjects, regardless of whether they receive manipulation or a non-therapeutic 'sham' treatment.

Further research is needed before more conclusive results can be drawn on this subject, and as such the results of this study shouldn't discourage the present use of thoracolumbar manipulation for the treatment of restricted spinal motion in the clinical setting.

ACKNOWLEDGEMENTS

The authors would like to thank Simon Nawrocki, Luke Fuller and Matthew Daly for their assistance in the testing procedures and data collection, and Patrick McLaughlin for his assistance in incorporating the three-dimensional magnetometer into the design of the ARMDno3.

REFERENCES

[1] Kapandji IA. *The Physiology of the Joints. 2nd Edition Volume 3 - The Trunk and Vertebral Column.* London: Churchill Livingstone; 1974.

[2] Norkin CC, Levangie PK. *Joint Structure & Function. 2nd Edition.* Philadelphia: F.A. Davis Company; 1992.

[3] Gavin D. The effect of joint manipulation techniques on active range of motion in the mid-thoracic spine of asymptomatic subjects. *The Journal of Manual & Manipulative Therapy.* 1999; 7(3): 114-122.

[4] Giles LGF, Singer KP, eds. *The Clinical Anatomy and Management of Back Pain Series Volume 2: Thoracic Spine Pain.* Oxford: Butterworth-Heinemann; 1999.

[5] Lewit K. *Manipulative Therapy in Rehabilitation of the Locomotor System. 3rd Edition.* Oxford: Butterworth-Heinemann; 1999.

[6] Refshauge K, Gass E, eds. *Musculoskeletal Physiotherapy: Clinical Science and Practice.* Oxford: Butterworth-Heinemann; 1995.

[7] Hoppenfeld S. *Physical Examination of the Spine & Extremities.* Connecticut: Appleton & Lange; 1976.

[8] Gibbons P, Tehan P. *Manipulation of the Spine, Thorax and Pelvis.* London: Churchill Livingstone; 2000.

[9] Greenman PE. *Principles of Manual Medicine. 3rd Edition.* USA: Williams & Wilkins; 1996.

[10] McKone WL. Osteopathic Athletic Health Care. Principles and Practice. London: Chapman & Hall; 1997.

[11] Brodeur R. The audible release associated with joint manipulation. *Journal of Manipulative and Physiological Therapeutics.* 1995; 18:155-164.

[12] Fryer G, Carub J, McIvor S. The effect of manipulation and mobilization on pressure pain thresholds in the thoracic spine. *Journal of Osteopathic Medicine*. 2004; 7(1):8-14.

[13] Basmajian J, Nyberg R. *Rational Manual Therapies.* Baltimore: Williams & Wilkins; 1993.

[14] Grieve GP. *Mobilisation of the Spine: A Primary Handbook of Clinical Method. 5th Edition.* UK: Churchill Livingstone; 1991.

[15] McClune T, Walker C, Burton K. Osteopathic management of thoracic spine pain. In: Giles LGF, Singer KP, eds. *The Clinical Anatomy and Management of Back Pain Series Volume 2: Thoracic Spine Pain.* Oxford: Butterworth-Heinemann; 1999: 257-267.

---

[16] Whittingham W, Nilsson N. Active range of motion in the cervical spine increases after spinal manipulation (toggle recoil). *Journal of Manipulative and Physiological Therapeutics.* 2001; 24(9): 552-555.

[17] Clements B, Gibbons P, McLaughlin P. The amelioration of atlanto-axial rotation asymmetry using high velocity low amplitude manipulation: Is the direction of thrust important? *Journal of Chiropractic Medicine.* 2001; 4(1): 8-14.

[18] Surkitt D, Gibbons P, McLaughlin P. High velocity low amplitude manipulation of the atlanto-axial joint: effect on atlanto-axial and cervical spine rotation asymmetry in asymptomatic subjects. *Journal of Osteopathic Medicine.* 2000; 3(1): 13-19.

[19] Nilsson N, Christensen HW, Hartvigsen J. Lasting changes on passive range of motion after spinal manipulation: a randomised, blind, controlled trial. *Journal of Manipulative and Physiological Therapeutics.* 1996; 19(3): 165-168.

[20] Nilsson N. A randomised controlled trial of the effects of spinal manipulation in the treatment of cervicogenic headache. *Journal of Manipulative and Physiological Therapeutics.* 1995; 18(7): 435-440.

[21] Cassidy JD, Lopes AA, Yong-Hing K. The immediate effect of manipulation versus mobilisation on pain and range of motion in the cervical spine: a randomised controlled study. *Journal of Manipulative and Physiological Therapeutics.* 1992; 15: 570-575.

[22] Nansel D, Peneff A, Quitoriano J. Effectiveness of upper versus lower cervical adjustments with respect to the amelioration of passive rotational versus lateral-flexion end-range asymmetries in otherwise asymptomatic subjects. *Journal of Manipulative and Physiological Therapeutics.* 1992; 15: 99-105.

[23] Nansel D, Peneff A, Cremata E, Carlson J. Time course considerations for the effects of unilateral lower cervical adjustments with respect to the amelioration of cervical lateral-flexion passive end-range asymmetry. *Journal of Manipulative and Physiological Therapeutics.* 1990; 13: 297-304.

[24] Nansel D, Cremata E, Carlson J. Effect of unilateral spinal adjustments on goniometrically-assessed cervical lateral-flexion end-range asymmetries in otherwise asymptomatic subjects. *Journal of Manipulative and Physiological Therapeutics.* 1989; 12: 419-427.

[25] Koes B, Mameren van H. Reproducibility of range of motion measurements of the spine with the CYBEX EDI 320. *Proceedings of the 3rd International Physiotherapy Congress, Hong Kong.* Sydney, Australia: Link printing. 1990; 442-447.

[26] Lenehan KL, Fryer G, McLaughlin P. The effect of muscle energy technique on gross trunk range of motion. *Journal of Osteopathic Medicine.* 2003; 6(1): 13-18.

[27] Daly M, Fryer G. The short term effects of MET on thoracic range of motion. Unpublished thesis. Victoria University, 2004.

[28] Gibbons P, Tehan P. *Manipulation of the Spine, Thorax and Pelvis.* London: Churchill Livingstone; 2000; pp167-72, 205-208.