Forces Generated in High Velocity, Low Amplitude Manipulations of Both the Dominant and Non-Dominant Rib 1 Costotransverse Joints: A Pilot Study.

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ABSTRACT

Objective: To determine the force/time characteristics of prone rib 1 High Velocity, Low Amplitude (HVLA) manipulations.

Design: Quantitative study.

Setting: Biomechanics Laboratory, Victoria University.

Participants: 12 volunteers.

Intervention: Prone, cross-handed HVLA to rib 1 bilaterally.

Outcomes measured: Forces during manipulation: preload, pre-thrust dip, peak force and post-thrust dip.

Results: a) Dominant side: Mean preload = 171 N ($\pm$ 19 N); Mean peak force = 599 N ($\pm$ 66 N); Mean thrust duration = 0.303s ($\pm$ 0.027 s); Mean thrust velocity = 1,528 N/s ($\pm$ 167 N/s). b) Non-dominant side: Mean preload = 165 N ($\pm$ 17 N); Mean peak force = 598 N ($\pm$ 45 N); Mean thrust duration = 0.316s ($\pm$ 0.059 s); Mean thrust velocity = 1,308 N/s ($\pm$ 174 N/s).

Conclusions: Preload and peak thrust force closely related to each other and the production of a joint cavitation. No significant differences between the force/time characteristics of thrusts to dominant and non-dominant sides, other than post-thrust dip. The practical relevance of this parameter however, is questionable.

Key Words:

HVLA, Spinal Manipulation, Force, Thrust, Ribs.

INTRODUCTION

Although research into manual therapies is now more prevalent in the literature than previously, many gaps remain in the understanding of the mechanics of high velocity, low amplitude (HVLA) manipulative techniques. Such manipulations are a principal therapeutic technique for osteopaths, chiropractors and physiotherapists and are characterised by the skilful application of a short, sharp thrust to move a joint beyond the limits of its passive range of motion[1]. HVLA is a widely accepted treatment modality for both primary musculoskeletal dysfunctions and dysfunction secondary to visceral disease, where hypomobility or movement restrictions are present.

Over time several factors have been theorised to be crucial to the production of a cavitation or ‘crack’ on application of a HVLA technique. These factors include velocity, force, momentum, impulse, energy, vertebral oscillation and stiffness. The exact relationship between each of these factors and their individual significance is questionable and has been widely debated.[2-11] The cavitation itself and its importance has also been debated. Widely believed by the osteopathic profession to not be critical for resultant therapeutic benefits of HVLA treatment[12], a cavitation is thought to be rapid separation of joint planes when a critical level of force is applied.[13] The ‘pop’ or ‘crack’ sound on cavitation, is believed to be created by the rushing of fluid into a low pressure area formed by the rapid increase in joint volume that results from this separation of joint planes. According to Conway[14] however, the production of a cavitation is extremely important to many physical therapy clinicians who judge the success of HVLA treatment on the production of the audible pop. The mechanism for the therapeutic benefits of HVLA has also been debated and is generally accepted as being a combination of articular and periarticular changes. These include increased quality of movement due to the cavitation and its effect on the joint capsule and adjoining ligaments and resetting of nociceptors and proprioceptors due to rapid stretching of surrounding musculature.

To date the bulk of research into the actual mechanics of HVLA has focussed on the forces applied during the thrusting procedure[9,15-21]. This research has presented a series of recurring themes or notions regarding these forces. The two most theorised are the idea that a critical force exists which must be applied to a joint in order to produce a cavitation. In short, the greater the force applied to a joint, the greater the degree of joint distraction and thus the closer that joint is to reaching it's critical force and producing a cavitation. The second recurring concept is that of preload - a preadjustive force typically introduced as a counter-tension between the two bones that contribute to the joint being manipulated. This preload is credited with allowing practitioners to localise the application of the critical force to a single desired joint, as well as taking the joint closer to its critical force by producing a degree of preliminary joint distraction[12].

Although the existence of these force phenomena has been verified in the majority of research experiments[14,16] , many questions remain. The aim of this investigation was to record and analyse force/time characteristics of a prone rib 1 costo-transverse joint thrust. This was to determine if a significant difference exists in the forces or speed of force application required to produce a successful manipulation of the dominant and non-dominant sides.

Several other factors are also theorised to in part dictate the success of manipulative therapy, these include psychological factors such as trust and fear, as well as mechanical variables such as the weight of both practitioner and patient.

METHODOLOGY

Participants

One (1) male manipulator, five (5) males and seven (7) females participated in this study. The manipulator was a registered osteopath who had several years experience using the technique. Participants were osteopathic students who were screened for spinal deformity and pathology and had received HVLA treatment in the past with no ill effect. All participants completed an informed consent form.

Facilities and Equipment

All data collection was performed in the Victoria University biomechanics laboratory (City, Flinders Campus). An AMTI (Massachusetts, USA) force platform was used to collect experimental data. A wooden box the size of the platform was positioned on it to ensure that the full weight of the plinth above was transferred to the force platform. The sampling rate for the platform was set at 500Hz. Raw data from the force platform was digitised and transferred to the AmlabII computer program. Statistical analysis of data was carried out with Microsoft Excel Data Analyser 3.5.

Procedure

Each participant was given an information package upon expression of interest. This package included an information sheet outlining the proposed procedures and their associated risks, a general health inquiry, as well as informed consent and withdrawal of consent forms. Each participant was asked to return all but the withdrawal of consent form prior to the collection of any data. No participant was granted inclusion without a signed and witnessed consent form. (See appendices for information to participants sheet, medical history form, consent form and withdrawal of consent form.)

Upon arrival for data collection, the researcher reviewed each participant's medical history and informed consent forms and vertebro-basilar insufficiency testing was performed. Based on this information participants were then included or excluded from the study. Prior to any manipulation all participants were informed that the aim of the thrust was to produce a cavitation or an audible 'pop'. Participants were then asked to place themselves prone upon the treatment table and the force platform was zeroed with the subject, the plinth and the wooden box on top. The practitioner was then asked to take up the pre-thrust position and, when comfortable, to proceed with the thrust. If a thrust was unsuccessful in producing a cavitation the practitioner was allowed one more attempt. The same practitioner was used in all manipulations to ensure the most reliable reproduction of thrust positioning.

Each subject was then returned to neutral and the practitioner was asked to repeat the procedure on the participants' contralateral side. Once the manipulation was repeated and data collected for the contralateral side all participants were free to leave.

Parameters measured by the force platform included:

Preload force (N): A quasi-static load applied to the segment to be thrusted, in the same direction as the intended load of the manipulation. Its purpose is to reduce the elastic dampening of the thrust through compression of soft tissues and movement of the joint through the available range of motion[22].

Peak thrust force (N): The maximum force applied during the dynamic component of the thrust force.

Time (S): The duration of the dynamic component of the thrust force.

Pre-thrust dip (N): The drop in magnitude of the preload force immediately prior to the peak thrust force.

Post-thrust dip (N): The drop in magnitude from the preload force immediately after the peak thrust force.

The only secondary measures were whether an audible cavitation was produced and the velocity of thrust application.

All primary measures are depicted in Figure 1, a typical force time profile of an HVLA thrust.

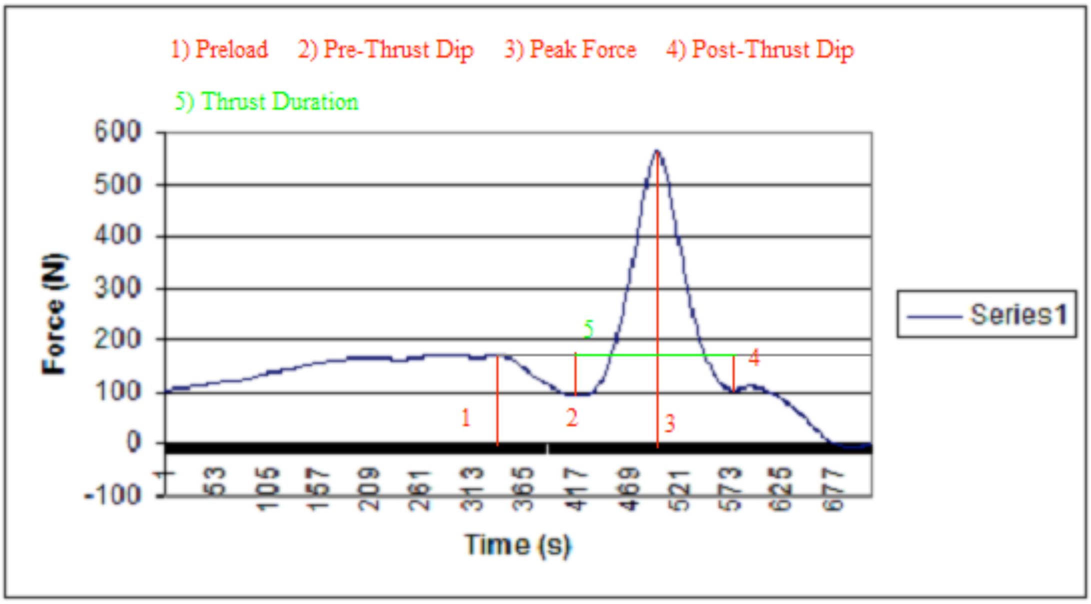

Figure 1. *A typical force/time profile depicting primary measures.*

These data were then analysed using descriptive statistics, paired t-tests and effect size (Cohen's d for dependence tests). Analysis was performed with Microsoft Excel Data Analyser 3.5.

RESULTS

Cavitation was achieved on the first attempt in 66.6% of trials, cavitation was achieved on the second attempt in 87.5% of cases where the first attempt failed. In the case of one subject, no cavitation was attained in two attempts on their dominant side. Descriptive statistics for all participants dominant side are shown in Table 1 and for the non-dominant side in Table 2. Results of paired t-tests (p) and effect size (Cohen's d) calculations are also included.

Significance values in Tables 1 and 2 indicate the results of unilateral comparisons of primary measures between failed and successful attempts on the same joint. The only statistically significant difference lies in the post-thrust dip on the non-dominant side, as seen in table 2 (p=0.018).

Effect sizes noted in Tables 1 and 2 vary considerably. The most apparent commonalities here are the very large effect sizes noted between normalised peak thrust forces and velocity of force application of successful and unsuccessful thrusts (Normalised peak thrust force; dominant d = 1.2 ; non-dominant d = 1.0. Thrust velocity; dominant d = 1.8 ; non-dominant d = 0.8). A large effect is also noted between successful and unsuccessful peak thrust forces to the non-dominant side (d = 0.9).

It is also worth noting that the mean forces of successful thrusts were always greater than that of unsuccessful thrusts.

Table 1: *Means, Standard deviations, P and d values for the participants' dominant side.*

Dominant	**Successful n = 3**		**Unsuccessful n = 3**			
	Mean	**SD**	**Mean**	**SD**	**p**	**d**
Preload Force	171 N	19 N	158 N	12 N	0.467	0.5
Pre-Thrust Dip	78 N	19 N	75 N	20 N	0.403	0.2
Peak Trust Force	599 N	66 N	566 N	62 N	0.055	0.3
Post-Thrust Dip	157 N	46 N	93 N	30 N	0.116	0.7
Normalised Peak Force	521 N	107 N	401 N	57 N	0.161	1.2
Thrust Duration	0.303 s	0.027 s	0.312 s	0.028s	0.654	-0.3
Thrust Velocity	1528 N/s	167 N/s	1308 N/s	174 N/s	0.327	1.8

Table 2: Means, Standard deviations, P and d values for the participants' non-dominant side.

Non-dominant	Successful n = 4		Unsuccessful n = 4			
	Mean	SD	Mean	SD	p	d
Preload Force	165 N	17 N	155 N	13 N	0.185	0.7
Pre-Thrust Dip	71 N	21 N	57 N	9 N	0.109	0.6
Peak Trust Force	598 N	45 N	521 N	122 N	0.190	0.9
Post-Thrust Dip	117 N	42 N	93 N	35 N	0.018	0.3
Normalised Peak Force	458 N	47 N	376 N	99 N	0.185	1.0
Thrust Duration	0.316 s	0.059s	0.302 s	0.033 s	0.672	0.5
Thrust Velocity	1334 N/s	101 N/s	1219 N/s	282 N/s	0.545	0.8

Paired t-tests were also conducted to identify significant differences between primary measures from the dominant to non-dominant side. Table 3 demonstrates that the only significant difference again lies in the post-thrust dip (p= 0.011). Table 3 data also indicates that the mean forces of successful thrusts to the dominant side were greater than that of successful thrusts to the non-dominant side.

Table 3: Descriptive statistics, paired t-tests and Cohen's effect size to compare dominant to non-dominant sides

Successful thrusts	Dominant side n=11		Non-dominant side n=11			
	Mean	SD	Mean	SD	p	d
Preload Force	171 N	19 N	165 N	17 N	0.092	0.3
Pre-thrust Dip	78 N	19 N	71 N	21 N	0.249	0.3
Peak Thrust Force	599 N	66 N	598 N	45 N	0.555	0.0
Post-thrust Dip	157 N	46 N	117 N	42 N	0.011	0.7
Normalised Peak Force	458 N	79 N	440 N	50 N	0.520	0.3
Thrust Duration	0.303 s	0.027 s	0.316 s	0.054 s	0.501	0.0
Thrust velocity	1523 N/s	289 N/s	1440 N/s	280 N/s	0.501	0.3

DISCUSSION

It is often suggested that there is a certain 'finesse' required for successful manipulation and while the exact mechanical components of this 'finesse' are still unknown, it would appear that more than just brute force is required. Previous investigations using sound and force recording equipment simultaneously, have revealed that in some cases cavitation actually occurs post peak thrust force[15,20], suggesting that it is not solely peak thrust force that dictates the production of a cavitation. This study supports this notion in that no statistically significant differences between the peak thrust forces of successful and unsuccessful manipulations, on either the dominant ($p = 0.055$) or non-dominant ($p = 0.190$) side, were found.

Preadjustive force has been acknowledged and quantified in several experimental studies[3,4,15,18,20,21]. All of these studies show the use of varying levels of preload. Trials using similar techniques in a true clinical setting failed to demonstrate the use of any significant preload in more than 83% of manipulations[21]. This was determined by a single measure t-test comparing the mean of the forces applied to zero. To determine the significance of preload forces used in this study the same procedure was applied. Although this study demonstrated that significant preload forces were used by the manipulator ($p>0.000$), they were not found to be significantly different from unsuccessful to successful thrusts on either the dominant ($p > 0.467$) or non-dominant ($p > 0.185$) side.

The question has also been raised that if peak and preload forces do not independently dictate a successful 'crack' then perhaps it is the difference between the two - the normalised peak value[20] – that is the critical factor. The present study found no significant difference in the normalised peak value between successful and unsuccessful thrusts on either the dominant ($p = 0.161$) or non-dominant ($p = 0.185$) side.

Velocity, another factor thought to be pivotal to the production of cavitation on manipulation, was also investigated in this study. No statistically significant differences in thrust velocity were noted between successful and unsuccessful thrusts either, not on the dominant ($p = 0.327$) or non-dominant sides ($p = 0.545$).

The only statistically significant ($p = 0.018$) difference between the force/time characteristics of successful and unsuccessful thrusts (of the same joint) was noted as an increase in the magnitude of the post-thrust dip in successful manipulations of the participants' non-dominant side. Differences in all other primary measures were deemed to be non significant.

What is worth considering here is the question of what is statistical significance? Is statistical significance ($p>0.05$) a true gauge of a meaningful difference between two measures or should a significant difference simply be the difference that exists between successful and unsuccessful outcomes? In which case the data obtained in this study would be significant regardless of significance level. The use of effect size is particularly helpful here, where Cohen's d is a direct manifestation of the variable being examined, an indication of how far apart the means of two groups are in terms of their own standard deviation. It has been suggested that effect size is a more appropriate measure particularly when dealing with a small sample size[23].

Where differences between successful and unsuccessful thrusts are concerned, effect size allows a completely different interpretation of data. As noted in Tables 1 and 2 effect size values for comparisons of primary measures vary largely ($d = -0.3 – 1.2$). Of particular importance are those effect size values relating to the significance values previously discussed. On participants' dominant side, medium sized effects were noted between successful and unsuccessful, preload and peak thrust force means ($d = 0.5$, $d = 0.3$ respectively). On the participants' non-dominant side larger effects were noted between successful and unsuccessful thrusts (Preload, $d = 0.7$; peak thrust force $d = 0.9$).

This may indicate that differences between successful and unsuccessful preload and peak thrust forces need not be statistically significant to produce a successful outcome. This appears to be the case when comparing normalised peak forces from successful to unsuccessful thrusts. On the participants' dominant side t-tests revealed no significant difference ($p = 0.161$) but effect size was large ($d = 1.2$). Statistical analysis revealed a similar trend on the non-dominant side ($p = 0.185$; $d = 1.0$). It also appears to be the case when considering thrust velocities on both the dominant ($p = 0.327$; $d = 1.8$) and non-dominant ($p = 0.545$; $d = 0.8$) sides. Though these differences are non-significant, they demonstrate a large difference between means that may be enough to precipitate a cavitation. It is possible that with greater participant numbers, statistically significant results would be revealed.

Much of the research into the forces used in HVLA treatment of the cervical, thoracic, lumbar spine and the sacroiliac joints has investigated regional similarities and differences. There is, however, paucity of research regarding the existence of such similarities and differences between joints on contralateral sides of the body. This pilot study attempts to address this matter. Using the same five primary measures (i.e. preload, prethrust dip, peak force, post thrust dip and thrust duration) paired t-tests and effect size testing were used to detect and quantify any differences in force/time characteristics of manipulations from the participants' dominant to non-dominant sides. Although the dominant side was found to require greater forces, greater variations in forces and a higher velocity of force application to produce cavitation, for the most part these findings were not statistically significant. The only significant difference was recorded in the post-thrust dip. There was a significantly larger ($p = 0.011$) post-thrust dip on the participants' dominant side. Effect sizes allowed for a similar interpretation of data, the only difference in effect size worthy of note lay between the post-thrust dips from dominant to non-dominant sides ($d = 0.7$).

Hass[2-4] proposed that critical force may be a constant factor that remains the same for any one joint, practitioner and patient combination. With few significant changes in primary measures from one trial to the next, one may think that Hass was right. When considering effect size, however, several large differences are noted. In contemplating the notion that critical force may be a constant factor, it should be taken into account that previous studies have identified a difference in the peak thrust force and force at the time of cavitation[15,20]. It is speculated that the force at cavitation is a more accurate measure of critical force than peak force as used in the present study. Put simply, this means that the authors cannot speculate on the uniformity of the critical forces used in these trials as it would appear that we do not have an accurate representation of them. To investigate this further, future research could replicate this study with the inclusion of simultaneous sound and force recording as performed in previous studies[15, 20]. The prospect of replication brings to light questions of reproducibility, facets of which have already been mentioned such as practitioner and patient weight and psychological factors such as trust and fear. Other factors to consider are the plinth used, due to its presumed dampening of forces recorded due to cushioning and the force platform used.

What can be concluded from the few significant differences in primary measures between trials in this study, regardless of any discrepancies between cavitation and peak thrust force, is that the practitioner appeared to apply roughly the same time/force characteristics in most manipulation attempts. This may indicate that rather than modifying techniques to suit the unique requirements of the joint being manipulated, as is commonly claimed, manipulative therapists repeatedly administer the same generic thrust to the bulk of manipulations. This also supports the idea that using the same practitioner repeatedly ensures the most reliable reproduction of thrust positioning. A factor that must be taken into consideration here, is that the practitioner used in this study was a relatively new graduate. Although he had several years experience with this particular technique, his palpatory skills may be less than that of a practitioner of 10+ years clinical experience. Thus his ability to detect variations in the mechanical requirements of any one joint may be limited.

As previously noted, large effect sizes were reported in some of the primary measure comparisons. This may mean that although not statistically significant, the differences are large enough to elicit the desired outcome. Clinically this has the opposite implication. Perhaps the practitioner has such finely tuned palpatory and manipulative skills that any modifications made to the technique are too precise to be detected by the force platform. Further investigations are again recommended before any valid conclusions can be made. Future research could replicate this study using both an experienced and inexperienced practitioner and comparing the uniformity of their thrust characteristics. A larger participant sample size would also be recommended.

When considering the practical relevance of the statistically significant differences noted in post-thrust dips, it is important to remember that the bulk of cavitations appear to occur prior to peak force. This indicates that this post-thrust dip is unlikely to be an important factor in the production of a cavitation or successful manipulation. As post-thrust dip is measured as a dip below the original preload, the next question to address is whether the significant difference identified is actually a reflection of differences in preload. As previously discussed preload forces appear to be intimately related to the production of a cavitation.

CONCLUSIONS

The only statistically significant difference between successful and unsuccessful thrusts was noted as an increased post-thrust dip in successful manipulations to the non-dominant side. Differences in all other primary measures were deemed to be non significant. This also appears to be the case between the force/time characteristics of thrusts to dominant and non-dominant sides. The practical relevance of this is however questionable.

Effect size data indicates that differences between successful and unsuccessful thrusts need not be statistically significant to produce a successful outcome. In which case, it would appear that preload force and peak thrust force are both intimately related to each other and the successful production of a cavitation. This may be independently or more probably combined in the form of a normalised peak thrust force value. It would also appear that thrust velocity is also intimately related to successful production of a cavitation.

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