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ABSTRACT

Objective: This study investigated the effects of rapid articulation on multiple levels of the costovertebral joints, using a rapid rib raising technique.

Design: The research was conducted as a randomised, cross-over, blinded, placebo controlled study.

Method and Subjects: Thirty asymptomatic participants (age 22.4± 2.75yrs) attended three sessions over a three week period. Measures of sympathetic output included blood pressure, heart rate, respiratory rate and pain pressure threshold and were recorded at the end of each rest and intervention period.

Results: There was a significant increase in respiration rate (*P*=0.00) after rapid articulation when compared to placebo and control groups. No other measures showed significant change.

Conclusion: A rapid rib raising technique, when specifically targeting the sympathetic nervous supply of the lungs, creates an increase in respiration rate, and does not have a significant effect on heart rate, blood pressure or pain pressure threshold.

Keywords: Osteopathy, rib raising, sympathetic nervous system, articulation, mobilisation

INTRODUCTION

Articulation, or mobilisation, is widely used by Osteopaths as a diagnostic and therapeutic technique,[1] however it is unclear how it produces its clinical effects. Numerous studies have examined the physiological mechanisms by which articulation elicits its clinical effects both locally and peripherally,[2-6] with much of this research focusing primarily on how manual therapy of the cervical spine causes an increase in markers of sympathetic function such as heart rate, respiration rate, blood pressure and analgesic measures such as pain pressure threshold. The clinical effects of manual therapy are still unclear when applied to other areas of the spine.

Two theories have been proposed explaining why articulation increases the activity of the sympathetic nervous system (SNS) and are based on the premise that articulation and other manual therapy modalities affect specific parts of the SNS. The first theory is the dorsal periaqueductal grey matter of the midbrain (dPAG) stimulation theory[2-6] and the second, the local sympathetic ganglia activation theory.[3,6,7] The first theory contends that articulation stimulates the dPAG to elicit changes of heart rate, respiration rate, blood pressure and pain pressure threshold. The development of this theory in humans evolved from observations of dPAG stimulation in animal studies by Carrive[8] and Lovick.[9] Stimulation of the dPAG in animal testing showed increased blood pressure, heart rate, respiration rate, analgesia, vascular conductance and muscle blood flow in the hind limbs (sympathoexcitation). Co-ordinated hind tail, jaw and tail movement also occurs with dPAG stimulation in animal research.[9] The results of human studies on the effects of mobilisation on the cervical spine[2,3,5,6] parallel those observed in animal studies conducted by Carrive[8] and Lovick[9], and hence the dPAG was used as a possible explanation of the sympathetic output results observed in humans.

The physiological responses observed during cervical mobilisation include elevated heart rate, respiration rate and blood pressure,[3,5] analgesia[4,6] and sudomotor changes.[6] Only mechanical analgesia is associated with mobilisation of the cervical spine, not thermal analgesia.[5] Mechanical analgesia pathways are non-opioid in nature, are not reversed by naloxone and do not develop tolerance towards stimulation.[10,11] The increase observed in blood pressure in human studies[3-5, 12] occurs due to regional vasoconstriction which is similar to what Carrive's[8] dPAG research observed. Cervical mobilisation has also been demonstrated to increase skin conductance and decrease skin temperature,[2,4,13] both of which are known measures of SNS output, and are caused by reduced cutaneous vasomotor activity.[2] Studies have also reported that the placebo intervention had no notable affect,[2-6] thus indicating that movement of the C5/6 joints is required to elicit similar changes to those noted in the studies by Carrive[8] and Lovick[9]. The dPAG theory has been suggested as the physiological mechanism that causes the change in SNS output observed during cervical spine and upper limb mobilisation.[2-6,14,15]

The local activation theory is that mobilisation directly stimulates local sympathetic fibres due to movement occurring between articular structures.[3,7] This theory states that the increase in heart rate is due to the lower cervical ganglia having sympathetic fibres that are connected with the heart. Manual contact, when applied to the neck, can also affect carotid baroreceptor activity which may also explain the change in blood pressure and heart rate.[3] As the costovertebral joints lie in close proximity to the sympathetic ganglia, and are closely related to the spinal cord, they may be moved in a similar way to neural mobilisation techniques.[7] Because the dPAG only extends as far as the cervicodorsal junction, with only a few fibres reaching T1-2,[16] more research is required to understand the full effects of manual therapy below the cervical spine. Therefore it is important to note that local sympathetic fibre stimulation could play a role in manual therapy below the cervical spine and the theory should not be dismissed.

Mobilisation has also been demonstrated to increase the pain pressure threshold (PPT) in symptomatic participants locally[6] and within the relevant dermatome when mobilising the C5/6 segment.[12] However, PPT is only influenced when mobilisation is applied peripherally to the radiohumeral joint in symptomatic participants and not in asymptomatic participants.[15] It is possible that cervical and costotransverse joint mobilisation may elicit different analgesic affects with the asymptomatic patient, thus further research is required. Mobilisation of the thoracic spine has also been found to be a more effective method for reducing perceived pain when compared to the response immediately following post high-velocity, low-amplitude manipulation (mean increase of 28.42 kPa compared to 11.99 kPa). [17]

Chiu and Wright[2] noted that faster rates of mobilisation (2 Hz compared to 0.5Hz) caused significantly larger skin conductance values, which is consistent with the results reported by Peterson *et al*.[13] Chiu and Wright[2] postulated that the difference between skin conductance values was due to less movement occurring at the cervical joints over a 30 second period, therefore reducing the amount of sympathetic stimulation.

Rib raising is an articulatory treatment technique applied to the costovertebral joints and is said to influence the sympathetic nervous system (SNS) due to the close anatomical relationship to the thoracic sympathetic ganglia[1,18] as they lie anteriorly to costovertebral joint capsule in the paravertebral gutter.[19] Anecdotal evidence states that rib raising will cause either inhibition or excitation of the sympathetic nervous system if techniques are applied at a slow or fast rate respectively, and the response is mediated by the thoracic sympathetic ganglia.[20] However the statement that rib raising will inhibit or excite the SNS can be challenged as other research [2, 13] has shown this is not the case with mobilisation of the cervical spine, but no evidence is available using a specific rapid rib raising technique or the involvement of the thoracic spinal ganglia. A rapid rate increases sympathetic stimulation as demonstrated by Peterson *et al.*[13] and Chiu and Wright[2] when applied to the cervical spine. The slower rate (0.5 Hz) of mobilisation still increases sympathetic stimulation but not to the same extent as noted in the rapid rate

(2 Hz).[2] Clinically it is important to identify any sympathetic nervous system changes that are occurring due to the rapid rib raising technique so its clinical effects can be fully understood.

There has been little research examining the effects of mobilisation/articulation on sympathoexcitation when applied to areas of the spine other than the cervical spine, as well as whether multiple levels of application of these techniques produce a different response. This research aimed to investigate these effects by articulating the costovertebral joints of T1-6 using a rapid rib raising technique and examining its effects on heart rate, respiration rate, systolic and diastolic blood pressure and PPT.

METHOD

Participants

Thirty (N = 30) asymptomatic and apparently healthy participants (age 22.4± 2.75yrs), with no prior exposure to rib raising techniques, were recruited randomly from the student population at Victoria University. Participants were excluded if they presented with any of the pathologies described in Table 1. Written informed consent was obtained prior to testing from each participant and the study was approved by Victoria University Human Research Ethics Committee. Participants were instructed to abstain from stimulants such as cigarette smoking, consumption of substances containing caffeine and performing any exercise at least two hours prior each intervention.

Procedures

The study was conducted as a randomised, cross-over, blinded, placebo controlled study. Volunteers were required to attend three separate days one week apart for approximately 10 minutes. The week break between intervention applications was to ensure a wash out period for each different intervention. Participant's order of treatment was determined by computer randomisation (Figure 1).

The data acquisition researcher was blinded to the type of intervention each participant received and the treating therapist was blinded to the results of each measurement. Participants were not informed of the results of the tests during each of the intervention sessions nor could they see the data acquisition to eliminate the possibility of positive biofeedback

Initially, participants were asked to rest for two minutes. Then the intervention was applied for one minute. The patient then rested again for one minute and the intervention was applied again (one minute) using a similar methodology previously described by Mc Guinness *et al.* [3] and Vicenzino *et al*. [5]

Heart rate was sampled using a finger pulse transducer and respiration rate was measured using a calibrated rubber ruler. Both were recorded using PowerLab/8s (ADInstruments) and was sampled at 20 hertz. Further analysis of respiration rate and heart rate used Chart for Windows software (ADInstruments). Blood pressure (both systolic and diastolic) was measured by a manual calibrated sphygmomanometer and stethoscope. Pain-pressure threshold was measured using a Somedic Algometer Type 2, Sweden. The algometer was applied to T4 spinous process which has an average pain pressure threshold of 324 kPa/cm^2.[21] The algometer was calibrated prior to each measurement being taken with the 2cm tip. Pressure was applied perpendicular to the spinous process of T4 at a consistent and steady rate of 30k/Pa. [17] Three measurements were taken then averaged. All measurements were taken by the data acquisition researcher.

Interventions

Rib raising

A rib raising technique over rib angles 1-6 was performed as the treatment intervention.[22] The participant lay in the supine position and the therapist was seated at the head of the treatment table placing their hands under the patient's ribcage, with fingers contacting on participants rib angles, working from ribs one to six consecutively. The therapist pulled gently cephalad, articulating both the costotransverse and costovertebral joints[22] and was conducted at a rate of two hertz, performed over a one minute period, creating a combined 120 articulations of costovertebral joints T1-6. The rate was controlled by a metronome set to the required rate. This was set on silent to eliminate patient awareness and was visualised by the treating therapist for the whole treatment intervention.

Non-Intervention Group

Participants in the non-intervention group were required to lie supine on the treatment table with the treating therapist contacting the rib angles of ribs 1-6 but not inducing any movement. The treating therapist was also positioned at the head of the table.

Control Group

Participants in the control group were required to lie supine however the treating therapist did not have any physical contact with the participant and was positioned at the head of the table. Both placebo and control interventions followed the same pattern of time and measuring of the outcomes.

Data Analysis

The pre and post experimental condition data was converted into maximum percentage change to enable comparison to Vicenzino *et al.*[5] and McGuiness *et al.*[3] research. This was then statistically analysed using SPSS version 11.0, with an alpha level of $p \leq 0.05$. Five one way ANOVA with a priori contrasts were used to determine the differences in maximum percentage change for the measures of sympathetic output used in this study. A measure of effect size, Cohen's F, was calculated from Vicenzino *et al.*[5] (N=24) research and was determined as being between 0.8125 to 1.208 for respiration rate, blood pressure and heart rate. Using this calculation of effect size, thirty participants were required to gain an approximate power of one in this research.

RESULTS

The mean (±SD) maximum percentage change of heart rate, PPT, respiration rate, systolic blood pressure and diastolic blood pressure is illustrated in Figure 3 and Table 2. Rib raising produced a statistically significant increase in respiration of 53%, ($F_{2,29}$=20.781, *P*=0.00). When compared to the intervention, placebo obtained only a 10% increase (*P*=0.00) and control a 4% increase (*P*=0.00). Partial Eta Squared is reported as 0.719, indicating a very large effect size.

There was an observed change in heart rate for all groups (RR: 7% increase, P: 2% decrease, C: 1% increase), however this was not statistically significant ($F_{2,29}$=2.456, *P*=0.092). A-priori contrasts revealed no statistical significance between placebo (*P*=0.08) and control groups (*P*=0.325) when compared to the rib raising intervention. Partial Eta Squared levels reported at 0.053, indicating a medium effect size.

There were no notable observed changes in systolic blood pressure with only the placebo group increasing (RR: 0%, P: 1% decrease, C: 0%) and there was no statistical significance found between groups ($F_{2,29}$=0.259, *P*=0.773). A priori contrasts also revealed no significant interactions between the placebo group (*P*=0.753) and control conditions (*P*=0.992) when compared to the intervention group for systolic blood pressure. Partial Eta. Squared was reported at 0.006, indicating a very small effect size.

There were also no notable observed changes in diastolic blood pressure, with only the control group showing a small increase (RR: 0%, P: 0%, C: 1% increase) and no statistical significance was reported between groups ($F_{2,29}$=0.349, *P*=0.349). A priori contrasts also revealed that there were no significant interactions between the placebo condition (*P*=0.914) and the control group (*P*=0.571) when compared to the rib raising intervention. Partial Eta Squared values were reported as 0.024 indicating a small to medium effect size.

All PPT groups increased from resting values. PPT was not significantly different between groups ($F_{2,29}$=0.261, *P*=0.771) when analysing maximum percentage change data. The rib raising group exhibited a 10% increase that was determined not significantly different to placebo (6% increase, *P*=0.837) or the control group (11% increase, *P*=0.994). Partial Eta Squared values were 0.006, indicating a very small effect size.

DISCUSSION

This study demonstrated that in a young, healthy, asymptomatic population, rib raising applied to costovertebral joints 1-6 bilaterally at a rate of 2Hz, produces an increase in respiration rate, but does not produce statistically significant change in systolic or diastolic blood pressure, heart rate or pain pressure threshold. The intervention group's increase in respiration rate was also significant when compared to placebo and control.

The observed increase in respiration rate is possibly due to local sympathoexcitation at thoracic vertebrae 1-6 costovertebral joints. As there were no statistically significant changes in the other measures of sympathetic output, it is unlikely that the increase in respiration rate is caused by dPAG stimulation as described by Vicenzino *et al.*[5] and McGuiness *et al*.[3] Therefore rib raising may influence the SNS by movement occurring at the costovertebral joints. The theory proposed by Butler[7] and McGuiness *et al.*[3] suggests that movement of the costovertebral joints influences the thoracic sympathetic trunks. Rib raising of costovertebral joints T1-6 appears to influence respiration rate, possibly due to specifically stimulating the local sympathetic nerves that supply the lungs. An increase in heart rate of 6% that is not significant however is still important and can not be dismissed as incidental due to the shared nerve supply of the heart and lungs (T2-4). A proposed theory as to why a rib raising technique possibly doesn't elicit its effects via the dPAG physiological mechanism is that the dPAG only extends as far as T1-2 and there is no direct link to the Interomedial spinal column which extends through the thoracic spine and lumbar spine that contains the last preganglionic sympathetic nerves.[8,16] This indicates that the dPAG may not be directly involved when manual therapy is applied below the cervical spine and upper limb.

This research produced a greater change in respiration rate when comparing this study's maximum percentage change to other previous works. Vicenzino *et al.*[5] produced a 36% maximum change in respiration compared to 53% increase in the current study. This difference may be accounted for by the different areas of the body that were articulated, because the thoracic area articulated has a larger neural communication to the lungs.[19] McGuiness *et al.*[3] showed a 44% increase in respiration rate which is closer to the findings of this study. Both McGuiness *et al.*[3] and Vicenzino *et al.*[5] used lateral glide mobilisation of grade three oscillations, as described by Maitland[23] who advocates a rate of application of 2Hz. An assumption to be made about the McGuiness *et al.*[3] and Vicenzino *et al.*[5] studies is that they used the rate of 2 Hz making the results theoretically comparable to this study.

The participants did not consciously adapt their respiration rate to the rate of application of rapid rib raising, other wise ther would have been an increase of breathing rate to the same number of articulations per minute, 120. This was not the case.

A comparison can be made to the research of Wheatly *et al.*[24] who investigated the effects of rib raising on lung function. These researchers demonstrated significant improved short term lung function in both asthmatic and non-asthmatic participants by using a rib raising technique. Lung function was measured by FEV_1 and FVC and one of the proposed mechanisms of action was due to a direct stimulation of the sympathetic supply to the lungs. Further research is required to see whether the increase in respiration rate occurs concurrently with the increase in lung function.

Pain pressure threshold demonstrated no statistically significant change when a rapid rib raising technique was applied to asymptomatic participants. This correlates with studies by Vicenzino *et al.*[4] that showed an increase in pain pressure threshold was only observed when spinal mobilisation was applied to symptomatic elbow participants who had peripheral joint mobilisation when compared to the asymptomatic elbow participant. In participants that presented with cervical spinal pain, Sterling *et al*.[6] demonstrated a 23% increase in PPT which is consistent with the findings of Vicenzino *et al*.[12] findings of a 29% increase in PPT in the participant with pain in the elbow who received C5/6 mobilisation. This indicates that by influencing the sympathetic nerve supply of a particular structure that is painful the manual therapist can decrease the pain perceived. This is further supported by Vicenzino *et al*.[15] who demonstrated that hypoalgesia occurred peripherally with 'mobilisation with movement', shown by an increase in PPT at the symptomatic elbow, and not on the asymptomatic side. However, Vicenzino *et al*.[4] demonstrated that with cervical mobilisation of C5/6 there is an increase in PPT at the C5/6 joint in asymptomatic participants. The different results observed in asymptomatic and symptomatic participants could be attributed to the different area of the body that were mobilised, as Vicenzino *et al*.[4] used cervical mobilisation to influence a change on fore quarter pressure at the elbow, and Vicenzino *et al*.[15] used mobilisation with movement of the elbow joint.

Changes in PPT in the current study were different from those described by Fryer *et al*.[17] The average percentage change in the Fryer *et al*.[17] study was as 28.42 kPa (P<0.01) compared to our maximum percentage change of 105.63 kPa (P=0.879). A possible explanation for this result was that Fryer *et al*.[17] used asymptomatic participants and their most symptomatic segments and not asymptomatic participants with the same segment tested every measurement, as utilised in this research. Fryer *et al*.[17] also used average percentage change, and not maximum percentage change, which makes comparison difficult.

No statistically significant change was demonstrated between groups in regards to heart rate, systolic and diastolic blood pressure in asymptomatic participants. Heart rate and systolic blood pressure have all been shown to increase with single cervical spine mobilisation.[3,5] Vicenzino *et al.*[5] demonstrated a 13% increase in heart rate, which is further confirmed by McGuiness *et al.*[3] who obtained a 10.5% increase in heart rate compared to our maximum percentage change of 6%, which was not statistically significant but comparable. However the large standard deviation in the placebo group could be a confounding factor as to why heart rate did not reach statistical significance. The difference observed between these three studies is that this current research specifically targeted the lungs sympathetic nerve supply, T1-

6.[19] and not the cardiac nerve supply. A possible explanation of the comparable responses of heart rate between these three studies could be due to rib raising influencing the T2-4 nerve roots. These was not targeted specifically but were influenced due their shared nerve supply of T2-4[19] with the lungs. These levels did not receive as many articulations as the other areas, and was not repeatedly stimulated. This could also be a reason why the heart rate only increased slightly, but did not reach statistical significance.

Contrasting blood pressure changes within different research reinforces the differences noted between Vicenzino *et al.*[5] and this research as the results of both are not comparable. Vicenzino *et al.*[5] noted a 14% increase for both systolic and diastolic blood pressure and McGuiness *et al.*[3] a 12.5% increase in diastolic blood pressure and a 4.5% systolic blood pressure. This indicates that the dPAG is not the likely physiological action used to create the change in respiration rate in this case as otherwise there would be a concurrent increase in both systolic and diastolic blood pressure, heart rate and pain pressure thresholds. Hence it can be postulated that local sympathetic pathways were used to create the observed response in measures of sympathetic output.

A change in systolic blood pressure has also been shown after application of an upper cervical adjustment. Systolic blood pressure immediately decreased by 10.9mm Hg. in elderly patients.[25] This was deemed statistically significant ($P<0.001$) and this is not comparable to this study. In a similar study to Knutson[25], Purdy *et al.*[26] found that touching, massage or manipulation of the suboccipital muscles and joints lead to a decrease in pulse amplitude and height. Celander *et al.*[27] also showed that upper thoracic manipulation decreased systolic blood pressure, had an unknown effect on diastolic blood pressure and also caused a decrease in blood levels of plasma fibrinogen and in this case indicates an increase in tone of the parasympathetic nervous system, a known physiological response.[27] The previous study's results can not be compared to the current investigation as the applications of joint movement are applied at different rates and also have different qualities. However it is interesting to note the differences observed in regards to sympathetic output, which in manipulation the output is decreased. It has also been proposed that manipulation uses a different physiological pathway to create change, namely the cervicosympathetic reflex or the pressor reflex[25] which is due to the different type of movement of manipulation (high velocity and low amplitude with one repetition) compared to articulation (many, low velocity and high amplitude).

Vicenzino *et al.*[5] and McGuiness *et al*.[3] obtained results by mobilisation of the cervical spine, supporting the theory that costovertebral joints use a different mechanism to elicit cardiac sympathetic changes when compared to the cervical spine. This is further supported by the dPAG only extending as far as the cervicodorsal region[16].

Peterson *et al.*[13] postulated that different amounts and qualities of movement could cause different levels of sympathoexcitation. Chiu and Wright[2] supported this postulation by demonstrating that a low level rate of application of 0.5 Hz did not produce as much change in skin conductance as the rate of 2Hz due to a decrease amount of movement occurring within the joint. Skin temperature was not shown to be significantly altered. However Kappler and Kelso[28] showed that with manipulation of the T2-5 thoracic segments skin temperature does increase within the relevant dermatome. This difference in results could be due to the different types of application of movement within the joint, as manipulation is applied only once and at a greater velocity than mobilisation, hence is a different type of quality and this needs further investigation.

Most of the previous research mentioned is based on the cervical spine, where as this research is based on the thoracic spine. A comparison must be made between the two even though different areas of the spine where mobilised as there is no previous research completed on the thoracic spine.

Conclusion

The present study demonstrated a change in respiration rate and heart rate, although the latter was not significant, following the application of rib raising to the costotransverse joints of ribs 1-6 at a rate of 2Hz, in young asymptomatic participants. It is suggested that further research be undertaken to determine whether similar results would be obtained in a symptomatic population that were determined to have a thoracic dysfunction, and also whether the application of other techniques (eg. HVLA manipulation) has a similar effect. The addition of other indicators of sympathetic function (eg. skin conductance) may also be useful. This research contributes further knowledge to the expanding area of manual medicine, and aids in an evidence based approach to treatment techniques.

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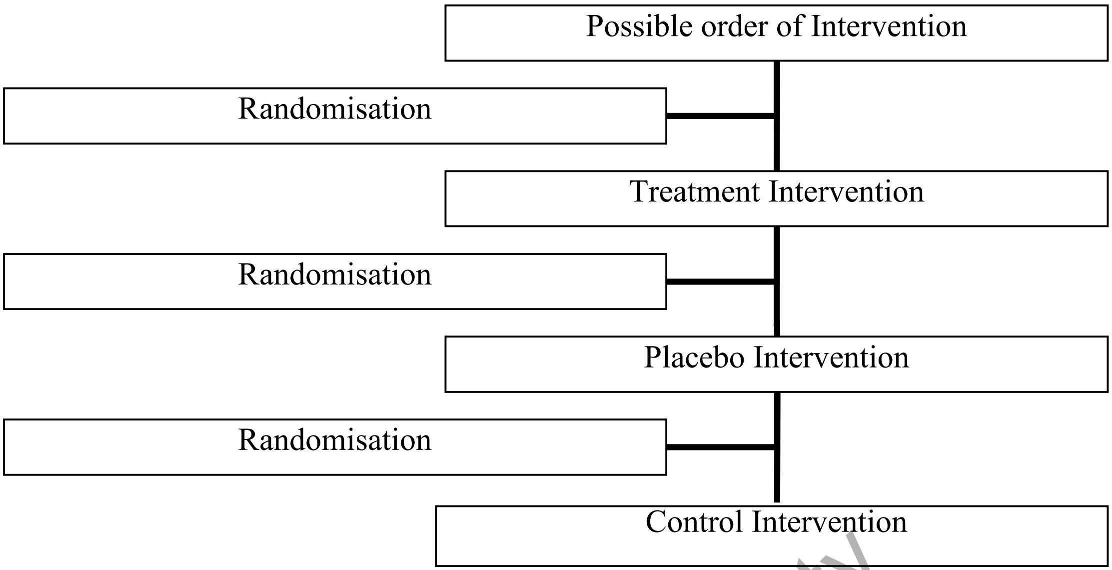
Category	Pathology
Spinal pain	Thoracic or cervical pain Degenerative joint disease Inflammatory spondyloarthropathies
Cardiac pathologies	Hypertension Cardiac arrhythmias Any participant taking heart related medications
Respiratory pathologies	Uncontrolled asthma
Long term corticosteroid users	Chronic asthma Chronic eczema
Treatment	No manual therapy treatment was to be undertaken throughout the testing period
Neurological pathologies	Any condition effecting the autonomic nervous system such as multiple sclerosis

Table 1. Study exclusion criteria

Figure 1. Computer randomisation and Possible order of intervention



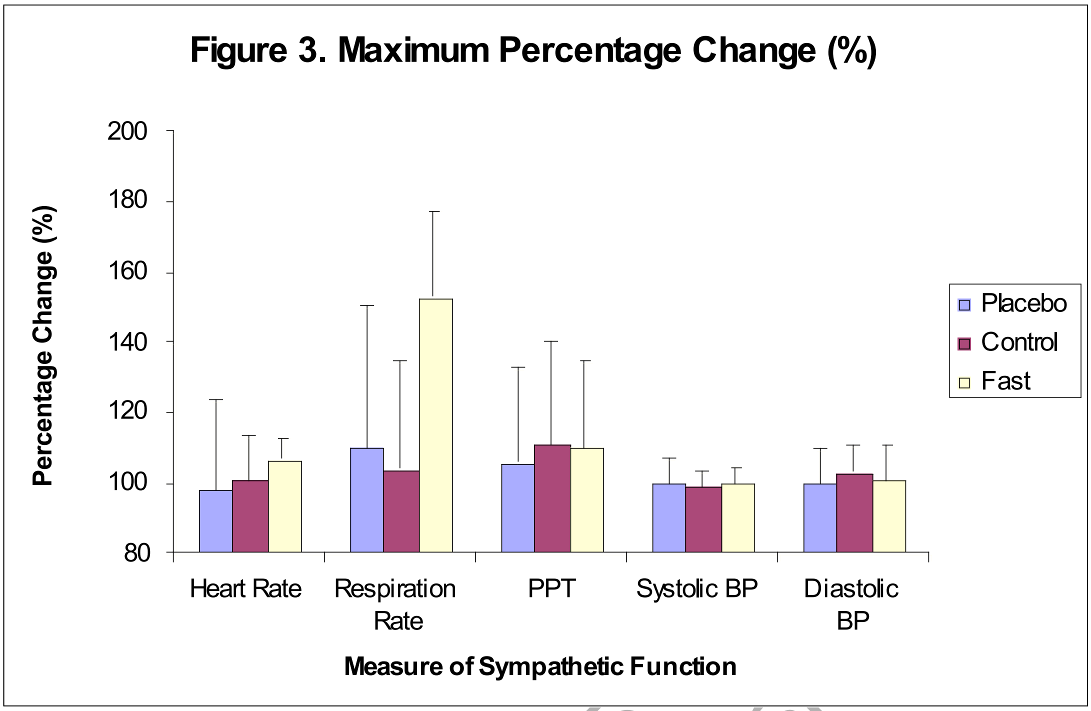


Figure 3. Maximum Percentage Change (%)
Percentage Change (%)
200
180
160
140
120
100
80
Heart Rate
Respiration Rate
PPT
Systolic BP
Diastolic BP
Measure of Sympathetic Function
Placebo
Control
Fast

	Intervention	Placebo	Control
Respiration rate	40.0	24.5	30.5
Heart rate	25.20	5.9	12.4
Systolic BP	6.9	4.6	4.1
Diastolic BP	9.5	9.6	7.5
PPT	26.8	24.3	29.5

Table 2. Standard Deviation of maximum percentage change for dependent variables