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### **How to cite this minor dissertation**

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## **COVER LETTER**

This is an original journal article and is not under consideration for publication in another pre-reviewed medium.

I intend to submit this journal article to the Journal of Chiropractic Medicine. It should be considered to be published. The study is titled “**The Effects of Cervical Spine Manipulation on Pressure Pain Threshold and Pinprick Sensitivity**”

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## **ETHICAL CLEARANCE**



### **FACULTY OF HEALTH SCIENCES RESEARCH ETHICS COMMITTEE**

NHREC Registration: REC 241112-035

### **ETHICAL CLEARANCE LETTER (RECX 2.0)**

Student/Researcher Name	Murtagh, K	Student Number	201011052
Supervisor Name	Dr DM Landman	Co-Supervisor Name	-
Department	Chiropractic		
Qualification	367		
Research Title	The Effects of Cervical Spine Manipulation on Pressure Pain Threshold and Pinprick Sensitivity		
Date	01 February 2019	Clearance Number	REC-01-186-2018

Approval of the research proposal with details given above is granted, subject to any conditions under 1 below, and is valid until 31 January 2020.

**1. Conditions:**

None.

**2. Renewal:**

It is required that this ethical clearance is renewed annually, within two weeks of the date indicated above. Renewal must be done using the Ethical Clearance Renewal Form (REC 10.0), to be completed and submitted to the Faculty Administration office. See Section 12 of the REC Standard Operating Procedures.

**3. Amendments:**

Any envisaged amendments to the research proposal that has been granted ethical clearance must be submitted to the REC using the Research Proposal Amendment Application Form (REC 8.0) prior to the research being amended. Amendments to research may only be carried out once a new ethical clearance letter is issued. See Section 13 of the REC Standard Operating Procedures.

**4. Adverse Events, Deviations or Non-compliance:**

Adverse events, research proposal deviations or non-compliance must be reported within the stipulated time-frames using the Adverse Event Reporting Form (REC 9.0). See Section 14 of the REC Standard Operating Procedures.

The REC wishes you all the best for your studies.

Yours sincerely,

A handwritten signature in black ink, appearing to read 'C Stein'.

Prof. Christopher Stein  
Chairperson: REC  
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# THE EFFECTS OF CERVICAL SPINE MANIPULATION ON PRESSURE PAIN THRESHOLD AND PINPRICK SENSITIVITY

A research dissertation presented to the Faculty of Health Sciences, University of  
Johannesburg, as partial fulfilment for the Master's degree in Technology, Chiropractic  
by

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Date: 15/7/2019

## THE EFFECTS OF CERVICAL SPINE MANIPULATION OF PRESSURE PAIN THRESHOLD AND PINPRICK SENSITIVITY

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### **ABSTRACT**

**Purpose:** The aim of this study was to analyse the potential effects of cervical spine manipulation on experimental mechanical pain, locally and remotely, in asymptomatic individuals. Mechanical pain tested pressure pain threshold (PPT) and pinprick sensitivity (PPS), before and after left- or right-sided cervical spine manipulation.

**Method:** This was a single blind, randomised study consisting of 100, healthy male and female participants between the ages of 18 - 65 years. Random allocation into two even groups; group A (control group) and group B (intervention group) required a once-off consultation. Objective data was collected using the Wagner's Pressure Algometer to measure deep mechanical stimuli. Subjective data was collected from the same locations using the Owen Mumford's Neuropen and tip to measure superficial sharp mechanical stimuli. Mechanical stimuli were applied at bilateral remote points on the medial calf and bilateral local points on the paraspinal muscles of the respective cervical spine level. Data was collected over three time intervals and analysis conducted using non-parametric tests. Within the time frame, group B participants received a cervical spine manipulation and readings between groups compared to assess for spinal manipulative therapy (SMT) influence. Inter-analysis using the Mann-Whitney test and intra-analysis using the Friedman test and Wilcoxon Signed Ranks test were used to analyse the changes.

**Results:** Statistical and clinical changes were noted for PPT and pinprick sensitivity for the intervention group who received spinal manipulation. These differences were noted at local and remote regions tested by the algometer and Neuropen. These findings suggest that cervical spine manipulation may have had an effect on the central nervous system and pain modulation. Cervical spine manipulation reduced deep pressure sensitivity significantly for the intervention group with local and remote effects noted over the ten minute time interval. It was also noted that cervical spine manipulation reduced pain sensitivity for superficial pinprick stimuli, with notable changes for the intervention group, both locally and remotely, over the ten minute time interval.

**Conclusion:** According to all data discussed and changes noted for both pinprick sensitivity and pressure pain threshold, it can be deduced that chiropractic spinal manipulation does influence the pain sensitivity elicited by the algometer and the Neuropen. In this deduction SMT decreased pain sensitivity for superficial, sharp pain and deep mechanical pain with immediate hypoalgesic effects, locally and remotely.

**Key Words:** Chiropractic manipulation, cervical spine, mechanical stimuli, pressure pain threshold, pinprick sensitivity, neurophysiological effects.

## **INTRODUCTION**

Chiropractic plays an integral role in the conservative treatment and management of neuro-musculoskeletal conditions that cause pain. Chiropractors and osteopaths are the two principal health care professionals specialised in this form of manual therapy as an intervention for patients suffering from pain.<sup>1</sup> The worldwide prevalence of neck pain is on the incline.<sup>2</sup> The demand for cost-effective, non-invasive treatments is increasing, especially in South Africa, where more than 82 in 100 people are dependent on public health services and government financial support for illness and disease.<sup>3,4</sup>

Clinical evidence of spinal manipulative therapy (SMT) for pain relief related to neuro-musculoskeletal causes is apparent, yet the mechanisms responsible are still not clearly understood. Given the paucity of evidence-based clinical research determining the direct neurophysiological effects of chiropractic manipulation, further investigation is warranted.<sup>5</sup> Some researchers propose that spinal dysfunction may be linked to altered afferent input to the central nervous system.<sup>6</sup> Several theories have suggested both central and peripheral mechanisms are involved in spinal manipulation. These studies used varying types of stimuli and suggested that SMT effects the nervous system at multiple levels thus relieving pain.<sup>6</sup>

In the Journal of Pain, Bialosky et al. (2014) suggest that SMT is associated with vicissitudes in pain sensitivity. This is because SMT alters the afferent input of nociceptive fibres or central nervous system interference resulting in modulation of pain and central sensitisation. Several researchers propose that SMT affects all modulating systems, including the central nervous system.<sup>11</sup>

PPT has been extensively tested for changes following chiropractic manipulation. However, PPS, has not. Clinical research on this form of experimental mechanical pain can provide much needed insight on the neurological component of SMT adding to its clinical significance as a conservative treatment method.<sup>7,8,9</sup>

SMT is a manual therapy applied to restricted joints to improve biomechanical function and elicit a neurological effect.<sup>11</sup> This neurological effect is proven to occur locally with mechanoreceptor activity influencing nociceptive input to higher centres, but this effect may also occur remotely, indicating central nervous system involvement, therefore, in turn, remote mechanical pain responses would be altered.<sup>5,6,10</sup>

It is possible that SMT applied to the lower cervical spine influences pain sensitivity, with local and remote effects.<sup>8</sup> Neck related problems are a common complaint giving persons reason to seek Chiropractic care.<sup>2</sup>

This research will therefore assist in determining the neurological effects of Chiropractic manipulative therapy targeted at the cervical spine in the presence of two different forms of mechanical stimuli. It may highlight underlying mechanisms involved in SMT and its role in facilitating nervous system physiology. As the effects of the intervention were assessed locally and remotely, this study may contribute to a better understanding of the neurophysiological impact of SMT on PPT and PPS.

## **METHOD**

### **Ethics**

This study was approved by the University of Johannesburg's Health Sciences Faculty Research Ethics Committee (NHREC reg: REC241112-035) on 1 February 2019 (REC-01-186-2018) and was conducted between March and April 2019 at the University of Johannesburg's Chiropractic Clinic.

### **Study Design**

This study was a single-blind randomised trial. Participants were recruited by word of mouth from the University of Johannesburg, Doornfontein campus where the study was conducted. A total selection of one hundred male or female participants between the ages of 18-65 years were recruited for the study (n=100) and was at random. Refer to Figure 1 (CONSORT diagram) outlining the study design.

### **Selection Criteria**

Participants were screened to check inclusion and exclusion criteria before full assessment was done. Each participant voluntarily took part, having read the information letter outlining the purpose, protocols and procedures of the research study and informed consent was given by each before beginning the assessment.



## **Inclusion Criteria**

To be included in the study, participants could be male or female but should be 18 to 65 years. As the study was conducted to assess nerve pain responses the patient needed to be healthy and pain-free with asymptomatic cervical spine motion restriction of a minimum of one spinal segment between and inclusive of C4-C7 spinal levels (right or left sided, identified by motion palpation).

## **Exclusion criteria**

Participants were excluded from the research if there was a complaint of acute, subacute or chronic neck pain; a history of spinal or lower limb surgery, trauma or chronic illness (i.e. cancer/HIV) that may have caused nerve damage or injury (i.e. hypoalgesia/hyperalgesia). Any neurological abnormality or disease causing abnormal sensory perception such as central nervous system diseases (Huntington's disease, Multiple Sclerosis, Parkinson's disease), or peripheral nervous system diseases (diabetes, vitamin deficiencies). Participants were also excluded if there had been intake of nervous system depressant or suppressors in the past 24 hours. Participants were also screened for contra-indications to SMT or red flag signs/symptoms that would exclude them.

## **Once-off Visit**

Each participant was given an information letter pertaining to the research study to be conducted, as well as a thorough verbal explanation. They were instructed to read the information letter and give written consent thereby confirming they had full knowledge of the procedure and protocols that would be conducted for the research study. A comprehensive case history was taken, a full physical examination conducted and a cervical spine regional completed. Motion palpation carried out on the cervical spine identified restricted segments and paraspinals that were tested as well as for the intervention applied (group B). Participants were marked with a non-permanent marker at all four locations for both groups: a) mid-portion of the medial head of gastrocnemius muscle, bilaterally, and b) C4-C7 paraspinal muscles, bilaterally, respective to the level of motion restriction.

These locations were modified from Dorron et al.'s (2016) research study on lumbar spine manipulative therapy intervention effects on PPS and PPT.

First readings for PPS were done systematically at the four points with the Neurotip and Neuropen. Immediately post- PPS data was collected, PPT readings were taken in a synonymous order (data recorded at 0-minutes). Readings were then retaken at 2-minutes, (immediate post-intervention for group B), then 10-minutes (group B post-intervention), in a synonymous order as initial readings. PPS data was collected first at each time interval to limit tissue distortion caused by the pressure algometer.

The Owen Mumford Neuropen and Neurotip was used to measure pinprick sensitivity stimulates superficial, small, A-delta nociceptive fibres. The Neurotip used per participant was a single use, sterile pin that uses a standardised, repeatable, calibrated 40 gram force, which was applied by the researcher at each location.<sup>12,13,14</sup> Each participant would indicate on a numerical sharpness scale after each reading. In a research study on the effects of lumbar spine manipulation on PPT and PPS, locally and remotely, Dorron et al. (2016) verified this device as a reliable measuring tool and that standardised testing and application was reproduceable thus validating the device as a quantifiable tool to test changes in sensory input to sharpness.<sup>8</sup>

The Wagner pressure algometer (2cm diameter algometer tip) was used to measure PPT and stimulates deep, A-delta and C nociceptive fibres. PPT was determined as the point of discomfort and therefore tissue distortion that was reached when the participant vocalised that pain/discomfort was first felt. This was indicated as a value on the gauge indicating kilograms of force applied (kgf/cm<sup>2</sup>) at each point. Each PPT set of readings was done following PPS, with identical application to point of contact. The repeatability and reliability of the Wagner pressure force gauge to measure pain and pain threshold had been proved and validated by researchers in studies published in medical, osteopathic and chiropractic associated journals.<sup>15,16</sup>

Group B participants received intervention manipulation by the researcher who utilised cervical break and rotary thumb techniques, participant dependant. Only segments below C3 were included and manipulated to limit possible involvement of trigemino-cervical nucleus.<sup>16</sup>

Data analysis included descriptive statistics where inter- and intra-analysis was performed. Data collected for PPS and PPT was recorded at three-time intervals: 0-minutes (reading one/pre-intervention), at 2-minutes (second reading/post-intervention) and 10-minutes (last reading/post-intervention). All data collected by the researcher was analysed with the assistance of a STATKON statistician (University of Johannesburg). Non-parametric testing was used for inter- and intra-analysis. The normality of variables was checked using the Kolmogorov-Smirnov test.

Intragroup analysis consisted of comparative tests done within each group and statistical analysis compared each participant's readings at each point over time intervals; 0-minutes, 2-minutes and 10-minutes. The non-parametric test chosen for this analysis was the Friedman Test because three time periods needed to be compared. A further non-parametric test, the Wilcoxon Signed Ranks Test, was done to interpret the relationship between time frames to ascertain at which interval the greatest change occurred within group A. Comparative analysis was completed between initial and second reading, second and last reading as well as initial and last readings. At this point of analysis, the Bonferroni adjustment was applied to ensure accuracy and to limit errors of statistical significance, specifically with multiple comparative tests or more than one set of variables being tested. This lowers the alpha value that was used to justify significance for the Wilcoxon Signed Ranks Test, as p-value being  $\leq 0.017$ .

Intergroup analysis was also performed to assess for statistical significance between the groups for both variables. This was done using Mann-Whitney tests. P-value was set as 0.05 for the purpose of these statistics. This numerical value allows for efficient representation of the value of data captured. Less than or equal to 0.05 is considered statistically significant and is shown as  $p \leq 0.05$ , whereas greater than 0.05 is not and is shown as  $p > 0.05$ . For the purpose of this analysis Bonferroni adjustment was applied to limit errors of statistical outcomes as a large number of readings needed to be compared (p-value  $< 0.17$ ).

## **RESULTS**

Participants in group A ranged from 18 years to 65 years of age with a mean age of 29.8 years. Participants in group B ranged from 20 years to 65 years of age, with a mean age of 32.1 years.

Each group consisted of fifty participants, group A consisted of thirty females (60%) and twenty males (40%). Group B consisted of twenty females (40%) and thirty males (60%). Therefore within the research study fifty participants were female (50%) and fifty participants were male (50%).

Utilizing tests stipulated earlier analysis of the data sets were conducted for PPS at each region and PPT at each region. Comparison between PPS readings taken over time for percentage change at the right cervical region was done, refer to table 1. The intervention group mean values had a bigger change than the control group A. The control group had a decreased sharpness from the initial reading to second reading by 8.5%. The intervention group had a 12.2% decrease in sharpness between the two readings. The control group sharpness rating only decreased by 4.3% to the last reading and did not have statistical significance as the p-value was 0.033 (p-value > 0.017), whereas the intervention group decreased by a significant 49% between the two time frames. The comparison between the initial and final readings revealed that group A had a decreased sharpness by a total of 12%, whereas the intervention group had a decreased sharpness by a total of 55%. All other respective readings had statistically significant decreases at each time interval (p-value < 0.017).

Comparisons between PPS readings taken over time for percentage change at the left cervical region were done, refer to table 1. The intervention group mean values had a bigger change than the control group A. The control group had a decreased sharpness of 12% from the initial reading to the second reading. The intervention group had a 21% decrease in sharpness between the two readings. The control group sharpness rating only decreased by 5.8% to the last reading whereas the intervention group decreased by a significant 45% between these two readings. The comparison between the initial and final readings revealed that group A had a decreased sharpness by a total of 17%, whereas the intervention group had a decreased sharpness by a total of 57%. All readings had statistically significant decreases at each time interval (p-value < 0.017).

The Mann-Whitney test had been conducted on data for the cervical spine region pinprick sensitivity with statistically significant differences noted between groups. These differences were noted between the groups at the right cervical region at the last reading with a p-value of 0.000 (p-value < 0.017), with a large effect size. Statistically significant differences were also noted at the left cervical region for the last reading with a p-value of 0.000 (p-value < 0.017), with a large effect size.

Statistical significance was noted for PPS between time intervals ( $p\text{-value} \leq 0.017$ ) for right and left calf regions, refer to table 2, therefore noting little to no change for the control group. The intervention group changes were noted between initial, second and last readings with a synonymous  $p\text{-value}$  of 0.000 ( $p \leq 0.017$ ). It was noted that the biggest change occurred 10-minutes after intervention had been applied. Comparison between PPS readings taken over time for percentage change at the right calf region was done. The intervention group mean values have a bigger change than the control group A. The control group had a 15% decrease in sharpness between the initial and the second reading. The intervention group had a 19.8% decrease in sharpness between the two readings. The control group sharpness rating only decreased by 5.8% between the second and last reading whereas the intervention group decreased by a significant 41% between the two time frames. The comparison between the initial and final readings revealed that group A had a decreased sharpness by a total of 17%, whereas the intervention group had a decreased sharpness by a total of 52%. All respective readings had statistically significant decreases at each time interval ( $p\text{-value} < 0.017$ ).

Comparison between PPS readings taken over time for percentage change at the left calf region was done, refer to table 2. The intervention group mean values had a bigger change than the control group A. The control group had a decrease in sharpness from the initial reading to the second reading by 14%. The intervention group had a 19.9% decrease in sharpness between the two readings. The control group sharpness rating decreased by 19% between the second and last reading whereas the intervention group decreased by a significant 33.5% between these two readings. The comparison between the initial and final readings revealed that group A had a decreased sharpness by a total of 30.6%, whereas the intervention group had a decreased sharpness by a total of 46.7%.

The Mann-Whitney test was conducted for overall statistical analysis of data for intergroup differences. The medial calf region pinprick sensitivity ratings between groups had statistically significant differences. These differences were noted between the groups at the initial reading on the left and right calf with a  $p\text{-value}$  of 0.000 ( $p\text{-value} < 0.017$ ). The right calf comparison at 0-minutes had a small to medium effect size and the left calf comparison at 0-minutes had a medium effect size.

Comparison between PPT readings taken over time for percentage change at the right cervical region was done, refer to table 3. The intervention group mean values have a bigger increase in PPT than the control group A.

The control group had an increased threshold of 2.8% from the initial reading to second reading. The intervention group had a 31.5% increase in threshold between the two readings. The control group only had a 1.5% increase in threshold between the second and last interval. The intervention group increase was also marginal with an increase of 5.3% between the two time frames. The comparison between the initial and final readings revealed that group A had an increased PPT by a total of 4.4% whereas the intervention group had an increased PPT by a total of 38%. All other respective readings had statistically significant increases at each time interval ( $p\text{-value} < 0.017$ ).

Comparison between PPT readings taken over time for percentage change at the left cervical region were calculated using mean value differences, refer to table 3. The intervention group mean values have a bigger difference between time intervals than the control group A. The control group had a surprising 1.8% decrease in PPT from the initial reading to the second reading whereas the intervention group had a significant 27% increase in PPT between the two readings. The control group then increased by 2.7% between the second and the last reading. The intervention group increased by a marginal 5.9% between these two readings. The comparison between the initial and final readings revealed that group A had an increased PPT by a total of 0.8% whereas the intervention group had an increased PPT by a total of 34%. All readings had statistically significant changes that occurred between each time interval analysed ( $p\text{-value} < 0.017$ ).

The Mann-Whitney test was conducted for overall statistical analysis of data for intergroup differences. The cervical spine region comparative testing for PPT had statistically significant differences between the groups. These differences between groups were noted at several intervals. The right and left cervical region comparison of data from the second reading was statistically significant with a  $p\text{-value}$  of 0.000 ( $p\text{-value} < 0.017$ ) for both the left and right regions. There was a large effect size noted for the left and right side, indicating clinical significance of data collected for PPT and potential effect of the intervention. Significant differences were also noted at left and right cervical regions for the last reading with a  $p\text{-value}$  of 0.000 ( $p\text{-value} < 0.017$ ), with a large effect size.

Comparisons between PPT readings taken over time for percentage change at the right calf region were done, refer to table 4. The intervention group mean values have a bigger increase in PPT than the control group A. The control group had an increased threshold of 1.2% from the initial to the second reading.

The intervention group had a 21% increase in threshold between the two readings. The control group only had a 2.6% increase in threshold between the second and last interval, yet the intervention group increase was also marginal with an increase of 3.9% between the two time frames. The comparison between the initial and final readings revealed that group A had an increased PPT by a total of 3.8% whereas the intervention group had an increased PPT by a total of 46.7%. All respective readings had statistically significant increases at each time interval ( $p\text{-value} < 0.017$ ).

Comparisons between PPT readings were taken over time for percentage change at the left calf region, refer to table 4. The intervention group mean values have a bigger difference between time intervals than the control group A. The control group had a 2.9% increase in PPT from the initial reading to the second reading whereas the intervention group had a significant 22.7% increase in PPT between the two readings. The control group then increased by 1.4% between the second and the last reading. The intervention group increased by a marginal 3.7% between these two readings. The comparison between the initial and final readings revealed that group A had an increased PPT by a total of 3.7% whereas the intervention group had an increased PPT by a total of 27.5%.

The Mann-Whitney test was conducted for overall statistical analysis of data for intergroup differences. The calf region comparative testing for pressure pain threshold had statistically significant differences between groups. These differences between groups were noted at several intervals. The second reading on the right and left calf regions had statistically significant differences noted between the groups. The right calf had a  $p\text{-value}$  of 0.002 ( $p\text{-value} < 0.017$ ), with a medium effect size and the left calf region had a  $p\text{-value}$  of 0.000 ( $p\text{-value} < 0.017$ ), also concluded with a medium effect size. Statistically significant differences were also noted for the last readings for both the right and left calf regions with  $p\text{-value}$  as 0.000 ( $p\text{-value} < 0.017$ ). Both comparisons at the last reading (10-minutes) had a medium to large effect size.

## **DISCUSSION**

Depicted changes in sharpness rating to pinprick stimuli applied to the respective cervical spine level were analysed. There were statistically significant decreases of sharpness sensitivity at the left and right region over time and this was noted within both groups.

But it was deduced after analysis of all results that pinprick sensitivity decreased over the 10-minute time frame, with the intervention group responding with a greater decrease in sharpness sensitivity at the global cervical region 10-minutes after spinal manipulation was applied.

Depicted changes in sharpness rating to pinprick stimuli applied to the medial head of the gastrocnemius muscle (medial calf region) were analysed. There were statistically significant decreases of sharpness sensitivity at the left and right regions over time and this was noted within both groups. All readings had statistically significant decreases at each time interval ( $p\text{-value} < 0.017$ ). Therefore, it should be noted that the greatest change in PPS ratings occurred for the intervention group, on the left and right calf regions, immediately after intervention was applied. The control group change occurred mainly at the left calf region between the second and last readings.

Depicted changes in PPT by the application of blunt mechanical stimuli applied to the respective cervical spine level were analysed. Statistically significant increases were noted at the left and right region over time and this was noted within both groups.

It can therefore be deduced from the results that PPT increased over the 10-minute time frame at the cervical regions. The control group had very marginal changes and though statistically significant, the data is not clinically significant outside of comparative data for the intervention group. As no intervention was applied, it is suspected that tissue distortion from the device tip stimulated local receptors in the tissue layers that created a mild increase in PPT in the area. The intervention group responded with a greater increase in PPT at the cervical region, specifically noted at the last reading, 10-minutes post-intervention application.

Depicted changes in PPT by the application of blunt mechanical stimuli applied to the medial calf region were analysed. There were statistically significant increases noted at the left and right region over time and this was noted within both groups.



It should also be noted that the greatest change in PPT readings occurred for the intervention group, on the left and right calf regions, 10-minutes after intervention was applied with little change that occurred immediately after intervention application. It is also noted that little change occurred over time for readings for the control group. All readings had statistically significant changes that occurred between each time interval analysed ( $p\text{-value} < 0.017$ ).

It can therefore be deduced from the results that the increased PPT occurred over the 10-minute time frame. Noted small changes occurred over the time intervals for the control group, yet these were not clinically significant changes. The intervention group responded with a greater increase in PPT at the calf regions 10-minutes after spinal manipulation was applied, indicating clinical significance of the data collected.

A limitation of this study would be that there have not been many research studies on PPS, and potential effects of manual therapies such as mobilization. Further studies should assess the effects of other manual therapies comparative to SMT, with a control group to further enhance the understanding PPS and how reliable it was in assessing central nervous system mechanisms. Another limitation was limited research on mechanical sensory stimuli (not limited to mechanical), therefore further tests using multiple stimuli should be assessed. PPS having not really been assessed in a clinical setting limited literature to review in order to compare results. Therefore, future studies should assess PPS with other manual therapies to assess PPS response.

With reference to data analysed in this research study, it should be noted that to eliminate the aforementioned limitations, this research study consisted of two devices that elicited a response from different components of the nervous system: pinprick sensitivity stimulating superficial A-delta nociceptive fibres and PPT stimulating both A-delta and deep C nociceptive fibres. These two devices were also assessed at multiple locations on each participant; local to the area where spinal manipulation was applied, as well as remotely at bilateral regions on the lower limbs. The remote sites specifically were of value as these readings assisted in determining if the manipulation had central modulation effects.

This study was adapted from a previous study carried out by Dorrón et al. (2016)<sup>8</sup> that assessed the effects of lumbar spinal manipulation at multiple regions of the body for both pinprick sensitivity and pressure pain threshold.

Pinprick sensitivity has not been a widely used device, especially with reference to manual therapy research. Dorrón et al. (2016)<sup>8</sup> tested this device with relation to the lumbar spinal manipulation and its effects on pinprick sensitivity and pressure pain threshold, locally and remotely. Study outcomes for the lumbar spinal manipulation revealed a decrease in sharpness rating and pain sensitivity to pinprick stimulation, with systemic responses. This coincides with the outcomes of this research study.

It was noted that statistically significant differences occurred for both groups, but a greater effect on pain sensitivity was noted after spinal manipulation had been applied to the intervention group, with the highest decrease occurring 10-minutes after the intervention had been applied. These results were identified at local and remote regions tested for group B. A possible reason for the result outcomes of systemic decrease in sharpness rating and pain sensitivity is the central influences activating modulatory mechanisms, previously mentioned in the literature review, as a result of the spinal manipulation influencing the central nervous system, either directly or indirectly.

Multiple research studies and systematic reviews focused on PPT as the only experimental sensory modality tested.<sup>6,7,8,9</sup> The consensus of results concluded the same findings as this research study.

PPT has been a more commonly utilised device to assess effects of spinal manipulation on experimental pain as identified in Coronado et al.'s (2012)<sup>10</sup> systematic review and meta-analysis. It was evident that after a comprehensive review of cervical spinal manipulation and potential effects on the PPT, that previous research studies had synonymous outcomes of an effect increase in the PPT following a spinal manipulation.<sup>5,6,8</sup>

It should be noted that for this research study there were significant increases in PPT at all regions tested, with group B having a greater increase over time than group A. Statistically significant differences were noted within group B for both post-intervention readings and intergroup comparative analysis, with medium to large effect sizes between groups, locally and remotely. These outcomes for PPT demonstrate and further support the probability of central nervous system involvement and the influence of spinal manipulation on pain modulatory mechanisms and higher centres as earlier mentioned in the literature review.

## **CONCLUSION**

This research study showed that spinal manipulative therapy applied to the lower cervical spine did influence pain sensitivity, with local and remote responses. As a result of this research study, the neurological effects of manipulative therapy targeted at the cervical spine in the presence of two different forms of painful mechanical stimuli were identified, with statistically significant changes that had occurred.

The intervention group demonstrated clinical changes to both pinprick sensitivity and pressure pain threshold, with statistical significance identified at these respective changes. The control group had minor changes of pinprick sensitivity readings as well as pressure pain threshold readings, but most were not statistically significant. The changes of the control group may have been caused by tissue sensitisation due to mechanical stimulation of receptors at the location being tested.<sup>9,18,19</sup>

The statistically significant and clinical changes that were identified indicate the potential underlying mechanism involved in manipulative therapy and the role it plays in facilitating nervous system physiology. As effects of the manipulation were assessed in the intervention group at local and remote regions, this study showed the neurophysiological influence of cervical spinal manipulation on experimental mechanical pain.

These effects may have occurred at the level of the peripheral receptors in the skin, the neurons carrying the electrical signal, the spinal cord, ascending sensory pathways or at higher centres. Nevertheless, this study has further highlighted and supported the proposed effect of cervical manipulation on central modulatory mechanisms.

## **ACKNOWLEDGEMENTS**

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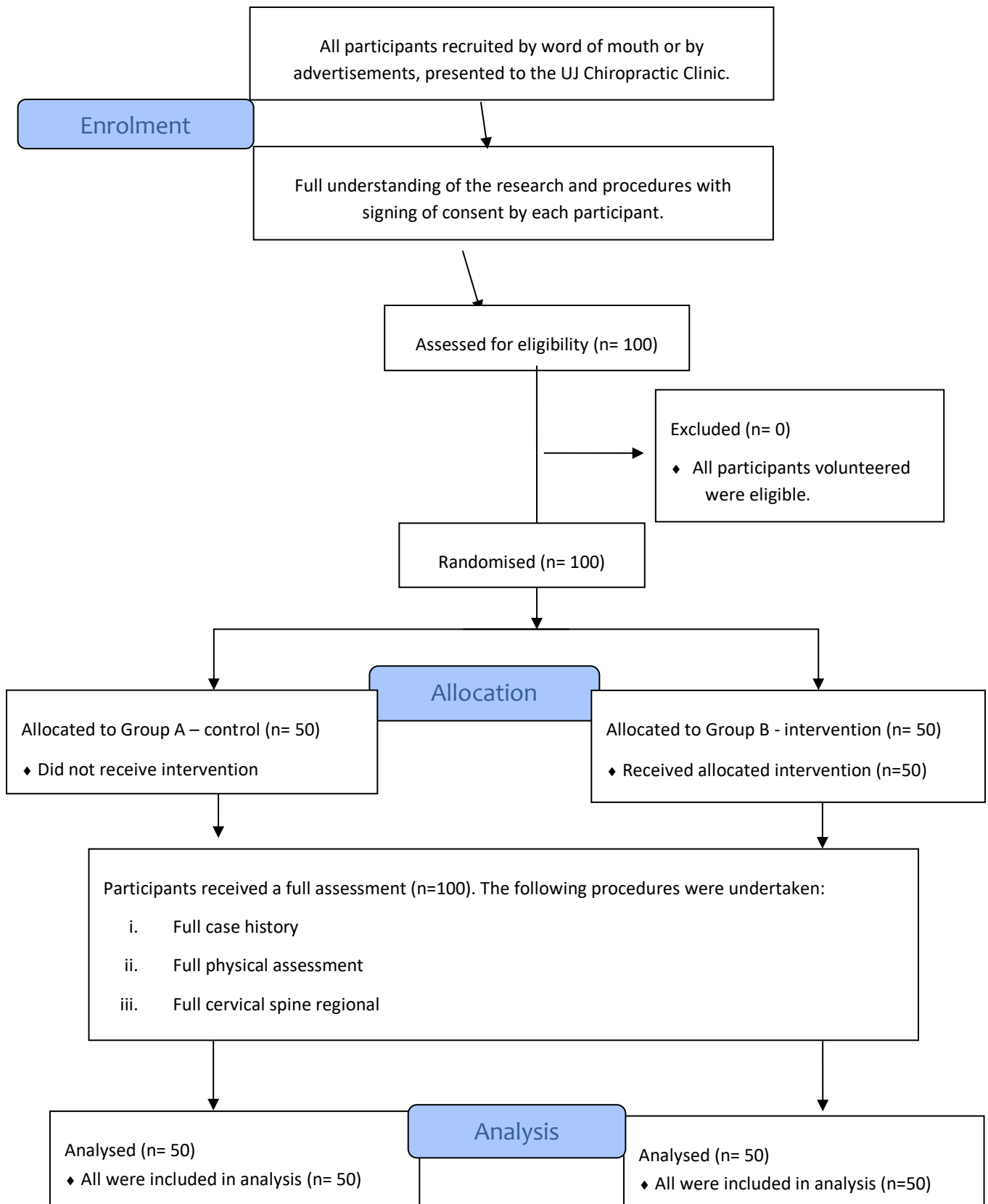
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## **FIGURES**



**Figure 1: CONSORT flow diagram, summarising participant involvement and overview of the research methodology that was implemented for this study.**

## **TABLES**

With reference to tables: 1, 2, 3 and 4.

*M-W*, Mann-Whitney; *R1*, right first reading; *R2*, right second reading; *R3*, right last reading; *L1*, left first reading; *L2*, left second reading; *L3*, left last reading.

\* indicates statistical significance of value – prompting effect size calculation.

**Table 1: Intergroup data analysis of cervical spine PPS readings, containing comparative median values, Mann-Whitney (M-W) Ranks, P-values and effect size.**

Location	Readings	Groups	Median value	M-W Ranks	P-value	Z-value	Effect Size
Cervical spine paraspinal region (PPS)	R1 (0 mins)	A	4	45.38	0.071	-1.803	N/A
		B	4	55.62			
	R2 (2 mins)	A	3.5	47.22	0.248	-1.155	N/A
		B	4	53.78			
	R3 (10 mins)	A	3	65.20	<b>0.000*</b>	-5.178	<b>0.52</b> (large effect size)
		B	2	35.80			
	L1 (0 mins)	A	4	47.27	0.253	-1.143	N/A
		B	4	53.73			
	L2 (2 mins)	A	4	52.63	0.454	-0.749	N/A
		B	3	48.37			
	L3 (10 mins)	A	3	66.38	<b>0.000*</b>	-5.602	<b>0.56</b> (large effect size)
		B	2	34.62			

**Table 2: Intergroup data analysis of calf region PPS readings containing comparative median values, Mann-Whitney (M-W) Ranks, P-values and effect size**

Location	Readings	Groups	Median value	M-W Ranks	P-value	Z-value	Effect Size
Medial calf region (PPS)	R1 (0 mins)	A	3	43.29	<b>0.010*</b>	-2.588	<b>0.26</b> (small to medium effect size)
		B	3	57.71			
	R2 (2 mins)	A	2	45.66	0.086	-1.718	N/A
		B	3	55.34			
	R3 (10 mins)	A	2	55.83	0.045	-2.002	N/A
		B	1	45.17			
	L1 (0 mins)	A	3	39.81	<b>0.000*</b>	-3.793	<b>0.37</b> (medium effect size)
		B	4	61.19			
	L2 (2 mins)	A	2	43.92	0.018	-2.357	N/A
		B	3	57.08			
	L3 (10 mins)	A	2	51.20	0.799	-0.254	N/A
		B	2	49.80			

**Table 3: Intergroup data analysis of cervical spine PPT readings, containing comparative data of median values, M-W Ranks, P-value and effect size.**

Location	Readings	Groups	Median value	M-W Ranks	P-value	Z-value	Effect Size
Cervical spine paraspinal region (PPT)	R1 (0 mins)	A	2.45	46.75	0.195	-1.297	N/A
		B	2.8	54.25			
	R2 (2 mins)	A	2.55	36.46	<b>0.000*</b>	-4.844	<b>0.49</b> (medium to large effect size)
		B	3.5	64.54			
	R3 (10 mins)	A	2.6	34.7	<b>0.000*</b>	-5.453	<b>0.55</b> (large effect size)
		B	3.65	66.30			
	L1 (0 mins)	A	2.4	47.43	0.287	-1.064	N/A
		B	2.8	53.57			
	L2 (2 mins)	A	2.45	35.99	<b>0.000*</b>	-5.008	<b>0.5</b> (large effect size)
		B	3.4	65.01			
	L3 (10 mins)	A	2.5	35.13	<b>0.000*</b>	-5.304	<b>0.53</b> (large effect size)
		B	3.55	65.87			

**Table 4: Intergroup data analysis of calf PPT readings, containing comparative median values, Mann-Whitney (M-W) Ranks, P-values and effect size.**

Location	Readings	Groups	Median value	M-W Ranks	P-value	Z-value	Effect Size
Medial calf region (PPT)	R1 (0 mins)	A	3.45	55.17	0.106	-1.615	N/A
		B	3.15	45.83			
	R2 (2 mins)	A	3.45	41.31	<b>0.002*</b>	-3.175	<b>0.3</b> (medium effect size)
		B	4	59.69			
	R3 (10 mins)	A	3.55	39.05	<b>0.000*</b>	-3.958	<b>0.4</b> (medium to large effect size)
		B	4.2	61.95			
	L1 (0 mins)	A	3.45	51.64	0.691	-0.397	N/A
		B	3.3	49.36			
	L2 (2 mins)	A	3.5	40.29	<b>0.000*</b>	-3.526	<b>0.32</b> (medium effect size)
		B	4	60.71			
	L3 (10 mins)	A	3.6	38.03	<b>0.000*</b>	-4.306	<b>0.43</b> (medium to large effect size)
		B	4.2	62.97			



## AUTHOR DECLARATION

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by both of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

We further confirm that any aspect of the work covered in this manuscript that has involved either experimental animals or human patients has been conducted with the ethical approval of all relevant bodies and that such approvals are acknowledged within the manuscript.

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## Author Agreement

I, Dr Dirkie Maria Landman, the corresponding author, certify that all authors have seen and approved the manuscript being submitted.

The article submitted is the authors' original work, has not received prior publication and is not under consideration for publication elsewhere.

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