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 Health SA Gesondheid. It should be considered to be published. The study is titled "A Case Series Describing the Effect of Thoracic Manipulation on qEEG."

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ETHICAL CLEARANCE

UNIVERSITY OF JOHANNESBURG

FACULTY OF HEALTH SCIENCES

RESEARCH ETHICS COMMITTEE

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TO WHOM IT MAY CONCERN:

STUDENT: BHAMJEE, S
STUDENT NUMBER: 201213264

TITLE OF RESEARCH PROJECT: A Case Series Describing the Effect of Thoracic Manipulation on qEEG

DEPARTMENT OR PROGRAMME: CHIROPRATIC

SUPERVISOR: Dr C Bester **CO-SUPERVISOR:** Dr G Hardie

The Faculty Academic Ethics Committee has scrutinised your research proposal and confirm that it complies with the approved ethical standards of the Faculty of Health Sciences; University of Johannesburg.

The REC would like to extend their best wishes to you with your postgraduate studies.

Yours sincerely,

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A Case Series Describing the Effect of Thoracic Manipulation on qEEG

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

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A CASE SERIES DESCRIBING THE EFFECT OF THORACIC MANIPULATION ON qEEG

Purpose: The purpose of the study was to describe any potential changes that chiropractic manipulation of the thoracic spine may have on brain qEEG readings.

Method: A descriptive design following a case series approach was used to record changes in qEEG readings before and after a chiropractic manipulation. The study took place at the University of Johannesburg's Doornfontein campus, in the Chiropractic clinic. The study comprised of 10 participants with thoracic motion restrictions. The brainwave activity of each participant was measured and recorded using the qEEG. A pre- manipulation reading was taken, which comprised of the measurement of the participants' brain wave activity with their eyes open and then with their eyes closed. A post-manipulation reading was taken immediately after, also measured with eyes open and then eyes closed. Thirty minutes later a second post manipulation reading was taken, measured with eyes open and then eyes closed. The data was converted into mean values of the brain waves, delta, theta, alpha and beta. The results were analysed and described to find the relationship between the manipulation and the different areas of the brain with its associated brain wave activity.

Results Changes of particular interest were found across all three lobes. Alpha and delta wave changes in the parietal lobe were indicative of a relaxed and reflective state in participants. Changes in the delta and beta waves in the temporal and frontal lobe also showed the manipulations potential to increase the relaxed state in participants. Although, it should be noted that throughout the trial participants were in lying down in a quiet and un-stimulatory environment, which may also have contributed to the changes demonstrated.

Conclusion: This study fully describes 10 participants and the manipulation effect on qEEG.Based on the results, chiropractic manipulation of the thoracic spine does have an effect on qEEG readings. However the motivation behind the results remain inconclusive. A larger group of participants are needed and the variables need to be more controlled to make a definite conclusion and allow for statistical analysis.

Key Words: qEEG, qEEG bands, Thoracic spine, Facet joints, Brain, Chiropractic Manipulation.

INTRODUCTION

The human body transmits thoughts, emotions and behaviours by means of neurons. Brainwaves are the electrical impulses produced between these neurons. Electroencephalograms measure brainwave activity within the brain. Quantitative electroencephalogram (qEEG), is also used to measure neurophysiology, neural function as well as neurological deficits (Martini, 2012). Chiropractic manipulations affect the nervous system (Barwell*et al*., 2004), however its effect on the central nervous system remains a debated issue. Lystad and Pollard, 2009 stated that the use of qEEG in future chiropractic research is strongly recommended hence creating the need for such a study. Recent studies on cervical manipulation have shown some effect on brain qEEG, however other areas of the spine have not been investigated.

qEEG

Brain waves can be measured using a qEEG.Brain related electrical potential, intra-cranial electrical currents and the resulting voltages on an individual scalp can be measured (Kropotov, 2009; Loo & Barkley, 2005). qEEG is also used to measure neurophysiology, neural function as well as neurological deficits (Martini, 2012). The qEEG consists of alpha, beta, theta and delta waves (Pizzagalli, 2007).

qEEG Bands

There are four major bands that can be recorded when measuring brain wave activity. Namely; alpha, beta, theta and delta. These waves have been analysed in this study. According to Kropotov and Panomarev (2009), cortical activity is measured in frequency and amplitude, which can be viewed as waveforms. Refer to Figure 1.1, which depicts a typical reading of a normal adult's brain waves.

The alpha band is the first band that the review focuses on. In this band, activity ranges between 8-13 Hz (Fisch, 1999; Pizzagalli, 2007). During mental attention or when a human being has their eyes open, the alpha band can disappear (Klimesch, 1999; Pizzagalli, 2007). The alpha waves are known to be stronger in the parietal, temporal and occipital lobes (Pizzagalli, 2007). There is speculation that the alpha waves are also involved in mental processing (Kilmesh, 1999).

The second type of band are the beta bands which are found between 13-25 Hz and are present during the wakeful state of a human being (Pizzagalli,2007). The beta band can be further divided into three different types namely precental beta, posterior beta and generalised beta. When a human being is in a state of drowsiness, the activity in the precental and posterior beta waves increase (Daube& Rubin, 2009; Tatum *et al*., 2007). According to Niedermeyer (2005), beta activity is found in every healthy adult.

Theta bands are measured in frequencies of 4-8 Hz and are also found during sleep patterns in humans (Pizzagalli, 2007). Two different types of theta waves have been described in the wakeful state of a

human being according to Schacter (1977). The first is linked to drowsiness and impaired information processing and the second is associated with focused attention, mental effort and effective stimulus processing. According to Nuwer, Marc, Hovda, Schrader & Vespa (2005), there is insufficient research on a number of factors that impacts on theta band measurements. These include mood disorders such as anxiety or depression, sleep disorders or mild head injuries. These factors will be considered as part of the scope of this study.

The last type of band recorded are the delta bands. Delta bands can either be associated with normal sleep patterns in humans or indicate a neurological pathology and are reflected in low frequencies of 1-4 Hz (Pizzagalli, 2007).

Thoracic Spine

The thoracic skeleton takes the shape of a domed birdcage with horizontal bars formed by ribs and costal cartilages. It is supported by a breastbone called the sternum and thoracic vertebrae (Moore *et al.,* 2010; Martini &Nath, 2012). The thorax contains respiratory as well as cardiovascular organs. The thoracic skeleton comprises of 12 pairs of ribs and their associated costal cartilages, 12 thoracic vertebrae and their intervertebral discs and the sternum. Refer to Figure 1.2 for an overview of the thoracic skeleton.

Facet Joints

The zygopophyseal joints are synovial plane joints found between each vertebral segment. They are innervated by articular branches of the medial branch of the posterior rami as well as the recurrent meningeal branches of the spinal nerves (Moore *et al.,* 2010). Within these facet joints the capsule is innervated by three types of nerve endings.

The Brain

A brief overview of the brain anatomy will be discussed, in particular the lobes and its functions because those areas are relevant to this study. Refer to Figure 1.3 for an overview of the brain and its lobes. The brain consists of the cerebrum, cerebellum and the brain stem. The cerebrum divides into two hemispheres by the falx cererbri. Each hemisphere is further divided into four lobes, namely the parietal, frontal, occipital and temporal lobes, (Moore *et al.*, 2010).

The parietal lobe is known as the primary sensory cortex. Neurons in this region receive somatic sensory information from receptors for conscious perception of touch, pressure, pain, vibration, taste and temperature (Martini & Nath, 2009). The lobe is divided into somatosensory area I and somatosensory area II. Somatosensory area I is known as the somatosensory cortex and is more

extensively used due to its higher degree of localization of different regions of the body (Hall & Guyton, 2011).

The frontal lobe is known as the primary motor cortex which neurons fire information for the voluntary control of skeletal muscles (Martini & Nath, 2009). The prefrontal cortex receives and organizes information from all other areas of the cortex. Hence once the processing in the other lobes are complete the information is first sent to the frontal lobe (Martini & Nath, 2009).

Conscious perception of visual stimuli is processed in the occipital lobe, which is known as the visual cortex (Hall & Guyton, 2011). The visual association area enables an individual to make sense of information that they see and recognize a person or an object (Missankov, 2009).

The temporal lobe is divided into the auditory cortex and the olfactory cortex. Neurons in this region receive the perception of hearing and smell respectively (Martini & Nath, 2009). The primary auditory cortex receives information from the opposite ear, due to the cross over in the neural pathway, which will be discussed later on in this chapter. The meaning of the auditory stimulus is interpreted and understood in this lobe (Missankov, 2009).

Chiropractic Manipulation

A chiropractic manipulation is defined as a high velocity low amplitude thrust, that if applied to the cervical spine can alter somatosensory processing (Taylor & Murphy, 2008). All studies that have been carried out were in relation to the cervical spine because of its close connection to the higher order centers. However no reported studies could be found in relation to the thoracic spine, hence creating a need for this type of study.

A joint restriction may cause functional neurophysiological changes in the central nervous system referred to as neuroplastic changes. This in turn may extend beyond the mechanical lesion site (Taylor *et al.*, 2010). Both increased and decreased afferent input changes CNS functioning (Taylor & Murphy, 2008).

A manipulation is also known as facet joint “gapping”. When a manipulation is applied to the spine the tension in the joint capsule may occur resulting in a cavitation. The reason its called “gapping” is because the space between the articular surfaces separate causing the gas in the synovial fluid to be released. The result is an audible click (Jones, Yelverton & Bester, 2014).

MATERIALS AND METHOD

Participants who met the following criteria were allowed to participate in the study:

- Between the ages of 18 and 45 years old. Degenerative changes that may interfere with the study typically occur after the age of 45 (Galbusera, F *et al.*, 2014).
- Either male or female.
- Must have had at least one thoracic spine restriction which was confirmed during the screening process by motion palpation, which is a technique used to assess the mobility of each spinal segment in all planes of motion(Espositos&Philipson, 2005).

Participants who presented with the following could not partake in this study:

- Participants that had received full spinal medical or physical treatment within the preceding six weeks of screening
- Participants who demonstrated, during physical exam or history taking, any contra-indications to the application of chiropractic manipulation (Appendix D).
- Any perceived spinal pain by the patient.
- Any chiropractic manipulation in the 6 weeks preceding the study or during the study other than that performed by the researcher.
- Open scalp wounds as this increases the risk of infection from the qEEG cap.
- Criteria that could influence qEEG readings:
    - Use of anxiolytic or anti-depressant medication (including but not exclusive to Barbiturates, Benzodiazepines, Selective Serotonin Reuptake Inhibitors, Serotonin and Norepinephrine Reuptake Inhibitors, Tricyclic antidepressants, Monoamine Oxidase Inhibitors, Remeron and Wellbutrin)
    - Alcohol or drug abuse
    - Nicotine or caffeine consumption within 5 hours prior to participation in the study, as these products are considered stimulants and may alter brain wave activity
    - Uncontrolled epilepsy as this may result in altered brain wave activity and thus not produce accurate results
    - History of previous head trauma that resulted in on going neurological deficits
    - Participants with any history of any diagnosed mental conditions such as Alzheimer's disease, Parkinson's disease, Autism and Schizophrenia.
    - Any situations that may have resulted in noted recent excessive stress such as being a victim of a crime, divorce, death of a family member or other life changing events.

Methodology

Advertisements were placed in various public spaces around the University of Johannesburg (UJ) (Please refer to Appendix A). Other methods such as social networks (Facebook and Twitter) and word of mouth were also used to recruit participants.

The research study was conducted at the UJ Chiropractic clinic in Doornfontein. The study consisted of 10 participants. Every participant received an explanation of the information and consent forms. Thereafter, they underwent a screening process, which consisted of a full medical history and physical examination. This confirmed inclusion criteria as well as ensured that no exclusion criteria were present. Motion palpation of their thoracic spine was included in the physical examination in order to identify any restrictions.

At the time of recording each of the initial qEEG readings, the room was always dimly lit and the curtains were drawn. All equipment used remained out of sight of the participant at all times. This ensured minimal exposure of the participant to visual stimuli. The participant was requested to be silent during the trial. This ensured that each participant was exposed to the same environment.

A pre-manipulation reading of each participant was recorded once the cap was securely placed on the participant's head. The *International 10-20 Electrode Placement System* was used in this study.

Objective Measurement

The following system was used to record qEEG measurements :

1. A computer, keyboard, monitor and mouse to record and display the information captured.
2. MP150 data acquisition system which includes:

- A lycra cap (CAP 100C), which contains tin electrodes that read the signal from the head surface.
- Amplifiers known as the Electroencephalogram Amplifier Module (EEG 100C), which amplifes physiological signals as well reject interference or noise. They also protect the patient from hazardous shock.
- Signal information needs to be changed from analog to digital in order to be saved to the computer's memory, hence an AD convertor was needed.
- Ethernet cable to connect the MP150 system to the computer.

Tranformer connects the MP150 to the wall socket.

The *International 10-20 Electrode Placement System*is an accepted standardized system for electrode placement. The system standardizes physical placement and designations of electrodes on the scalp. The head was divided into equal distances from prominent skull landmarks, such as the nasion, preauricular points and inion, in order to provide coverage of all necessary regions of the brain. Electrodes were placed according to adjacent brain areas (Teplan, 2002). The cap was sterilized through the use of rubbing alcohol prior to each use. Conductive gel was placed on each electrode and then the cap was placed on the participant's head. The participant was asked to lie down and relax on a plinth, while two readings were taken. One reading was taken whilst their eyes were open and one with

their eyes closed. During the consultation, notes were captured of any stimuli that occurred during the reading, so that the epochs could be moved to compensate for artefacts that may coincide with unintended stimuli prior to the analysis.

The first post manipulation readings were recorded immediately after the manipulation was delivered to each participant. A second reading was recorded for each participant once a period of 30 minutes had elapsed post manipulation. The participants were requested to wait quietly in the treatment room until the 30-minute reading was recorded.Each reading was extended for a 4-minute time lapse at each time interval. This is because each reading comprised of two phases. The first was a period of 2 minutes of 'open-eyed' recordings and the second was a period of 2 minutes of 'closed-eyed' recordings.

Treatment

The treatment consisted of a thoracic spine manipulation, which is a low amplitude, high velocity thrust delivered to the restricted segments found during the motion palpation. A diversified chiropractic manipulation used was the Anterior Thoracic. Indications for this technique are an anteriorly or posteriorly displaced segment.

RESULTS

In the course of recording brain wave readings, it is possible that external stimuli may unduly impact on the readings. In order to mitigate the effects of these external stimuli, the epochs in this study have been moved. A detailed description of any disturbance observed is presented on a case per case basis. The results of this study fully describes 10 participants and the manipulation effect on qEEG.Based on the results, chiropractic manipulation of the thoracic spine does have an effect on qEEG readings. However the motivation behind the results remain inconclusive. A larger group of participants are needed and the variables need to be more controlled to make a definite conclusion and allow for statistical analysis.

Demographic Analysis

10 participants of different ages and gender took part in this research. The age ranged from 19- 40 years old, resulting in an average age of 26 years and 8 months, across all participants. 2 out of the 10 participants were male contributing to 20% of the sample size. The rest of the participants were female, which made up 80% of the sample size.

Average Age	Minimum Age	Maximum Age	Proportion of male participants	Proportion of female participants
26 years and 8 months	19 years	40 years	20%	80%

Data Analysis

All the data was then sorted out according to the individual frequency parameters of each bandwidth i.e. delta, theta, alpha and beta. This process was repeated on all three channels of the 12-minute data recording per patient. The values were then entered into a Microsoft Excel spread sheet. The next step was to calculate the average of the mean power values for each brain wave. These values were then analysed, with a specific focus on the trends found across the pre manipulation, post manipulation and 30-minute post manipulation phases.

DISCUSSION

The aim of the study was to determine whether or not a chiropractic manipulation to the thoracic spine would alter the brain wave activity of participants. A qEEG was used to measure the voltage of the brainwaves across the three lobes. There were fluctuations in the results of all 10 participants. The individual readings were taken and an average was produced and assembled into graphs (Figure 4.62). Pre-manipulation, immediately post- manipulation and thirty minutes post-manipulation averages of all the participants were produced.

The similarities and differences found across the three lobes will also be described. The change in the brain wave activity followed one of four of the following trends, namely: double increase, double decrease, increase-decrease or decrease-increase. The modal results of these trends are represented in the form of a pie chart, Figure 4.63.

a) Brain Neurology

All three lobes were affected in this study. This section will describe the pathway from the stimulus to different lobes of the brain that the participants may have experienced during the trial.

b) Parietal Lobe

Mechanoreceptive input travels via the dorsal-column medial lemniscus and terminate in the somatosensory cortex of the parietal lobe. Given that the thoracic spine was manipulated, the

mechanoreceptors in the joint capsule were stimulated. Therefore all participants experienced mechanoreceptive input from the manipulation. The manipulation may also have led to an improved brain chemistry, which will be discussed later on in this section (Holder, 2012).

Large myelinated fibres from mechanoreceptors enter the spinal cord via the dorsal nerve roots (Hall, 2011). They terminate on the primary sensory cortex as first order neurons. Axons carry information from the upper half of the body and ascend in a tract made of white matter. This matter is referred to as the fasciculus cuneatus. These axons synapse on the cuneatus nucleus in the brain stem.

Axons of the second order neurons leave the nuclei and cross over to the opposite side of the brain stem and enter a tract called the medial lemniscus. The crossing over of neurons is called decussation. Therefore sensations from the left side of the body are received on the right side of the primary sensory cortex (Hall, 2011).

Axons from the medial lemniscus synapse on third order neurons in the ventral posterolateral nucleus of the thalamus. This area of the brain is called the ventrobasal complex (Hall, 2011). The third-order neurons then synapse in the somatic sensory area located in the anterior aspect of the parietal lobe.

c) Temporal Lobe

This area is known as the primary auditory area of the brain. During a manipulation an auditory click can be heard. This sound can stimulate hair cells in the cochlear and activate the sensory neurons of the vestibulocochlear nerve (Martini & Nath, 2009). The axons of this nerve synapse on the right and left dorsal and ventral cochlear nuclei in the medulla oblongata. Information is then processed in the inferior colliculus of the mesencephalon. Synapse occurs on the medial geniculate nucleus of the thalamus before projecting to the auditory cortex of the temporal lobe. The only sounds that were involved were the instruction of the researcher and the sound of the cavitation caused by the manipulation.

d) Frontal lobe

Information from the primary sensory cortex (parietal lobe) and primary auditory area (temporal lobe) project to the frontal lobe. The area in the frontal lobe that this information projects to is the parieto-occipitotemporal association area. The pre- frontal cortex is proven to play a role in the modulation of SEP's (Brown & Staines , 2015).

The prefrontal cortex receives and organizes information from all other areas of the cortex. Once the processing in the other lobes are complete, the information is sent to the frontal lobe (Martini & Nath,

2009). Therefore changes in the parietal and temporal lobe may potentially also be reflected in the frontal lobe.

Chiropractic manipulations may also improve spinal neural integrity as well as neural dopaminergic pathways, which lead to an improved homeostasis and brain reward cascade (Holder, 2012). In the brain, dopamine functions as a neurotransmitter, which plays an important role in reward-motivated behavior. Dopamine also plays an important role in executive functioning, which occurs in the frontal lobe. It is believed that after a manipulation the body expresses a greater state of wellbeing which may be due to the tendency of the body to maintain internal stability (Holder, 2012). The spinal neural integrity may improve due to the improved sense of joint position after the manipulation was delivered (Haavik, 2011).All three lobes were stimulated by the thoracic manipulation in all 10 participants. Some changes were expected whereas others were inconclusive.

e) Group Average Results

Delta bands can either be associated with relaxation and normal sleep patterns in humans, or it can indicate a neurological pathology, which would be reflected in low frequencies of 1-4 Hz (Pizzagalli, 2007). Changes in the delta wave were observed across all three lobes. The largest increase in delta wave activity was seen thirty minutes after the manipulation in all three lobes. This is in accordance with the explanation by Barwell*et al.,* (2004), which suggests that this is either because the manipulation increased the resting or relaxation state of the participant, or it is due to the participant's motionless state.

Theta bands are measured in frequencies of 13-25 Hz and are also found during sleep patterns in humans (Pizzagali, 2007). The largest changes were seen in the parietal lobe, indicating activity in the somatosensory area of the brain. Thirty minutes after the manipulation was delivered in the parietal lobe, the theta wave activity increased to its peak. This long-term change was expected to occur in the frontal lobe due to the after effects of the manipulation that the brain was still processing (Kilmesh, 1999). However the increase in the activity in the theta wave can also be due to the motionless and quiet state of the participant.

During mental attention or when a human being has their eyes open, the alpha band could disappear (Klimesch, 1999; Pizzagalli, 2007). Theese bands are stronger in the parietal, temporal and occipital lobes (Pizzagalli, 2007). The biggest increase in alpha wave activity was observed in the parietal and temporal lobes. The activity had peaked thirty minutes after the manipulation was delivered.A similar trend was observed in the delta and theta waves. The manipulation delivered to the thoracic spine stimulated mechanoreceptive input, which may have been relieving and could potentially have resulted in the relaxation state of the participant. This may have resulted in an increased alpha activity in the

parietal lobe. The increase in alpha activity in the temporal lobe may have been due to the recognition process of auditory stimulation of the manipulation (Pizzagalli, 2007).

Beta bands are found between 4-8 Hz and are present during the wakeful state of a human being (Pizzagalli, 2007). Immediately after the manipulation was delivered, there was an increase in the beta wave activity across all three lobes, which is a result that was expected. This may suggest that the participant's sense of awareness was heightened immediately upon delivery of the manipulation. Thirty minutes later, the beta wave activity decreased in all three lobes. This decrease was not sufficient to have breached the base line voltage readings across all three lobes. This may indicate that the participant had returned to a relaxed state and the information being processed by the brain had decreased slightly (Pizzagalli, 2007).

Interpretation and analysis of the group averages will be used to analyse and interpret the brain wave trends and fluctuations across the lobes. For an overview of the trends, refer to Figure 4.61.

f) Similarities in Brain Wave Activity found across the Lobes

Across all three lobes the delta wave followed a double increase trend during the eyes open phase. The initial increase in delta activity in the parietal lobe suggests that the participants who showed this trend were in a more relaxed state of mind, which may be due to the environment of the study. The further increase may indicate that the manipulation has a long term relaxation effect on the brain due, to the relief of the stimulated mechanoreceptors of the joint capsule that was motion restricted (Barwell *et al.*, 2004).

The delta wave behaved in a similar manner in the temporal lobe. The increase in delta activity post manipulation may be due to the auditory stimuli from the manipulation that was being perceived by the temporal lobe. The further increase in delta activity thirty minutes later, may suggest that the auditory stimuli were being interpreted by the auditory cortex of the temporal lobe (Martini &Nath, 2009). The double increase trend of the delta wave in the frontal lobe was expected. This is due to the fact that all higher order interpretation of information occurs in the frontal lobe from all other association areas (Guyton *et al.*, 2011).

The theta wave activity followed the same decrease-increase trend in the parietal and temporal lobes. The minor decrease that was initially observed may suggest that a slight decline in mental alertness was experienced due to the relaxation state of the participant. The increase in theta activity could potentially indicate the long-term effects of mental alertness by the manipulation of the participant (Pizzagalli, 2007). This was an unexpected result, due to the fact that the manipulation showed a

conflicting effect of theta activity immediately after the manipulation was delivered compared to thirty minutes later.

A double increase in alpha activity was recorded across all three lobes during the eyes open phase. The result was not expected because the alpha wave activity usually decreases or is non-existent during mental attention and when the eyes are open (Klimesch, 1999; Pizzagalli, 2007). This increase may suggest that the manipulation had an increase in the relaxation and learning state of mind of the participant (Tatum IV, 2014).

The beta wave followed the same trend as the alpha and delta waves, showing a double increase trend across all three lobes. This was expected during the eyes open phase because that is when the beta wave is most present (Pizzagalli, 2007). Beta waves are best seen in the frontal lobe where the executive functioning occurs (Guyton.,*et al*, 2011). The most significant double increase was expected in the frontal lobe due to its connection with the temporal and parietal lobes. This may indicate that the participants were attentive while processing information in the prefrontal cortex (Teplan, 2002).

g) Differences in Brain Wave Activity found across the Lobes

The theta wave followed an increase-decrease trend in the frontal lobe compared to a decrease-increase trend that was followed in the parietal and temporal lobes. This was an unexpected result, as the frontal lobe receives information from surrounding association areas for interpretation (Guyton *et al*., 2011). This difference could be due to a decrease in the relaxation state of the participant to allow for greater mental activity (Tatum IV, 2014).

The next difference found was in the parietal lobe during the eyes closed phase. The alpha wave followed a decrease-increase trend, whereas in the frontal and temporal lobe a double increase trend was followed. This slight decrease in alpha activity was not expected because activity in this wave should increase when the eyes are closed (Kilmesh, 1999, Pizzagalli, 2007). There is no known literature to explain why this occurred and therefore the difference in alpha wave activity remains inconclusive.

The final difference that was recorded was the beta wave in the parietal lobe. An increase-decrease beta wave trend was followed in the temporal and frontal lobe during the eyes closed phase. In the parietal lobe, the beta wave followed a double increase trend. The thirty minutes post manipulation activity increased slightly which may suggest that the manipulation had no further effect over the long term (Pizzagalli, 2007).

h) Trends and Correlations

This study involved a total of ten male and female participants from varying age groups. Their age ranged from 19- 40 years old, resulting in an average age of 26 years and 8 months across all participants. Upon closer inspection of the participants' history, two out of the ten participants had previously been treated by a chiropractor. All participants were involved in some sort of exercise, which ranged from running to yoga. Only one participant had a traumatic injury involving a fracture of the right ulna in early childhood. All participants were asymptomatic and described their health as being between average to good. The sample size is not large enough to determine whether, age, gender, traumatic injuries, lifestyle or first time chiropractic manipulation had any evident influence on the results.

CONCLUSION

The objective of this research was to gather a case series describing whether or not chiropractic manipulation of the thoracic spine had any significant impact on the qEEG readings that were recorded for each participant in this study. This case series contributed to a larger data set.

This was a descriptive study and therefore each participant was described individually and the results were interpreted accordingly. Group averages were also generated and taken into account when describing the results for each participant. The results had either reflected an increase or decrease, post manipulation.

Changes were noted across all four brain waves post manipulation in all three lobes. Most of the waves underwent an increase in activity compared to a minority that decreased after the manipulation was delivered. The Minimal Clinical Important Difference (MCID) for qEEG in chiropractic has not yet been defined. Therefore an increase or decrease in the values are not enough to determine whether the chiropractic manipulation lead to a clinical important difference.

Many conjectures were made about the trends that were followed post manipulation prior to the commencement of this study. Based on the results, chiropractic manipulation of the thoracic spine does have an effect on qEEG readings. However the motivation behind the results remain inconclusive. Therefore a larger group of participants are needed and the variables need to be more controlled to make a definite conclusion.

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FIGURES

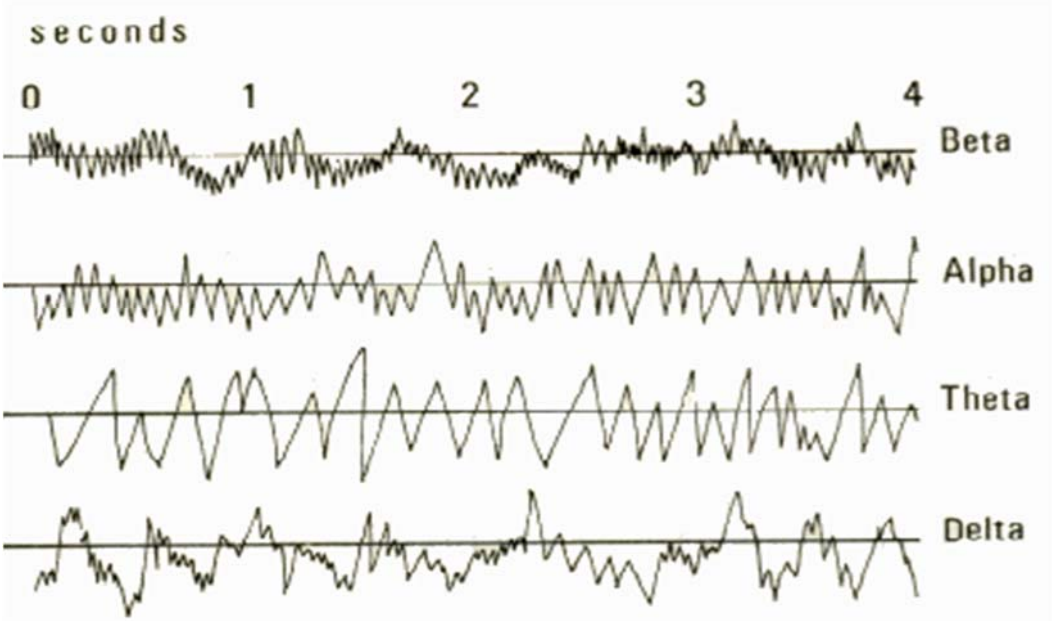


Figure 1.1 Normal adult brain waves

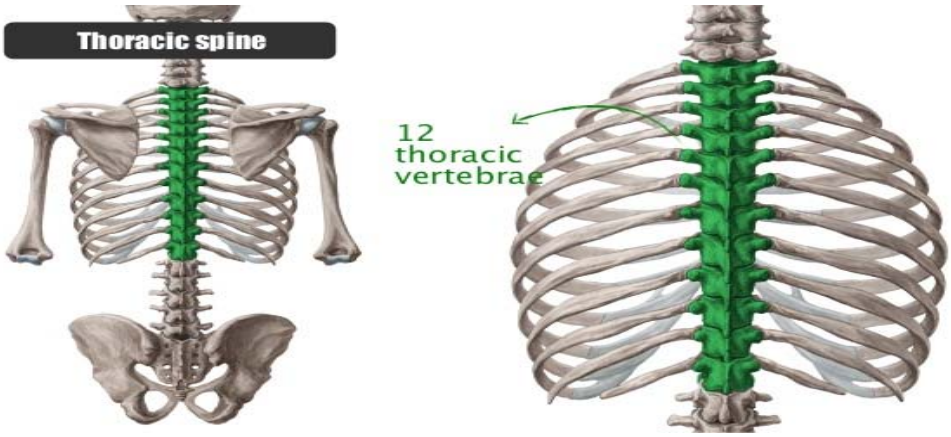


Figure 1. 2 The Thoracic Spine

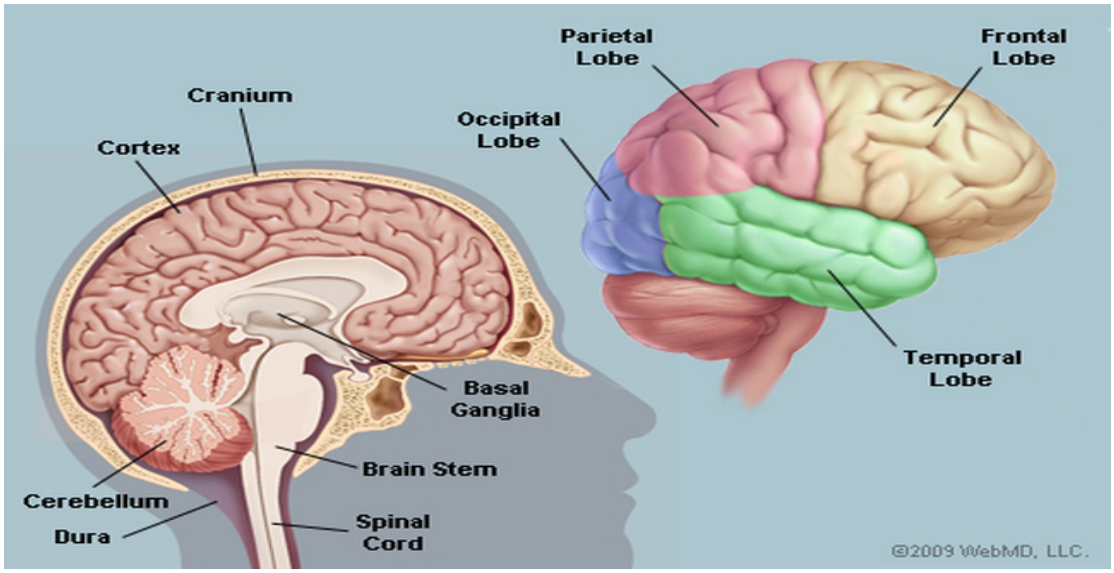


Figure 1. 3 The Brain

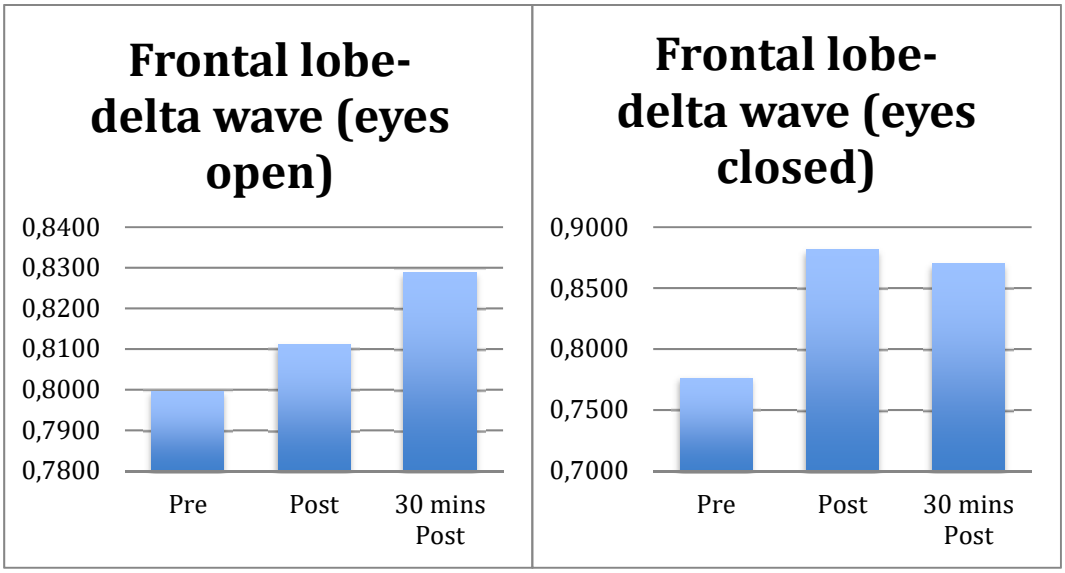


Figure 4.62: Showing the group averages of the delta waves across the frontal lobe

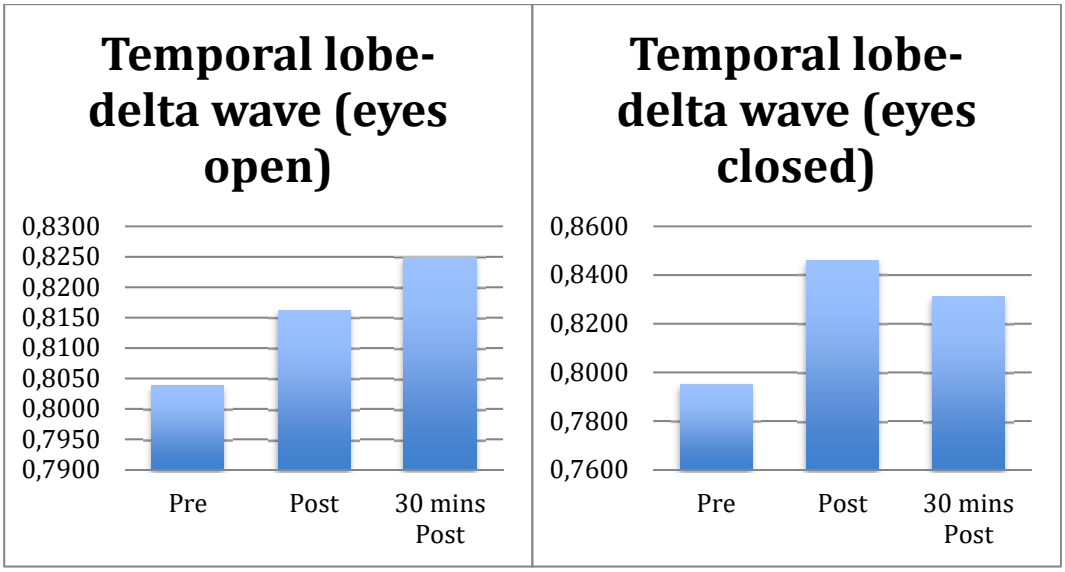


Figure 4.63: Showing the group averages of the delta waves across the temporal lobe.

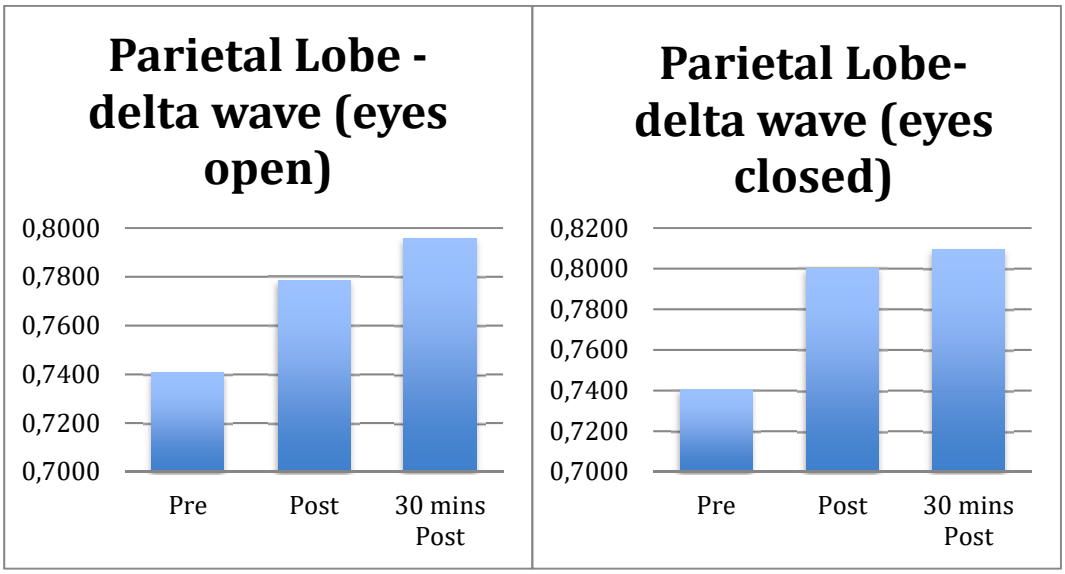


Figure 4.61: Showing the group averages of the delta waves across the parietal lobe.

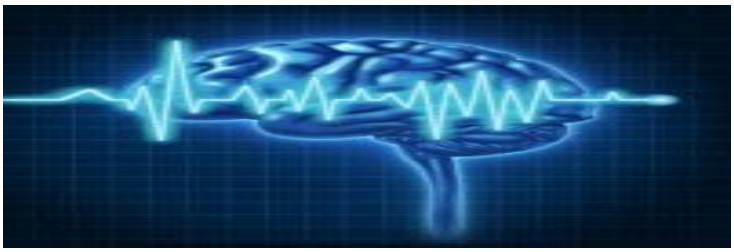
Ethics Clearance number: REC-241112-035

APPENDIX A

RESEARCH

VOLUNTEERS NEEDED

The Effect of Thoracic Manipulation on Brain Electroencephalogram



DESCRIPTION OF RESEARCH STUDY:

The aim of the study is to describe the effect of midback manipulation on brainwaves.

Your participation will take forty-five minutes. Chiropractic manipulation will be performed while an EEG measures your brain wave activity.

This study will take place between September 2016 and December 2016.

To participate: you must be between the ages of 18-45.

To learn more about this study, contact the principal investigator of the study, Saeedah Bhamjee, on 0827685707 or sadybhamjee@gmail.com

Saeedah Bhamjee	Saeedah Bhamjee	Saeedah Bhamjee	Saeedah Bhamjee	Saeedah Bhamjee	Saeedah Bhamjee	Saeedah Bhamjee	Saeedah Bhamjee	Saeedah Bhamjee	Saeedah Bhamjee
sadybhamjee@gmail.c	sadybhamjee@gmail.c	sadybhamjee@gmail.c	sadybhamjee@gmail.c	sadybhamjee@gmail.c	sadybhamjee@gmail.c	sadybhamjee@gmail.c	sadybhamjee@gmail.c	sadybhamjee@gmail.c	sadybhamjee@gmail.c

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 all 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.

We understand that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct communications with the office). He/she is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs. We confirm that we have provided a current, correct email address which is accessible by the Corresponding Author and which has been configured to accept email from Dr Charmaine Bester,charmainebester@gmail.com.

Signed by all authors as follows:

_____ _____

Saeedah Bhamjee Date:

_____ _____

Dr Charmaine Bester Date:

_____ _____

Dr Gareth Hardie Date:

Author Agreement

I, Charmaine Bester, 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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100 WORD ABSTRACT

Purpose: To describe any potential changes that chiropractic manipulation of the thoracic spine may have on brain qEEG readings.

Method: 10 participants with thoracic motion restrictions. The brainwave activity of each participant was measured using the qEEG. A pre- manipulation reading was taken, which comprised of the measurement of the participants' brain wave activity with their eyes open and then with their eyes closed. A post-manipulation reading was taken immediately after and thirty minutes later. The data was converted into mean values and analysed to find the relationship between the manipulation and the different areas of the brain with its associated brain wave activity.

Results: Changes were found across all three lobes. Alpha and delta wave changes in the parietal lobe were indicative of a relaxed and reflective state in participants. Changes in the delta and beta waves in the temporal and frontal lobe also showed the manipulations potential to increase the relaxed state in participants.

Full Title: A Case Series Describing the Effect of Thoracic Manipulation on qEEG.

7 Word Title: Thoracic Manipulation and its effect on qEEG.

Key Words: qEEG, qEEG bands, Thoracic spine, Facet joints, Brain, Chiropractic Manipulation.