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A Case Series Describing the Effect of Extremity Manipulation on qEEG

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

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Supervisor: ___________________________ Date: ____________________
DECLARATION

On this day of the month of February 2017
I, Devlin Sean Randal-Smith, declare that this is my own, unaided work. It is being submitted in partial fulfilment for the Master's Degree in Technology, in the programme of Chiropractic, at the University of Johannesburg. It has not been submitted before for any degree or examination in any other technikon or university.
Purpose: The aim of this study was to describe the effect that an extremity manipulation particularly a talocrural joint (TCJM) manipulation had on qEEG.

Method: A descriptive case series was chosen for this study. 10 participants that met the relevant inclusion and exclusion criteria were selected. The study looked to observe changes in the qEEG readings before and immediately following the extremity manipulation, as well as 30 minutes after the manipulation was delivered. The study took place in the Chiropractic Clinic at the University of Johannesburg’s Doornfontein campus. The 10 participants were screened for long axis extension talocrural joint restrictions. The qEEG was used to record the participants’ brain wave activity with their eyes open and then closed before any manipulation was given. Immediately following the manipulation, another recording was taken, again with the eyes open and then closed. Finally, the values 30 minutes post-maneipulation were captured. Once again with the eyes open and then closed. The qEEG data was converted into mean values of the brain waves, delta, theta, alpha and beta. These values were used to find any statistical significance in the results. An analysis of the results was performed to identify relationships between the manipulation and brain wave activity within each of the lobes (frontal, temporal and parietal).

Results: Findings of particular interest in this study were evident in all of the lobes. Beta and delta wave changes immediately following the manipulation, in the frontal lobe and temporal lobe were indicative of the participants’ increased relaxed/ resting states. Alpha and delta wave changes in the parietal lobe following the manipulation and 30 minutes later were also suggestive of the participants’ increased relaxed and reflective state. Also important to consider was the patients immobile and quiet state throughout the trial.

Conclusion: In this study, the findings are limited and inconclusive as there is no sure way to quantify how much of the increase in relaxation of the participant was a result of the extremity manipulation or the participants’ motionless and silent state. Research is severely limited on the relationship between peripheral joint manipulation and its effect on the brain. The only studies that exist are concerned with spinal manipulation. It is interesting to see that the degree of changes following the TCJM showed a similar extent of change as seen by the spinal studies. This could suggest that there are alternative factors responsible for the changes directly following the manipulation. The study has still made an encouraging contribution to the claim that chiropractic manipulation has an effect on qEEG readings, based on the
small changes seen throughout. Further investigation is required in order to offer substantial evidence on chiropractic extremity joint manipulation and its relationship to qEEG readings.
DEDICATIONS

I dedicate this research to my parents Helen and John Randal-Smith, who have always supported me. I love you very much.

My sister and best friend Philippa Jane, who still teaches me how to use a computer.

My Mama, who sent me love and prayed for me before every test.

To my beautiful girl Michela, many days and evenings spent with you doing this dissertation. Without you this would most certainly not have come together as smoothly as it did.

Some of my oldest friends, Ogy, Michele and CJ. Not forgetting some of the incredible friends I made along the way, Tazzy, Big Dev and Gals.
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CONTENTS

DECLARATION ...................................................................................................................... i
AFFIDAVIT .......................................................................................................................... ii
ABSTRACT ........................................................................................................................... iii
DEDICATIONS ..................................................................................................................... v
ACKNOWLEDGEMENTS ..................................................................................................... vi
CONTENTS ......................................................................................................................... vii
LIST OF FIGURES .............................................................................................................. x
LIST OF SYMBOLS ............................................................................................................. xiv
LIST OF ACRONYMS .......................................................................................................... xiv
LIST OF APPENDICES ......................................................................................................... xiv

CHAPTER ONE – INTRODUCTION .................................................................................... 1
  1.1 The Topic ...................................................................................................................... 1
  1.2 Aim ............................................................................................................................... 1
  1.3 Study Design ............................................................................................................... 1

CHAPTER TWO – LITERATURE REVIEW .......................................................................... 2
  2.1 Introduction ................................................................................................................... 2
  2.2 qEEG .............................................................................................................................. 2
    2.2.1 Introduction .......................................................................................................... 2
    2.2.2 Physiological Basis of EEG .................................................................................. 2
    2.2.3 EEG frequency bands ......................................................................................... 3
    2.2.4 Disturbances in EEG ........................................................................................... 7
  2.3 Anatomy and Physiology ............................................................................................ 7
    2.3.1 The Talocrural Joint ............................................................................................ 7
    2.3.2 The Talocrural Joint and its Innervation ............................................................... 8
  2.4 Somatic Sensory Pathways .......................................................................................... 9
    2.4.1 Dorsal Column- Medial Lemniscal System ......................................................... 10
    2.4.2 The Parietal Lobe and Associated Somatosensory Areas ..................................... 11
  2.5 Temporal Lobe ............................................................................................................. 11
  2.6 Frontal Lobe and its Association with the Parietal Lobe ............................................. 12
2.7 Chiropractic Manipulation .................................................................................. 12
2.7.2 Mortise Separation Manipulation .................................................................. 12
2.7.3 Benefits of Talocrural Joint Manipulation (TCJM) ...................................... 13
2.8 Relation of Extremities to the Central Nervous System ............................... 13
2.9 Chiropractic and its Effect on qEEG ................................................................. 14
CHAPTER THREE – METHODOLOGY .................................................................. 15
3.1 Introduction ........................................................................................................... 15
3.2 Study Design ........................................................................................................ 15
   3.2.1 Participant Recruitment ............................................................................. 15
   3.2.2 Sample Selection and size ......................................................................... 15
   3.2.3 Inclusion criteria ......................................................................................... 15
   3.2.4 Exclusion criteria ....................................................................................... 16
3.3 Objective Data ...................................................................................................... 16
   3.3.1 Introduction ................................................................................................ 16
3.4 Procedure ........................................................................................................... 18
3.5 Data Analysis ...................................................................................................... 20
3.6 Ethical Considerations ....................................................................................... 21
CHAPTER FOUR - RESULTS ................................................................................ 23
4.1 Introduction .......................................................................................................... 23
4.2 Cases .................................................................................................................. 23
   4.2.1 Participant 1 ................................................................................................ 23
   4.2.2 Participant 2 ................................................................................................ 30
   4.2.3 Participant 3 ................................................................................................ 36
   4.2.4 Participant 4 ................................................................................................ 43
   4.2.5 Participant 5 ................................................................................................ 49
   4.2.6 Participant 6 ................................................................................................ 55
   4.2.7 Participant 7 ................................................................................................ 61
   4.2.8 Participant 8 ................................................................................................ 67
LIST OF FIGURES

Figure 1: Screenshot from AcqKnowledge software of the alpha band. ..............................................................4
Figure 2: Screenshot from AcqKnowledge software of the beta band. .................................................................5
Figure 3: Screenshot from AcqKnowledge software of the theta band. ...............................................................6
Figure 4: Screenshot from AcqKnowledge software of the delta band. ...............................................................6
Figure 5: The Talocrural Joint (http://palmer-footandankle.blogspot.co.za/2012/08/ankle-pain-and-arthroscopy.html). ..............................................................................................................8
Figure 6: Photomicrograph of an anterior talofibular ligament showing one type-III (black arrow) and several type-II receptors (hollow arrows). ..................................................................................9
Figure 7: Photomicrograph of a section of a calcaneofibular ligament. An axon is seen to terminate in at least four type II mechanoreceptors (arrows)......................................................................................9
Figure 8: Somatosensory pathways (Ergi, 2012) ....................................................................................................11
Figure 9: Two somatosensory cortical areas, somatosensory areas I and II (HALL, 2011) .................................11
Figure 10: Electrode cap and electrode montage (Biopac Systems Inc., n.d.; 2,23-28, 90-92) ..........................18
Figure 11: Frontal Lobe (Channel 1): Eyes open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation .......................................................................................... 24
Figure 12: Frontal Lobe (Channel 1): Eyes closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ....................................................................................... 25
Figure 13: Temporal Lobe (Channel 2): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ................................................................................. 26
Figure 14: Temporal Lobe (Channel 2): Eyes closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ................................................................................. 27
Figure 15: Parietal Lobe (Channel 3): Eyes open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ....................................................................................... 28
Figure 16: Parietal Lobe (Channel 3): Eyes closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ....................................................................................... 29
Figure 20: Temporal Lobe (Channel 2): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ..................................................................................... 34
Figure 21: Parietal Lobe (Channel 3): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ..................................................................................... 35
Figure 22: Parietal Lobe (Channel 3): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ..................................................................................... 36
Figure 23: Frontal Lobe (Channel 1): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Figure 24: Frontal Lobe (Channel 1): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Figure 25: Temporal Lobe (Channel 2): Eyes Open at pre-adjustment, immediately post-manipulation and at 30 minutes post-manipulation

Figure 26: Temporal Lobe (Channel 2): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Figure 27: Parietal Lobe (Channel 3): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Figure 28: Parietal Lobe (Channel 3): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Figure 29: Frontal Lobe (Channel 1): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Figure 30: Frontal Lobe (Channel 1): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Figure 31: Temporal Lobe (Channel 2): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Figure 32: Temporal Lobe (Channel 2): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Figure 33: Parietal Lobe (Channel 3): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Figure 34: Parietal Lobe (Channel 3): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Figure 35: Frontal Lobe (Channel 1): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Figure 36: Frontal Lobe (Channel 1): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Figure 37: Temporal Lobe (Channel 2): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Figure 38: Temporal Lobe (Channel 2): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Figure 39: Parietal Lobe (Channel 3): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation
Figure 57: Parietal Lobe (Channel 3): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ................................................................. 72
Figure 58: Parietal Lobe (Channel 3): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ................................................................. 73
Figure 59: Frontal Lobe (Channel 1): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ................................................................. 74
Figure 60: Frontal Lobe (Channel 1): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ................................................................. 75
Figure 61: Temporal Lobe (Channel 2): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ................................................................. 76
Figure 62: Temporal Lobe (Channel 2): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ................................................................. 77
Figure 63: Parietal Lobe (Channel 3): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ................................................................. 78
Figure 64: Parietal Lobe (Channel 3): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ................................................................. 79
Figure 65: Frontal Lobe (Channel 1): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ................................................................. 80
Figure 66: Frontal Lobe (Channel 1): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ................................................................. 81
Figure 67: Temporal Lobe (Channel 2): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ................................................................. 82
Figure 68: Temporal Lobe (Channel 2): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ................................................................. 83
Figure 69: Parietal Lobe (Channel 3): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ................................................................. 84
Figure 70: Parietal Lobe (Channel 3): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation ................................................................. 85
Figure 71: Graphs Showing the Group Averages for Delta, Theta, Alpha and Beta Wave Activity in the Frontal, Temporal and Parietal Lobes while the Eyes were Open and Closed ......................................... 90
Figure 72: Pie graph demonstrating the distribution of the trends seen throughout all 10 participants’ testing ................................................................................................................................. 91
LIST OF SYMBOLS
Hz - Hertz
uV - microvolt
V^2 - root-mean—square average amplitude value

LIST OF ACRONYMS
CNS - central nervous system
qEEG - quantitative electroencephologram
SEPS - somatosenory evoked potentials
TCJM - talocrural joint manipulation

LIST OF APPENDICES
A - Advert
B - Information Form
C - Consent Form
D - Professor Burke Permissions Letter
E - Professor Fourie Permissions Letter
F - qEEG Equipment
G - Ethics Clearance Letter
H - Group Modal Results
I - Turnitin
CHAPTER ONE – INTRODUCTION

1.1 The Topic
An EEG is used to measure brainwave activity in real time (Pizzagalli, 2007). A quantitative encephalogram (qEEG) uses a set of quantitative methods aimed at processing signals produced by the EEG (Kropotov, 2010). According to Haavik-Taylor and Murphy, albeit that chiropractic manipulation is an effective modality in the treatment of pain and restoration of mobility, there is little known about the neurophysiological effect of the manipulation (Haavik-Taylor and Murphy, 2007). There is therefore a need to further our understanding of the neurophysiological effects of the chiropractic manipulation (Lystad and Pollard, 2009). Studies that have been done have investigated the potential effects of spinal manipulation on EEG and/or qEEG. None have considered the effects as a somatosensory response to manipulation. The goal will be to set out to see whether a chiropractic manipulation applied to an extremity will have any discernible effect on qEEG readings.

1.2 Aim
The aim of the study was to complete a case series, describing whether chiropractic manipulations to an extremity (the talocrural joint), have any noticeable changes on qEEG readings. To date, all studies on EEG have looked at spinal manipulation. Potential changes following extremity manipulation could demonstrate alternate motivations as to why these changes could be occurring.

1.3 Study Design
A descriptive design following a case study approach was used to track qEEG readings before and after the chiropractic manipulation. The study took place at the University of Johannesburg Doornfontein Campus, in the chiropractic day clinic. The case study consisted of 10 participants, each with a talocrural restriction. The qEEG was used to record the patients’ brain wave activity while their eyes were open and then closed. This was done prior to the manipulation which was considered as the initial or baseline reading. The manipulation to the extremity was then performed. Following the manipulation two measurements were taken; the first being immediately after the chiropractic manipulation and the second 30 minutes after the manipulation. This was done again with the eyes open and then closed.
CHAPTER TWO – LITERATURE REVIEW

2.1 Introduction
This chapter will review the relevant literature related to this study. Specifically, it will present brain neurology and how it relates to brain qEEG and function. It will also discuss the relevant anatomy of the talocrural joint and its relation to the central nervous system (CNS).

2.2 qEEG

2.2.1 Introduction
An EEG is used to measure the voltage produced by the depolarization of cortical pyramidal neurons in real time (Pizzagalli, 2007). Microdipoles representing pyramidal cells are positioned perpendicularly to the head’s surface. This placement of the electrode dipoles is most sensitive to currents at the surface produced at radial sources, particularly by the gyri. An EEG is therefore the measurement of brainwave activity in real time (Tatum, 2014).

EEG is a reasonably priced neuroimaging option (Lystad and Pollard, 2009). Quantitative Electroencephalogram (qEEG) is a set of quantitative methods aimed at processing signals produced by the EEG. A qEEG includes wavelet and spectral analysis (Kropotov, 2010). According to the American Psychiatric Association (1991), qEEG is a technique of great promise that should have a place along with other brain imaging techniques in researching brain illness (Blum et al., 2000).

2.2.2 Physiological Basis of EEG
In the CNS, excitatory post synaptic potentials are triggered at the apical dendrites of neurons via an action potential. The membranes of these dendrites become depolarized in contrast to the cell soma (Pizzagalli, 2007). This situation is regarded as a dipole. The area of positive charge is a source and the area of negative charge is regarded as a sink. Electrodes measure the sum of positive and negative charges in their surrounding area. This is why it’s necessary that the neurons are placed in a parallel fashion and are synchronised, so that the charges do not cancel each other out and therefore become unmeasurable.

Scalp recorded EEG oscillations are the synchronised synaptic activity of all the excitatory and inhibitory post synaptic potentials in collections of cortical pyramidal neurons. Thalamocortical and corticocortical connections are both involved in the formation of EEG waves (Baumbick, Hondorp, Miller, Penney & Kettner, 1992: 5; Jackson and Bolger, 2014).
2.2.3 EEG frequency bands

2.2.3.1 Introduction

EEG waveforms are a variation of bands and rhythms which are then further transformed and quantified and then analysed (Boutros, Galderisi, Pogarell and Riggio, 2011). Waveforms are a way to quantify cortical activity in an EEG. This is measured in terms of amplitude and frequency (Kropotov and Ponomarev, 2009).

The amplitude of the waveform is stated as the voltage of the EEG waves and is expressed in microvolts (µV).

EEG power is defined as the square of the amplitude (µV²) (El-Sayed, Larsson, Persson and Rydelius, 2002).

Frequency is defined as the number of oscillations within a given epoch (time frame) and is measured in Hertz (Hz) (Loo and Barkley, 2005). The EEG signal is composed of four frequency bands; namely alpha, beta, delta and theta.

2.2.3.2 Alpha Band

This is the dominant rhythm present in adults (Klimesch, 1999). It falls between a frequency of 8 Hz-13 Hz and is expressed between (10 and 45 Microvolts) 10-45 µV. Alpha rhythms occur mostly during relaxed wakefulness i.e. the patient is in a meditative state.

It can also be noted when patients are in a learning state of mind. This rhythm is distributed most commonly in the occipital regions, but shifts anteriorly during drowsiness (Tatum, 2014).

“Alpha blockage” is a severe diminishing of alpha rhythms and occurs with sudden alertness, opening of the eyes or focused mental attention (Pizzagalli, 2007).
2.2.3.3 Beta Band

This is the highest frequency in the active brain. It operates between 13 Hz-30 Hz and is expressed between (10 and 20 Microvolts) 10-20 µV (Barwell, Long, Byers and Schisler, 2004). Beta rhythms have been seen to increase during mental activation and information processing (Tatum, 2014). It is found in a frontocerebral distribution and often replaces alpha bands during focused attention and cognition. An increase in drowsiness causes wave activity to decrease (Pizzagalli, 2007).
Figure 2: Screenshot from AcqKnowledge software of the beta band.

2.2.3.4 Theta Band
These rhythms range between 4 Hz-7 Hz and are expressed as (less than 15 Microvolts) <15 µV. They are seen during light sleep, deep relaxation and conceptual development (Barwell et al., 2004). There are 2 types of theta rhythms. One has a widespread scalp distribution and is seen with impaired mental processing and decreased alertness. The other is found maximally in frontal or frontocentral head regions. Frontal theta is facilitated by emotions and during focused mental attention. It can also be found during hyperventilation and sleep (Tatum, 2014; Pizzagalli, 2007).
2.2.3.5 Delta band

These rhythms operate between 1 Hz-4 Hz. In healthy brains they are often seen during deep sleep, energy storage and the deep subconscious (Barwell et al., 2004). Excessive delta waves are considered abnormal i.e. they are seen in encephalopathy (Pizzagalli, 2007).

Figure 3: Screenshot from AcqKnowledge software of the theta band.

Figure 4: Screenshot from AcqKnowledge software of the delta band.
2.2.4 Disturbances in EEG

Lower somatosensory evoked potential (SEP’s) can be utilised as a sensitive and versatile diagnostic tool in neurological disease. Neurological disease may produce a slowing of spinal and scalp components (Mandel and Willis, 2000).

Conditions such as concussion and patients with chronic pain will also cause a slowing down of these potentials. Cerebral dysfunction has been shown to cause slowing down of brain wave processing (Duclos, Dumont, Wiseman-Hakes, Arbour, Mongrain, Gaudreault, Khoury, Lavigne, Desautels and Gosselin, 2014).

Bipolar disorder has shown a decrease in alpha brainwave synchronisation. A decrease is largely found in frontocentral and centroparietal connections (Kim, Bolbecker, Howell, Rass, Sporns, Hetrick, Breier and O'Donnell, 2013). EEG disturbances have also been noted in certain conditions including schizophrenia, depression, Alzheimer’s, ADHD and toxic exposure i.e. alcohol/ drug abuse (Blum et al., 2000).

2.3 Anatomy and Physiology

2.3.1 The Talocrural Joint

The distal ends of the tibia and fibula form a malleolar mortise into which the trochlea of the talus fits. The trochlea is the superior aspect of the talus. The interosseous ligament is found between the nearly congruent surfaces of the tibia and fibula.

The joint capsule of the ankle joint is thin anteriorly and posteriorly but stability is provided by the lateral and medial collateral ligaments on either side. The joint capsule attaches superiorly to the borders of the articular surfaces of the tibia and malleoli and inferiorly to the talus (Moore, Dalley, Agur, 2010).
2.3.2 The Talocrural Joint and its Innervation

Mechanoreceptors and free nerve endings have been found in every joint (Hogervorst and Brand, 1998). Receptors in joint capsules are abundantly innervated by mechanoreceptors and free nerve endings that detect pressure, tension and movement at the joint (Martini and Nath, 2009).

In 1967, Freeman and Wyke (F&W) published a classification system after performing a detailed anatomical and histological study of feline knees (Freeman and Wyke, 1967). There is evidence that the loss or damage of mechanoreceptors affects neuromuscular function (Hogervorst, Brand, 1998).

The ankle joint capsule has the presence of (F&W) type I, II and IV mechanoreceptors. The ankle ligaments have been found to have (F&W) type I, III and IV mechanoreceptors present (Hogervorst and Brand, 1998). Mechanoreceptors will be reviewed in more detail in the next sections.

2.3.2.1 Mechanoreceptors

**Type I**- These are slowly adapting receptors with a low threshold. Even at rest they are continually firing. This suggests that they provide postural sense to the CNS (Michelson and Hutchins, 1995).

**Type II**- These are dynamic and contain an element of rapid adaptation. They have a low threshold and are present during the beginning of joint motion. These are found abundantly throughout the ankle joint (Michelson and Hutchins, 1995).

**Type III**- These too are dynamic receptors. They have a high threshold and a low adaptation. They are activated during extreme movements and are also abundantly found in the human ankle joint (Michelson and Hutchins, 1995).

**Type IV**- These are free nerve endings in the tissues and are responsible for nociceptive function. They are also more numerous than other mechanoreceptors and found throughout the joint capsule (Hogervorst and Brand, 1998; Michelson and Hutchins, 1995; Rein, Hanisch, Zwipp, Fieguth, Lwowski and Hagert, 2013).
In figure 6 a single Type III is shown and several type II’s. Between the receptors, strands of collagen are present. The nerve endings are contained within the intervening septum. This shows that a single nerve axon can terminate in multiple mechanoreceptors of one type. In figure 7 a single nerve fibre could also supply several types of mechanoreceptors (Michelson and Hutchins, 1995). These small nerve fibres originate from nerves that are derived from the tibial nerve and deep peroneal nerve (Gardner and Gray, 1968; Moore et al., 2010). The tibial nerve originates from the sciatic nerve. The sciatic nerve originates from the anterior and posterior divisions of the anterior rami of spinal nerves L4-S3. The deep peroneal nerve originates from the common peroneal nerve which originates from the sciatic nerve (Moore et al., 2010).

2.4 Somatic Sensory Pathways
These pathways relay sensory information from the skin and musculature of the body wall, head, neck and limbs. The 3 pathways are the posterior column pathway, the spinothalamic pathway and the spinocerebellar pathway (Martini and Nath, 2009).
The spinocerebellar pathway, most specifically the ventral spinocerebellar tract, relays proprioceptive information from the muscle spindles and Golgi tendon organs of the trunk and lower limb. Most proprioceptive information is transferred to the cerebellum and therefore doesn’t reach consciousness (Patestas and Gartner, 2013). The posterior column/dorsal column/medial meniscus pathway carries very fine touch, pressure, vibration and a degree of proprioception (Martini and Nath, 2009). This pathway terminates in the primary somatosensory cortex rather than the cerebellum and it is for this reason that we will discuss this pathway in further detail.

2.4.1 Dorsal Column- Medial Lemniscal System
Sensory signals begin at the peripheral joint mechanoreceptors and terminate in the primary somatosensory cortex. Axons of the 1st order neurons travel via large myelinated nerve fibres to arrive at the dorsal roots of the spinal nerves (Hall, 2011). Axons from the superior half of the body ascend within the fasciculus cuneatus whereas axons arising from the inferior half of the body ascend within the fasciculus gracilis (Martini and Nath, 2009). Since the chiropractic manipulation was carried out on the talocrural joint. The dorsal column pathway from the inferior half of the body will be discussed.

Axons ascending within the fasciculus gracilis synapse in the nucleus gracilis in the medulla oblongata. Axons of the 2nd order neurons in the nucleus gracilis decussate to the other side of the brainstem and ascend in a tract called the medial lemniscus. The axons in these tracts then synapse on 3rd order neurons in the ventral nuclei of the thalamus. Information gets processed at these nuclei and is projected to the primary somatosensory cortex (Martini and Nath, 2009; Hall, 2011). Because of the decussation
at the medulla, the right side of the thalamus represents sensation from the left hand side of the body and vice versa (Hall, 2011).

Figure 8: Somatosensory pathways (Ergi, 2012)

2.4.2 The Parietal Lobe and Associated Somatosensory Areas
The parietal lobe is made up of the central sulcus anteriorly and is further bounded posteriorly by a line connecting the parieto occipital sulcus and the Sylvian sulcus (Ellis and Mahadevan, 2010). The post central gyrus makes up the posterior aspect of the central sulcus (or anterior parietal lobe), and it is here where the primary somatosensory cortex is found (Martini and Nath, 2009). The anterior portion of the parietal lobe has its function in interpretation of somatosensory signals. The posterior portion is concerned with higher levels of interpretation (Hall, 2011). Somatosensory area one and somatosensory area two are located in the anterior portion of the parietal lobe. Area one has been shown to be far more extensive and relevant and is sometimes referred to as the somatosensory cortex on its own. Area one has a large degree of localisation in the body. Albeit that most of what we understand about the somatosensory cortex comes from area one, area two does have a relationship to information received from the lower limb (Hall, 2011).

Figure 9: Two somatosensory cortical areas, somatosensory areas I and II (HALL, 2011)

2.5 Temporal Lobe
The temporal lobe is a portion of the cerebral cortex with critical functionality. It is involved in the establishment of long term as well as everyday memory and is affected by human ageing (Xu et al., 2016). The temporal lobe is separated from the occipital lobe by a vertical line from the upper end of the lateral sulcus. The important areas of the temporal lobe are the auditory cortex and the temporal association cortex. Both are concerned with the perception and integration of auditory stimuli.
Hair cell receptors within the cochlea are stimulated in response to auditory stimuli and in turn, activate sensory neurons. The cochlear branch of cranial nerve VIII is formed by the afferent branches of these neurons. Auditory sensations are then relayed to the cochlear nuclei of the medulla oblongata. These signals are then directed to the inferior colliculus before ascending to the medial geniculate nucleus in the thalamus. Finally this information is received by the auditory cortex of the temporal lobe (Hall, 2011; Martini & Nath, 2009).

### 2.6 Frontal Lobe and its Association with the Parietal Lobe

The frontal lobe consists of the cortex which is found anterior to the central sulcus of Rolando. It includes 2 important cortical areas, namely the motor cortex and the premotor cortex. Both are associated with voluntary movements (Hall, 2011).

Frontal SEP’s (somatosensory evoked potentials), represent early somatosensory input into non-primary motor areas. They provide insight into the sensory processing of motor control. Research supports the role of the prefrontal cortex in the modulation of these SEP’s (Brown and Staines, 2015).

The prefrontal association area receives pre-analysed sensory information from the parieto-occipitotemporal association area via a substantial bundle of subcortical nerve fibres (Hall, 2011).

The frontal lobe’s connections to the parietal lobe are defined by a chain of U-shaped connections between the adjacent lobes. These include the paracentral lobe, the hand knob region and the ventral group of connections (Catani et al., 2012).

### 2.7 Chiropractic Manipulation

#### 2.7.1 The Relaxation Potential of the Chiropractic Manipulation

Chiropractic spinal manipulation has been shown to produce a relaxation effect (Nielsen, Bronfort, Bendix, Madsen and Weeke, 1995). A study conducted by Hoiriis et al., 2004, concluded that spinal chiropractic manipulation was more efficient than placebo and muscle relaxants in reducing lower back pain. There is further research on the effect of spinal manipulation on relaxation but research is currently limited on the effects of extremity manipulation and its possible link to relaxation.

#### 2.7.2 Mortise Separation Manipulation

This manipulation is used to mobilize the talocrural joint and can also be utilized in a subacute ankle sprain. It consists of distraction of the articulation between the tibia and talus (Bergmann and Peterson, 2010). Talocrural joints that allow for greater degrees of dorsiflexion are more likely to produce a cavitation (Fryer, Mudge and McLaughlin, 2002).
2.7.3 Benefits of Talocrural Joint Manipulation (TCJM)

This manipulation has the potential to increase the functional performance of athletes with chronic ankle instability (Kamali, Sinaei and Bahadorian, 2017.) It has also been shown to allow elderly patients to partially compensate for the destabilising effect which is experienced when the participant closes their eyes due to proprioceptive stimulation (Vaillant, Vuillerme, Janvey, Louis, Braujou, Juvin and Nougier, 2008). Furthermore, foot and ankle manipulation has also shown to have a positive effect on healthy individuals by contributing to dynamic standing balance ability (Wassinger, Rockett, Pitman, Murphy and Peters, 2014).

Movement that’s created at the talocrural joint has the potential to increase ankle strength, mobility as well as weight bearing ability (An and Jo, 2017).

2.8 Relation of Extremities to the Central Nervous System

Maladaptive plastic changes result from musculoskeletal dysfunction (Daligadu, Haavik, Yielder, Baarbe and Murphy, 2013).

The measurement of SEP’s affords the ability to objectively assess the integrity of sensory and motor pathways, as well as areas of the CNS (Hwang, Sohn, Kim, and Jee, 2016). The primary somatosensory cortex plays an essential role in the processing of somatosensory information. It is also very necessary for the integration of motor and sensory signals which are required for skilled movement (Borich, Brodie, Gray, Ionta and Boyd, 2015).

The CNS can dynamically adjust and adapt to different sensory inputs from the foot and ankle. Experimental manipulations that have been conducted on the foot and ankle have shown mechanoreceptors present in the joint contribute to improve balance. It is postulated in this study that the CNS relies on somatosensory input from the foot and ankle to maintain balance and maintain an upright postural stance. The study also showed that experimental manipulations on the foot and ankle improved balance (Hlavackova and Vuillerme, 2012; Vuillerme and Pinsault, 2007). A study conducted by R. Palmieri showed that ankle joint effusion facilitated motor neuron pool excitability. An increase in H reflex wave activity was seen in the tibialis anterior, soleus and peroneus musculature. The study goes on to explain that the H reflex can be affected by many central pathways from the CNS (Palmieri, Ingersoll, Hoffman, Cordova, Porter, Edwards, Babington, Krause and Stone, 2004).
2.9 Chiropractic and its Effect on qEEG

The following are studies that discuss spinal manipulation and its relevance to the brain and CNS system. Since there is little research on chiropractic extremity manipulation and its effect on brain qEEG, we will discuss the following researches with the intention of showing that chiropractic spinal manipulation has an effect on the brain.

Continuous somatosensory stimulation of mechanical stimuli evokes a response in the cortex which can be measured by qEEG (Vlaar, van der Helm, and Schouten, 2015).

A study conducted by Barwell et al., 2004 theorized that the chiropractic manipulation has an effect beyond the dorsal horn of the nerve root to have a direct effect on the brain itself. The changes in brain waves seen are evident after the chiropractic manipulation but this may be a normal variation. The study is therefore inconclusive and more research needs to be done.

A study by Baumbick et al., 1992 mentions prior research which showed that there are large mechanoreceptors found in the facet joints in the cervical spine. Intersegmental motion at each cervical spine joint caused these mechanoreceptors to become excited, resulting in a summative effect. These signals eventually reach the thalamus, which fires to adjacent cortical areas and can be quantitatively measured by the qEEG.

According to Haavik-Taylor and Murphy, 2007 it is believed that the chiropractic manipulation has a neurophysiological effect by altering sensorimotor integration. However, they too believe that more research is required. This study also resulted in a change in frontal and parietal evoked potentials following a single manipulation to a dysfunctional segment. This change remained present for 20 minutes post manipulation before returning to baseline levels.

A study took 36 participants with upper cervical joint restrictions. These patients were then manipulated and their reaction time was measured. Results showed that there was an improvement in the patients’ reaction time. This implied that the chiropractic manipulation had an effect on cortical processing (Kelly, Murphy and Backhouse, 2000).
CHAPTER THREE – METHODOLOGY

3.1 Introduction
This chapter provides a framework for the research methods used for this study. This includes participant recruitment, sample size and selection, inclusion and exclusion criteria, treatment approach, handling the qEEG, collecting data, data analysis, ethical considerations and the methods used to increase the reliability and the validity of the study.

The aim of the study was to compile a case series to determine whether an extremity chiropractic manipulation had any discernible influence on qEEG readings and therefore brain wave activity. Data was collected pre- and post-manipulation and a comparison was made.

3.2 Study Design
A descriptive design followed by a case series approach was the most efficient way of describing and interpreting qEEG changes before and after the TCJM (Brink, 2006).

3.2.1 Participant Recruitment
The broadcast message function on Whatsapp messenger was utilised, as well as adverts that were placed around the University of Johannesburg (Appendix A). Word of mouth, or snowball sampling, was also used.

3.2.2 Sample Selection and size
Participants that were recruited were asked to read an information form (Appendix B) and sign a consent form (Appendix C) specific to this study. This confirmed that they fully understood all the procedures involved. Recruitment continued until 10 participants had met all the inclusion and exclusion criteria and were willing to take part. If any participants withdrew from the study, further recruitment would have taken place as a minimum of 10 participants was needed (Niazi et al., 2015).

As this was a descriptive study, each case was fully and extensively described and conducted as 10 individual case studies. This meant that no statistical analysis was necessary.

3.2.3 Inclusion criteria
The participants complied with the following in order to participate in this study:

- Participants had to be between the ages of 18 – 45 years
- Participants were required to read the information (Appendix B) and sign the consent form (Appendix C)
- Participants had to have at least one talocrural joint restriction. The talocrural joint is the joint formed by the tibia, fibula and the talus. This restriction was confirmed by motion palpation, which is a technique employed by chiropractors to locate joint restriction (Rubin, 2010).

3.2.4 Exclusion criteria
Participants who presented with the following were not allowed to participate in this study. These were screened during recruitment, history taking and initial physical examination.
- Any chiropractic ankle mortise manipulations or spinal manipulations in the three months that preceded the study.
- Any open wounds on the scalp
- Substance abuse such as tetrahydrocannabinol (THC), lysergic acid diethylamide (LSD-25) and phencyclidine (PCP)
- Caffeine, nicotine or any other stimulants were not permitted 6 hours prior to the participants’ readings
- Participants with diagnosed psychiatric conditions such as bipolar disorder, depression, anxiety, autism and schizophrenia
- Any noted recent excessive stress as a result of a life-altering event e.g. being a victim of crime, the death of a family member or divorce

3.3 Objective Data
3.3.1 Introduction
The qEEG equipment that was used for the trials was lent to the researcher by Professor Alban Burke from the University of Johannesburg’s Psychology Department (Appendix D). The specific qEEG used was the BIOPAC MP150 System which included the AcqKnowledge software.

The qEEG has met the high standards of reliability and validity when it comes to reading and recording brain activity, making it the hallmark of its field (Thatcher, 2010). According to the American Psychiatric Association 1991; qEEG is a technique of great promise that should have a place along with other brain imaging techniques in research of the brain (Blum et al., 2000). The qEEG software Acqknowledge has the capability to conduct a quantitative analysis of the recordings. Psychology student Meghann Bruce demonstrated the use of both the program and EEG equipment to the researcher.

The precision of the EEG allowed for highly accurate readings of the brain waves. This permitted for the analysis of fluctuations of EEG activity i.e., increases/decreases (Pizzagalli, 2007).
3.3.1.1. Hardware


- Data acquisition unit: MP150A-CE
  A high-speed system that uses an Ethernet cable that has been recorded at speeds of up to 400 kHz (aggregate).
- Universal interface module: UIM100C
  The interface between the MP150 and external devices.
- Ethernet Switch (for user-supplied Ethernet card or adapter): ETHSW1
- Transformer: AC150A
  +12 volt, 2.5 amp
  This cable connects the MP150 System to the AC mains wall outlet.
- Cables: CBLETH1 (2)
- EEG100C
  Neuronal brain activity is measured by a single-channel, high-gain, differential input and biopotential amplifier called the electroencephalogram amplifier module (EEG100C). There were three of these used during the trials. The EEG100C’s were connected to the BIOPAC MP150 System.
- CAP100C Electrode Cap
  It is a Lycra-type fabric cap with interlaced tin electrodes. The electrodes are arranged in the International 10-20 montage. The cables from the electrodes are connected to the EEG100C’s.

A Standard PC, mouse, keyboard and monitor were used.
See Appendix F for images of all the above.

3.3.1.2. Software

The system included AcqKnowledge Lab Assistant GLP software which was used to analyse and extract the relevant data that was needed. The software provides Network or Stand-alone solutions, Security Management, Data Archiving, Customizable Software Solutions, Advanced Audit Trails, Standard Operating Procedures, Validation and Algorithm Disclosure, Increased Productivity and Flexible Solutions for a Variety of Applications (Biopac Systems, Inc., n.d.). Although this system can accurately record on 6 channels, only 3 channels were used to record the brain waves. One was over the parietal lobe because the somatosensory region is located here (Scheperjans, Palomero-Gallagher, Grefkes, Schleicher and Zilles, 2005). The second and third channels were located over the frontal lobe and temporal lobe respectively.
3.4 Procedure
The study took place at the University of Johannesburg’s Doornfontein Campus, in the Chiropractic Day Clinic.

Each participant was treated as a new patient. This necessitated the completion of a case history, a full physical examination as well as a foot and ankle regional evaluation. Screenings for talocrural joint restrictions were performed via motion palpations before the process was initiated. This was done to eliminate any chance of false readings as a result of overstimulating the patient during the process. A baseline or pre-manipulation reading was taken for each participant. The reason for this recording was to remove any irregularities and this formed a fair comparison for each participant’s pre- and post-manipulation qEEG readings.

On arrival, once the case history, physical examination and foot/ankle regional were completed, the electrical cap was placed and secured on the participant’s head. See figure 10 below for an image of the electrode cap.

![Electrode cap (CAP100C)](image)

**Electrode cap (CAP100C)**

![International 10-20 electrode montage](image)

**International 10-20 electrode montage**

Figure 10: Electrode cap and electrode montage (Biopac Systems Inc., n.d.: 2,23-28, 90-92)

Electrodes F3 and F4 correlated to channel 1 and are found over the frontal lobe. The frontal lobe has connections with the parietal lobe of the brain (Catani et al., 2007.) Therefore, changes in the parietal lobe may cause a change in the frontal lobe. T5 and T6 are associated with channel 2, which is situated over the temporal lobe. Channel 3 correlated to electrodes C3 and C4 which were located over the somatosensory cortex in the parietal lobe. See figure 10 for the locations of the electrodes.
Using the nose as the central marker, these electrodes were placed in the midline of the body. This ensured that the electrodes were over the same area after the chiropractic manipulation was delivered to the restricted talocrural joint. The participant was then asked to lie down on the plinth and relax.

The researcher explained to the participant that they would be lying down for a total of 4 minutes per recording. For the first 2 minutes, the participants had their eyes open. After the first 2 minutes, the researcher indicated to the participant to close their eyes for the remainder of the time.

Once the participant verbally confirmed that they understood the instruction by repeating it, the first reading (pre-test reading) took place. This commenced as soon as the researcher clicked on the “start” button with the participants’ eyes open. The researcher and the participant tried to remain completely silent and still for the full 4 minutes to eliminate false readings. At the 2 minute mark, the participant was verbally instructed by the researcher to close their eyes.

As soon as the 4 minute period had elapsed, the cap was removed while the participant remained lying on the plinth (the electrical cap was very delicate and therefore manipulating with the cap on the patient may have caused damage to the equipment). As per the recruitment process, the talocrural joints had been previously evaluated for any long-axis extension restrictions using motion palpation and were recorded in the participant’s file. The restriction was then treated immediately using a chiropractic mortise separation manipulation. The cap was replaced to its original location and aligned as previously stated on the participant’s head. This was done to ensure that the cap was in the same position. The participant remained lying on his/her back for the entire process. Once again the participant was instructed to open their eyes so that the first post-manipulation recording could take place.

There were a total of two post-manipulation recordings, one being immediately after manipulation and the second at 30 minutes post-manipulation. The first reading was taken within 30 seconds of the TCJM’s. The identical procedure that was used in the pre-manipulation recording was repeated. The participant lay still with their eyes open for 2 minutes before they were instructed to close their eyes and the recording continued for a further 2 minutes.

Once the recording after the manipulation was completed, the participant remained on their back and waited quietly with the cap on. 30 minutes after the manipulations had been delivered the last recording took place. Again the same procedure was followed, with readings being recorded for 2 minutes with their eyes open and for 2 minutes with their eyes closed. The cap was then removed from the participant’s head and they were thanked for their time.
3.5 Data Analysis

The data analysis consisted of five phases:

- **Preparation of data:** Digital filtering was applied to restrict the qEEG recordings to frequency bandwidth 1 – 25 Hz, as this study was limited to readings of the following bandwidths:
  - Delta: 1 – 4 Hz
  - Theta: 5–8 Hz
  - Alpha: 9 – 12 Hz
  - Beta: 13 – 20 Hz

  In order to facilitate this the band-pass filter was set for 1 – 25 Hz.

- **Transformation of data**

  The first step in this procedure was the selection of individual, virtually artefact-free epochs. Six two-second epochs were extracted for each participant per condition (eyes-open and eyes-closed) for the three recording phases (pre-test, post-test 1 and post-test 2), for the three different cortical areas of the brain. Epochs were chosen within twenty seconds of each other but due to unforeseen artefacts i.e. body movements, noise, researcher error etc. The next closest epoch was selected.

  For each epoch that was selected, this data was transformed by means of a spectral analysis (a frequency analysis that consists of decomposing a qEEG signal into constituent periodic components by means of a mathematical equation). For the purposes of this study the equation that was used was the Fast Fourier Transform (FFT).

- **Extraction of mean power values**

  The next step in the data preparation was to transform the spectral analysis into meaningful numbers. Each of the epochs selected were clustered via use of the AcqKnowledge Software according to the frequency parameters set above and then the root-mean-square average amplitude (V2) value was extracted.

- **Obtaining the values for the domains of investigation**
The values that were extracted (as described above) were recorded for each individual participant on a spreadsheet as follows:

- Mean power value per epoch (6 x Eyes Closed and 6 x Eyes Open)
- For each of the 3 cortical sites
- For the pre-, post-manipulation and 30 minutes post-manipulation

Analysis of Data

In order to prepare the data for analysis, the mean score for each participant for each frequency bandwidth across the different epochs was calculated for both the “eyes open” and “eyes closed” stages. The mean scores for all patients were then investigated to ascertain any trends across the pre-manipulation, immediate post-manipulation and the delayed post-manipulation (30 minutes post-manipulation) phases.

3.6 Ethical Considerations

All participants that wished to partake in this particular study were requested to read the information letter (Appendix B) and sign the consent form (Appendix C) specific to this study. The information letter and consent form outlined the names of the researcher, purpose of the study and benefits of partaking in the study, participant assessment and treatment procedure. Any risks, benefits and discomforts pertaining to the treatments involved were also explained and that the participant’s safety was ensured (prevention of harm). The information and consent form also explained that the participant’s privacy would have been protected as only the researcher, patient and Professor Burkes’ assistant were in the treatment room and their anonymity was ensured as the participants’ information was converted into data and therefore could not be traced back to the individual. The form also stated that standard patient confidentiality would have been adhered to at all times when compiling the research dissertation. The participants were informed that their participation was on a voluntary basis and that they were free to withdraw from the study at any stage. Should the participant have had any further questions, these would have been explained by the researcher; whose contact details were made available. The participants were then required to sign the consent form only, signifying that they understood all that was required of them for this particular study. Results of the study would have been made available on request.

The patient files were stored in the strong room in a secure cabinet at the University of Johannesburg Chiropractic Day Clinic. The data was backed up onto an external hard drive and saved for a period of 2 years after the trial, thereafter the data would have been abolished.
Permission was acquired from Prof Fourie (Appendix E) to conduct research on UJ campus’s as it is possible some students will be involved in the study.

About this particular study, the risks were limited. Participants were warned of possible post manipulative discomfort of the talocrural joint. There was a very small risk of infection in the area where the electrodes from the cap contact the skin of the scalp. This risk was limited by sterilizing the cap with alcohol swabs prior to each use as well as excluding any participant with open wounds. There was also a small risk of skin irritation from putting the cap on and off, this was limited as the cap was only put on once during the trial.

If any concerning signs or symptoms were noted at any point in the study the participant would have been referred to the relevant health care practitioner.

No unforeseen complications arose but if such a situation had arisen, the participants would have been referred to the relevant health care professional.

This study was approved by the Research Ethics Committee of the University of Johannesburg (REC-01-62-2016) (Appendix G)

This study was checked for plagiarism and was found to have 6% similarity as seen in the Turnitin originality report in Appendix I. The receipt for the Turnitin plagiarism evaluation can also be found in Appendix I.
CHAPTER FOUR - RESULTS

4.1 Introduction
The following chapter contains the results obtained from the trials. As this was a descriptive study, all 10 individual cases will be described in detail. Group changes are also of interest and for noting in interpreting the individual change. For this reason the group changes will be presented following the individual cases.

It should be stated that any body movements, researcher error, noise and other stimuli can influence the qEEG readings, resulting in artefacts forming on the recordings. It was for this reason that some of the epochs had to be moved. This is necessitated when undergoing qEEG research in order to capture the most accurate and uninterrupted data within each 2 minute session.

4.2 Cases
Lumbar spine regionals were completed but were found to be unremarkable in terms of range of motion and orthopaedic tests and therefore weren’t included.

4.2.1 Participant 1

4.2.1.1 History and physical examinations
Participant 1 was a 25-year-old male student. He had previously been treated by a chiropractor but he had not been manipulated in the preceding 3 months. He therefore complied with the minimum inclusion criteria for the study.

His general health was good at the time although he suffered from haemochromatosis. Childhood illnesses included chicken pox and pneumonia. When the patient was in matric, he suffered from a left hand sided tibial plateau fracture with an associated torn meniscus. He also fractured his left scaphoid when he was at school and aggravated the injury in 2014. He had been hospitalised in both instances. The patient exercised 6 times per week. This included gym and equestrian.

A review of systems revealed no abnormalities and the physical examination was unremarkable. A left sided talocrural long axis extension restriction was detected.

4.2.1.3 Data analysis
Frontal Lobe: Eyes Open
All values ended up being higher 30 minutes post-manipulation when compared to their original baseline values.
The delta waves had a baseline reading of 0.108778 Volts$^2$/Hz. Immediately post-manipulation this voltage increased to 0.12854 Volts$^2$/Hz. At 30 minutes post chiropractic manipulation, the voltage of the delta waves had further increased to 0.146533 Volts$^2$/Hz. The delta waves followed an increase, increase trend.

The theta waves started with a voltage of 0.098992 Volts$^2$/Hz. This voltage increased post-manipulation to 0.104257 Volts$^2$/Hz and then increased to 0.113803 Volts$^2$/Hz by the final reading. In a similar trend to that of the delta waves, the theta waves increased and then further increased.

The alpha waves pre-test reading was 0.07319 Volts$^2$/Hz. This increased by a similar amount to the delta and theta waves, to 0.08071 Volts$^2$/Hz. Similar to the first two waves, the reading at 30 minutes had increased to 0.8141 Volts$^2$/Hz. The alpha waves followed an increase, decrease pattern.

The beta waves readings increased from pre-manipulation to immediately post-manipulation. Beta waves began at a baseline value of 0.05126 Volts$^2$/Hz and increased to 0.05568 Volts$^2$/Hz at the post-manipulation recording. Interestingly this was the only value to decrease 30 minutes post-manipulation to 0.05439 Volts$^2$/Hz, albeit that this decrease was very minimal and the overall beta value ended higher than the original baseline value. The beta waves followed an increase, decrease trend.

Refer to Figure 11 for a graphical representation of the above data.

![Figure 11: Frontal Lobe (Channel 1): Eyes open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation](image)

**Frontal Lobe: Eyes Closed**

All brain waves for the frontal lobe with the eyes closed showed the same trend of an initial decrease followed by an increase.
The delta waves began at a baseline value of 0.15663 Volts$^2$/Hz. Immediately post-manipulation the value dropped substantially by 0.047425 Volts$^2$/Hz to 0.109205 Volts$^2$/Hz. 30 minutes post-manipulation, the end value increased almost to the original baseline value but slightly lower, at 0.141338 Volts$^2$/Hz. The theta waves prior to the manipulation started with a baseline reading of 0.136188 Volts$^2$/Hz. Immediately post-manipulation it also experienced a decrease to a similar extent to that of the delta waves and was recorded at a reading of 0.093342 Volts$^2$/Hz. 30 minutes later this value had also increased towards the original baseline value but was now slightly lower at 0.119708 Volts$^2$/Hz. The alpha waves recorded a value of 0.09734 Volts$^2$/Hz as a baseline. It further decreased to 0.070195 Volts$^2$/Hz immediately after the manipulation. The value post-manipulation increased as well and at 30 minutes post-manipulation a recording of 0.088072 Volts$^2$/Hz was noted.

The beta waves began with a 0.069428 Volts$^2$/Hz baseline. This was followed by a decrease to 0.04919 Volts$^2$/Hz. After the 30 minute post-manipulation waiting period, this value also increased to a value only slightly less than the initial baseline reading - 0.061198 Volts$^2$/Hz. Refer to Figure 12 for a graphical representation of the above data.

![Participant 1 Frontal Lobe (Eyes Closed)](image)

Figure 12: Frontal Lobe (Channel 1): Eyes closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Temporal Lobe: Eyes Open**

All eyes open values for the temporal lobe showed a significant decrease post-manipulation and only a slight increase in value 30 minutes after the manipulation. This was still a value that was shown to be less than the original baseline value.
The delta waves began at a baseline value of 0.15006 Volts$^2$/Hz. This value was found to decrease quite substantially immediately after the manipulation to 0.100362 Volts$^2$/Hz. In the final reading this value increased only slightly and to a much lower value than that of the original baseline value - 0.118815 Volts$^2$/Hz.

The theta waves started at 0.131355 Volts$^2$/Hz. This value decreased significantly to 0.08721 Volts$^2$/Hz post-manipulation. This value after 30 minutes increased to 0.099183 Volts$^2$/Hz.

The alpha waves recorded a 0.09734 Volts$^2$/Hz initial value. This value dropped significantly to 0.06747 Volts$^2$/Hz immediately after the manipulation. The final value climbed back to 0.072768 Volts$^2$/Hz but this value was also significantly lower than the original baseline value.

The beta waves recorded a baseline value lower than all the other brainwaves at 0.066508 Volts$^2$/Hz. This value decreased by the smallest difference of all the waves post-manipulation. This value was noted at 0.046727 Volts$^2$/Hz and increased to just 0.050692 Volts$^2$/Hz 30 minutes post-manipulation.

Refer to Figure 13 for a graphical representation of the above data.

![Figure 13: Temporal Lobe (Channel 2): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation](image)

**Temporal Lobe: Eyes Closed**

All waves recorded slightly lower but relatively similar values to their eyes open counterparts. As per the temporal lobe with the eyes open, the trend seemed to show that there was a decrease in values all round immediately after the chiropractic manipulation. 30 minutes post-manipulation the values seemed
to increase only slightly to a value that was closer to the value produced directly after the manipulation, rather than the initial baseline value.

The delta waves noted a 0.139413 Volts²/Hz baseline reading. This value decreased substantially by 0.04481 Volts²/Hz to give an amount of 0.094603 Volts²/Hz post-manipulation. This value (in a similar fashion to those described in the temporal lobe eyes open) increased slightly after 30 minutes to 0.106465 Volts²/Hz, which was significantly lower than the initial baseline value.

The theta waves had an initial reading of 0.111827 Volts²/Hz. This value dropped to 0.080405 Volts²/Hz post-manipulation. 30 minutes post-manipulation, this value climbed slightly to 0.088715 Volts²/Hz which was closer to the post-manipulation reading than it was to the initial baseline value.

The initial reading produced by the alpha waves was slightly lower than delta and theta and recorded a value of 0.080232 Volts²/Hz. A decrease to 0.61443 Volts²/Hz was seen directly after the manipulation. 30 minutes post-manipulation this value climbed almost the same degree as the theta waves, to reach a value of 0.069332 Volts²/Hz.

The value of the beta waves was at the lowest of all its counterparts at 0.054402 Volts²/Hz and dropped to 0.042553 Volts²/Hz post-manipulation. Its value also steadied and a final value of 0.049357 Volts²/Hz was captured.

Refer to Figure 14 for a graphical representation of the above data.

Figure 14: Temporal Lobe (Channel 2): Eyes closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation
Parietal Lobe: Eyes Open

The delta waves increased to 0.134192 Volts$^2$/Hz post-manipulation from their original value of 0.115212 Volts$^2$/Hz. This was a significant increase of 0.01898 Volts$^2$/Hz. Delta waves for the parietal lobe were the only ones to show an increase, increase trend. This was shown by the final value noted 30 minutes after the manipulation as 0.14031 Volts$^2$/Hz.

The theta values began at an initial total of 0.0964 Volts$^2$/Hz. This value initially increased to 0.113113 Volts$^2$/Hz post-manipulation before dropping to 0.10768 Volts$^2$/Hz 30 minutes post-manipulation. The theta values showed an increase, decrease trend.

The alpha values seemed to show a similar trend to the theta above, as they increased from a baseline of 0.069275 Volts$^2$/Hz to 0.086415 Volts$^2$/Hz immediately after the chiropractic manipulation. 30 mins post-manipulation this value dropped to 0.07913 Volts$^2$/Hz. Alpha waves showed an increase, decrease trend.

The beta values were once again the lowest with a baseline value reading 0.047512 Volts$^2$/Hz. This value also increased and was noted at 0.059132 Volts$^2$/Hz post-manipulation. After 30 minutes the value dropped but did stabilise at 0.054728 Volts$^2$/Hz. The beta waves showed an increase, decrease trend.

Refer to Figure 15 for a graphical representation of the above data.

Figure 15: Parietal Lobe (Channel 3): Eyes open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation
Parietal Lobe: Eyes Closed

The parietal lobe with eyes closed was the only category to show a total increase both post-manipulation and 30 minutes later.

The delta waves showed an initial value of 0.095072 Volts²/Hz. This value increased significantly immediately after the chiropractic manipulation to a value of 0.138382 Volts²/Hz. This value further increased 30 minutes post-manipulation to 0.145308 Volts²/Hz.

The theta values showed an initial reading of 0.086458 Volts²/Hz which increased quite dramatically immediately after the manipulation and 30 minutes thereafter. The two values were 0.119057 Volts²/Hz and 0.123773 Volts²/Hz respectively.

The alpha values were 0.06558 Volts²/Hz initially but also peaked immediately after the manipulation to an amount of 0.08871 Volts²/Hz. These waves also continued to climb and a value of 0.091908 Volts²/Hz was captured 30 minutes after the chiropractic manipulation.

The beta waves once again recorded the lowest baseline reading, at a value of 0.045887 Volts²/Hz. This value climbed to 0.060195 Volts²/Hz immediately after the manipulation but only increased slightly and stabilised at 0.063173 Volts²/Hz 30 minutes post-manipulation.

Refer to Figure 16 for a graphical representation of the above data.
4.2.2 Participant 2

4.2.2.1 History and physical examinations
Participant 2 was a 20-year-old female student. She had never been treated by a chiropractor and therefore complied with the inclusion criteria for the study.
Her general health was good at the time. Her history revealed that she had chicken pox, pneumonia and suffered from ear infections as a child. The patient revealed that she has an allergy to Deep Heat. She exercises four times per week and takes the oral contraceptive.
A review of systems revealed no abnormalities and the physical examination was unremarkable. A left sided talocrural long axis extension restriction.

4.2.2.2 Data analysis
Frontal Lobe: Eyes Open
For participant 2 frontal lobe, eyes open there was a commonality found in all waves. This consisted of an increase immediately after the chiropractic manipulation which was followed by a decrease below the pre-manipulation reading.
The delta waves began at a baseline reading of 0.155915 Volts²/Hz. These waves increased significantly to 0.19512 Volts²/Hz immediately after the chiropractic manipulation. This value was seen to take a massive decline resulting in a value of 0.107462 Volts²/Hz, 30 minutes post-manipulation. This value was significantly lower than the initial baseline value.
The theta waves began at a slightly lower value of 0.121088 Volts²/Hz prior to the manipulation. This result increased but not to the same extent as the delta waves. A value of 0.09315 Volts²/Hz was captured. This result also was seen to decrease substantially 30 minutes post-manipulation to a value of 0.070223 Volts²/Hz. Note that this value was also lower than the baseline value initially taken prior to the manipulation.
The alpha waves had a starting value of 0.092597 Volts²/Hz pre-manipulation. A trend began to form similar to that of the first two waves stated. There was an increase to 0.108706 Volts²/Hz immediately after the manipulation, followed by a decrease below the starting baseline value 30 minutes later, the value of which was captured at 0.070223 Volts²/Hz.
The beta value experienced a very similar change to the alpha value. It increased slightly to 0.073475 Volts²/Hz after the manipulation, from an original baseline value of 0.063865 Volts²/Hz. This value was also seen to decrease significantly below the pre-manipulation reading and was captured at 0.0496 Volts²/Hz.
Refer to Figure 17 for a graphical representation of the above data
Figure 17: Frontal Lobe (Channel 1): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Frontal Lobe: Eyes Closed**
Similarly to the frontal lobe with the eyes open, the eyes closed counterpart experienced an increase in all wave values immediately post-manipulation. This was followed by a decrease 30 minutes post-manipulation that resulted in values that were lower than their initial baseline readings.

The delta waves recorded a pre-manipulation value of 0.14393 Volts$^2$/Hz. This was superseded by a value of 0.205506 Volts$^2$/Hz, which was a substantial increase of 0.061576 Volts$^2$/Hz post-manipulation. 30 minutes after the chiropractic manipulation the value dropped below the initial baseline value to give an amount of 0.097251 Volts$^2$/Hz.

The theta values started at 0.11518 Volts$^2$/Hz prior to the manipulation. This value climbed appreciably to 0.175328 Volts$^2$/Hz post-manipulation. This value dropped drastically to 0.085522 Volts$^2$/Hz 30 minutes post-manipulation. This was the greatest change seen out of all three waves measured for the frontal lobe with the eyes closed.

The alpha waves started at 0.086937 Volts$^2$/Hz prior to the manipulation. Immediately post-manipulation there was a substantial increase to 0.12723 Volts$^2$/Hz. This was followed by a drop 30 minutes post-manipulation to 0.078348 Volts$^2$/Hz. This drop was lower but nearer to the initial baseline reading for alpha waves.

The beta waves were captured at an initial baseline reading of 0.060438 Volts$^2$/Hz. This value increased to 0.086953 Volts$^2$/Hz immediately after the chiropractic manipulation. Similarly to the alpha waves, the beta waves also dropped 30 minutes post-manipulation to a value of 0.055187 Volts$^2$/Hz, which was below but close to the initial pre-manipulation value.
Refer to Figure 18 for a graphical representation of the above data

![Graph](image)

**Participant 2 Frontal Lobe (Eyes Closed)**

<table>
<thead>
<tr>
<th>Wave</th>
<th>Pre-manipulation</th>
<th>Immediately post-manipulation</th>
<th>30 minutes post-manipulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta</td>
<td>0.178128 Volts$^2$/Hz</td>
<td>0.103053 Volts$^2$/Hz</td>
<td>0.103558 Volts$^2$/Hz</td>
</tr>
<tr>
<td>Theta</td>
<td>0.142445 Volts$^2$/Hz</td>
<td>0.092218 Volts$^2$/Hz</td>
<td>Below initial baseline</td>
</tr>
<tr>
<td>Alpha</td>
<td>0.107473 Volts$^2$/Hz</td>
<td>0.066193 Volts$^2$/Hz</td>
<td>0.071148 Volts$^2$/Hz</td>
</tr>
<tr>
<td>Beta</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Temporal Lobe: Eyes Open**

All waves followed a decrease, increase pattern with the final value 30 minutes post-manipulation being a value which was lower than the original baseline value but closer to the number of Volts$^2$/Hz immediately post the chiropractic manipulation.

The delta waves experienced a large decrease of 0.075075 Volts$^2$/Hz from the initial value of 0.178128 Volts$^2$/Hz. The immediate post-manipulation reading was noted at 0.103053 Volts$^2$/Hz. 30 minutes post-manipulation this reading had stabilised at a value of 0.103558 Volts$^2$/Hz, which was only a minimal increase.

The theta waves also underwent a massive decrease to produce a value of 0.088212 Volts$^2$/Hz post-manipulation, from an original pre-manipulation value recorded at 0.142445 Volts$^2$/Hz. Finally at 30 minutes post-manipulation an increase to a value of 0.092218 Volts$^2$/Hz was seen. This value was also far below the initial baseline reading.

The alpha readings began at 0.107473 Volts$^2$/Hz and fell substantially to 0.066193 Volts$^2$/Hz immediately after the chiropractic manipulation. This value also increased slightly but seemed to stabilise at 0.071148 Volts$^2$/Hz which was at 30 minutes post-manipulation.
The beta readings were initially recorded at 0.07942 Volts$^2$/Hz. These values decreased to 0.046048 Volts$^2$/Hz immediately after the manipulation and seemed to stabilise at this value 30 minutes later. This gave a value of 0.049652 Volts$^2$/Hz, which was a very slight increase.

Refer to Figure 19 for a graphical representation of the above data

**Figure 19: Temporal Lobe (Channel 2): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation**

**Temporal Lobe: Eyes Closed**

The delta, theta and alpha waves all showed a dramatic decrease immediately following the chiropractic manipulation. The beta waves showed a decrease as well, but to a slightly lesser extent.

The delta waves noted an initial baseline reading of 0.214398 Volts$^2$/Hz. This value fell drastically to 0.088252 Volts$^2$/Hz immediately after administration of the chiropractic manipulation. 30 minutes after the manipulation was performed this number climbed and was captured at 0.107208 Volts$^2$/Hz. The delta waves followed a decrease, increase trend.

The theta waves started off with a reading of 0.161673 Volts$^2$/Hz. This value decreased drastically but to a lesser extent than the delta waves to give a reading of 0.087767 Volts$^2$/Hz. 30 minutes later the theta value had increased slightly to 0.090927 Volts$^2$/Hz. These were similar readings to those produced by the delta waves. The theta waves followed a decrease, increase trend.

The alpha value began at 0.117472 Volts$^2$/Hz and dropped noticeably to 0.06789 Volts$^2$/Hz post-manipulation. Thereafter it seemed to steady 30 minutes post-manipulation to a value of 0.068293 Volts$^2$/Hz. Alpha values followed a decrease, increase trend.
The beta values were the only waves to follow a decrease, decrease trend. From a baseline value of 0.079497 Volts²/Hz, the wave value declined to 0.048007 Volts²/Hz post-manipulation and further dropped to 0.047152 Volts²/Hz 30 minutes post-manipulation.

Refer to Figure 20 for a graphical representation of the above data

![Participant 2 Temporal Lobe (Eyes Closed)](image)

Figure 20: Temporal Lobe (Channel 2): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Parietal Lobe: Eyes Open**

All four waves showed a total decline in Volts²/Hz, both immediately after the chiropractic manipulation and 30 minutes post-manipulation.

The delta waves were shown to decrease post-manipulation to 0.14029 Volts²/Hz from an original baseline recording of 0.184592 Volts²/Hz. This value continued to decrease and was recorded at 0.100538 Volts²/Hz 30 minutes post-manipulation.

The theta waves which noted a 0.14924 Volts²/Hz baseline, dropped to 0.125487 Volts²/Hz immediately after the manipulation. This value continued to descend and 30 minutes post-manipulation, this value was captured as 0.086278 Volts²/Hz.

The alpha waves, which had an initial reading of 0.111 Volts²/Hz, fell very slightly to 0.093481 Volts²/Hz. They made a more significant decline in Volts²/Hz when they recorded a 0.064882 Volts²/Hz at 30 minutes post-manipulation.
The beta waves decreased to a lesser extent than their counterparts and went from a 0.07634 Volts$^2$/Hz pre-manipulation reading to 0.065693 Volts$^2$/Hz immediately after the manipulation. This value also continued to decrease 30 minutes post-manipulation to end off at 0.045337 Volts$^2$/Hz.

Refer to Figure 21 for a graphical representation of the above data.

![Participant 2 Parietal Lobe (Eyes Open)](image)

**Figure 21:** Parietal Lobe (Channel 3): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Parietal Lobe: Eyes Closed**

The delta, theta, alpha and beta waves for this category also showed a continual decline such as that seen when the eyes were open.

The delta waves saw the most dramatic drop. They recorded a baseline value of 0.201978 Volts$^2$/Hz. The result immediately after the chiropractic manipulation was 0.142558 Volts$^2$/Hz. This was a massive decrease of 0.05942 Volts$^2$/Hz.

The theta waves made less of an impact, but a significant drop was still seen between pre and post-manipulation. A reading of 0.158295 Volts$^2$/Hz pre-manipulation was followed by 0.121057 Volts$^2$/Hz immediately after the manipulation. A continual decline 30 minutes post-manipulation, captured a much more significant decline at 0.074825 Volts$^2$/Hz.

The alpha waves went from a 0.11566 Volts$^2$/Hz pre-manipulation reading to a dramatically decreased value of 0.090233 Volts$^2$/Hz post-manipulation. This value continued to decline 30 minutes after the manipulation was delivered and a value of 0.056517 Volts$^2$/Hz was captured.

The beta waves recorded a baseline value of 0.079193 Volts$^2$/Hz. This value decreased to 0.061863 Volts$^2$/Hz immediately after the chiropractic manipulation and further decreased to 0.039422 Volts$^2$/Hz 30 minutes thereafter.
Refer to Figure 22 for a graphical representation of the above data

Figure 22: Parietal Lobe (Channel 3): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

4.2.3 Participant 3

4.2.3.1 History and physical examinations
Participant 3 was a 23-year-old male accountant. He had previously been treated by a chiropractor but he had not been manipulated in the preceding 3 months leading up to the study and therefore complied with the inclusion criteria for the study.

His general health was good at the time. His history revealed that he had chicken pox as a child. The patient revealed that he trained at gym 4 times per week and played soccer and touch rugby once a week. He experienced a fall onto his left hand during a rugby game but X-rays revealed only soft tissue damage. He drinks and smokes hookah socially.

Family history revealed that his father suffers from type 2 diabetes and his mother suffers from high blood pressure and depression.
A review of systems revealed no abnormalities and the physical examination was unremarkable. A right sided talocrural long axis extension restriction was found.
4.2.3.2. Data analysis

Frontal Lobe: Eyes Open

All waves in this category seemed to show a correlation of an increase, increase trend. With the second increase (30 minutes post-manipulation) stabilising closer to the value seen directly after the chiropractic manipulation.

The delta waves started off with a baseline reading of 0.17858 Volts²/Hz. This value increased to 1.95347 Volts²/Hz immediately post-manipulation. 30 minutes after the manipulation was performed this value increased slightly but remained steady at 0.198898 Volts²/Hz.

The theta waves increased from a value before the manipulation of 0.142658 Volts²/Hz, to 0.151885 Volts²/Hz. This value further increased but also seemed to stabilise 30 minutes post-manipulation. This value was recorded at 0.163977 Volts²/Hz.

The alpha waves made less of an increase between pre and post-manipulation. The initial baseline reading was captured at 0.104042 Volts²/Hz and increased to 0.119717 Volts²/Hz post-manipulation. 30 minutes after the chiropractic manipulation, this value increased further and was measured at 0.119717 Volts²/Hz.

The beta waves increased by a smaller increment but showed a similar pattern to their counterparts, the initial increase from pre to post-manipulation being only 0.071965 Volts²/Hz to 0.74195 Volts²/Hz. This value then increased slightly but seemed to steady at 0.060925 Volts²/Hz post-manipulation.

Refer to Figure 23 for a graphical representation of the above data.

![Graph of Frontal Lobe (Eyes Open) showing wave patterns before, immediately after and 30 minutes after manipulation.](image-url)

**Figure 23:** Frontal Lobe (Channel 1): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation
Frontal lobe: Eyes Closed

The delta waves recorded a number of 0.180983 Volts$^2$/Hz pre-manipulation. This number increased dramatically to 0.214968 Volts$^2$/Hz immediately after the chiropractic manipulation. This value seemed to steady but did decrease 30 minutes later and a number of 0.202403 Volts$^2$/Hz was attained from the data. The delta waves followed an increase with only a slight decrease pattern.

The theta waves experienced a very similar pattern to that of the delta waves, with an increase from 0.146413 Volts$^2$/Hz pre-manipulation to a value of 0.164222 Volts$^2$/Hz post-manipulation. This was followed 30 minutes post-manipulation by a slightly decreased but steadied value of 0.162663 Volts$^2$/Hz. These waves followed an increase with a slight decrease pattern.

The alpha waves were the only waves to undergo an increase, increase trend for this category. The readings changed from a baseline value of 0.108082 Volts$^2$/Hz, to 0.118835 Volts$^2$/Hz immediately after the chiropractic manipulation and then to 0.120053 Volts$^2$/Hz 30 minutes later.

The beta waves were the only waves in this category that experienced a dramatic decrease in value immediately after the chiropractic manipulation. They went from a pre-recorded reading of 0.131477 Volts$^2$/Hz and dropped down to 0.79907 Volts$^2$/Hz following the manipulation. This value did increase slightly but stabilised closer to the value directly after the manipulation. This increase was measured at 0.082295 Volts$^2$/Hz. The beta waves followed a decrease, increase but stabilising trend.

Refer to Figure 24 for a graphical representation of the above data.

![Frontal Lobe (Eyes Closed)](image)

Figure 24: Frontal Lobe (Channel 1): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation
Temporal Lobe: Eyes Open

The delta waves made a dramatic increase from their original baseline recording of 0.168805 Volts²/Hz when compared to their reading immediately post-manipulation. This was noted at 0.20288 Volts²/Hz, which was seen to further increase to 0.205843 Volts²/Hz following the 30 minute interval post-manipulation. The delta waves were the only waves in this category that followed an increase, increase trend.

The theta waves didn’t show a great change and made a small decrease from 0.160462 Volts²/Hz to a post-manipulation reading of 0.159243 Volts²/Hz. This value only showed a minimal increase 30 minutes later and was recorded as 0.162853 Volts²/Hz. The theta waves showed a small decrease, increase pattern.

The alpha waves also showed a slight decrease between pre- and post-manipulation readings, which were 0.12298 Volts²/Hz and 0.115887 Volts²/Hz respectively. This value further increased to 0.118257 Volts²/Hz 30 minutes later. The alpha waves followed an increase, increase trend.

The beta waves followed a similar pattern to the theta waves. Both decreased from pre- to immediately post-manipulation, although the beta waves decreased by a slightly larger degree. The Beta pre-manipulation reading was captured at 0.086208 Volts²/Hz and dropped to 0.079235 Volts²/Hz. 30 minutes post-manipulation this reading increased slightly towards the baseline reading but read as 0.080945 Volts²/Hz. The beta readings followed a decrease, increase trend.

Refer to Figure 25 for a graphical representation of the above data

![Figure 25: Temporal Lobe (Channel 2): Eyes Open at pre-adjustment, immediately post-manipulation and at 30 minutes post-manipulation](image)
Temporal Lobe: Eyes Closed

All waves in this category experienced a drop post-manipulation that was met with a slight increase that seemed to steady at the same value as the post-manipulation reading.

The delta waves had a high pre-manipulation reading of 0.25027 Volts$^2$/Hz. This was followed by a dramatic decrease immediately after the manipulation. This value was captured at 0.177515 Volts$^2$/Hz. 30 minutes after the manipulation this value increased to 0.190447 Volts$^2$/Hz.

The theta waves also showed a significant decline from a pre-manipulation reading of 1.96862 Volts$^2$/Hz to 0.138092 Volts$^2$/Hz immediately after the chiropractic manipulation. The value increased to 0.152983 Volts$^2$/Hz 30 minutes later.

The alpha waves also showed a substantial drop between the original baseline value and the reading immediately following the chiropractic manipulation. A value of 0.146823 Volts$^2$/Hz was recorded prior to the manipulation and 0.101125 Volts$^2$/Hz was the value captured immediately after. This value increased minimally and stabilised at 0.112853 Volts$^2$/Hz 30 minutes post-manipulation.

The beta waves also showed a decrease initially. A value of 0.10236 Volts$^2$/Hz prior to manipulation dropped down to 0.069745 Volts$^2$/Hz thereafter. This value also increased slightly but seemed to steady at 0.07752 Volts$^2$/Hz 30 minutes later.

Refer to Figure 26 for a graphical representation of the above data.

Figure 26: Temporal Lobe (Channel 2): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation
Parietal Lobe: Eyes Open

All waves showed an increase, increase trend in this category. The waves seemed to make their most marked increase not immediately post-manipulation, but 30 minutes thereafter. The delta waves showed a small increase between pre- and post-manipulation, the values of which were 0.140407 Volts$^2$/Hz and 0.159467 Volts$^2$/Hz respectively. 30 minutes later the delta waves markedly increased from this value and the final value noted was 0.17983 Volts$^2$/Hz.

The theta waves had a baseline reading of 0.118588 Volts$^2$/Hz. This number also increased initially after the manipulation to 0.1255 Volts$^2$/Hz. The slightly larger increase also came 30 minutes later and a result of 0.149947 Volts$^2$/Hz was noted.

The alpha waves noted a pre-manipulation reading of 0.086193 Volts$^2$/Hz which increased to 0.094715 Volts$^2$/Hz immediately after the manipulation. This value increased to 0.113105 Volts$^2$/Hz 30 minutes later.

The beta values showed a more gradual increase and went from a baseline value of 0.059327 Volts$^2$/Hz to 0.065427 Volts$^2$/Hz post-manipulation. This value increased 30 minutes later to a final amount of 0.078745 Volts$^2$/Hz.

Refer to Figure 27 for a graphical representation of the above data.

![Graph](image.png)  
**Figure 27:** Parietal Lobe (Channel 3): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation
Parietal Lobe: Eyes Closed

All of the waves in this category followed a decrease, increase trend.

The delta waves noted a value Immediately post-manipulation of 0.164952 Volts$^2$/Hz, following a pre-manipulation reading of 0.178968 Volts$^2$/Hz. This value increased hugely 30 minutes later and was recorded at 0.229915 Volts$^2$/Hz.

The theta waves had a baseline value of 0.157063 Volts$^2$/Hz which dropped to a reading of 0.134742 Volts$^2$/Hz immediately after the chiropractic manipulation. The theta waves also increased markedly but to a lesser extent than those of the delta waves 30 minutes post-manipulation. A result of 0.173192 Volts$^2$/Hz was captured.

The alpha waves decreased from a pre-manipulation reading of 0.120023 Volts$^2$/Hz to 0.102422 Volts$^2$/Hz post-manipulation. 30 minutes later this value gradually increased to 0.124823 Volts$^2$/Hz, which was similar to but minimally higher than the original baseline value.

The beta values followed a very similar decrease, increase trend when compared to the alpha waves in this category. A decrease from a pre-manipulation reading of 0.08287 Volts$^2$/Hz to 0.07182 Volts$^2$/Hz immediately post-manipulation was recorded. This was followed by a gradual increase 30 minutes later that was very much the same as the baseline reading but slightly higher at 0.085418 Volts$^2$/Hz.

Refer to Figure 28 for a graphical representation of the above data.

![Graph of Participant 3 Parietal Lobe (Eyes Closed)](image)

Figure 28: Parietal Lobe (Channel 3): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation
4.2.4 Participant 4

4.2.4.1 History and physical examinations
Participant 4 was a 24-year-old male student. He had previously been treated by a chiropractor but he had not been manipulated in the preceding 3 months leading up to the study and therefore complied with the inclusion criteria for the study.

His general health was good at the time. His history revealed that he had chicken pox as a child. The patient revealed that he had previously injured his rotator cuffs bilaterally and his right calf. Surgical history revealed an appendectomy from the patient’s youth. He was hospitalized in 2012 for a kidney stone. He exercises four times per week. This consists of soccer, cycling and gym.
A review of systems revealed right sided shoulder tenderness and the physical examination was unremarkable. A left sided talocrual long axis extension restriction was detected.

4.2.4.2 Data analysis
Frontal Lobe: Eyes Open
The delta waves only showed a slight fall directly after the manipulation, decreasing from a baseline reading of 0.0758 Volts²/Hz to a value of 0.063642 Volts²/Hz. This value increased substantially 30 minutes post-manipulation to note a final reading of 0.156827 Volts²/Hz. The delta waves followed a decrease, increase trend.

The theta waves were the only waves to experience an increase, increase trend in this category, increasing from a baseline reading of 0.065098 Volts²/Hz to 0.101417 Volts²/Hz directly after the chiropractic manipulation. This value was then seen to increase to 0.136927 Volts²/Hz 30 minutes later. The alpha waves experienced a small decline between pre- and post-manipulation, decreasing from 0.048007 Volts²/Hz and giving a value of 0.43118 Volts²/Hz. This value gradually increased to 0.10641 Volts²/Hz 30 minutes later. Alpha waves experienced a slight decrease, increase trend.

The beta waves decreased minimally from 0.03372 Volts²/Hz pre-manipulation to 0.030362 Volts²/Hz immediately after. A substantial increase was seen 30 minutes later and a value of 0.074332 Volts²/Hz was noted. The beta waves followed a decrease, increase trend.
Refer to Figure 29 for a graphical representation of the above data
Figure 29: Frontal Lobe (Channel 1): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Frontal Lobe: Eyes Closed**

All waves in this category followed an increase, increase trend.

The delta waves made a relatively constant increase throughout, going from an original value of 0.07481 Volts$^2$/Hz to a post-manipulation reading of 0.098198 Volts$^2$/Hz. This was followed by an increase to 0.18369 Volts$^2$/Hz 30 minutes post-manipulation.

The theta waves increased in a similar fashion with a pre-manipulation reading of 0.064595 Volts$^2$/Hz superseded by a post-manipulation value of 0.077103 Volts$^2$/Hz. 30 minutes later this value increased by a larger extent to give an overall value of 147878 Volts$^2$/Hz.

The alpha waves increased from a baseline value of 0.047893 Volts$^2$/Hz to 0.057463 Volts$^2$/Hz post-manipulation. This increased by a slightly larger extent 30 minutes post-manipulation to give a value of 0.074428 Volts$^2$/Hz.

The beta waves started off with a pre-manipulation reading of 0.33692 Volts$^2$/Hz before increasing to 0.040005 Volts$^2$/Hz post-manipulation. A further increase could be seen 30 minutes later, that was captured at 0.074428 Volts$^2$/Hz.

Refer to Figure 30 for a graphical representation of the above data.
**Figure 30: Frontal Lobe (Channel 1):** Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Temporal Lobe: Eyes Open**

All waves in this category experienced an increase, increase trend.

The delta waves made a small increase between pre- and post-manipulation. An original baseline reading of 0.098515 Volts$^2$/Hz was followed post-manipulation with an increase to 0.117798 Volts$^2$/Hz. This value dramatically increased to 0.22577 Volts$^2$/Hz 30 minutes after the manipulation.

The theta waves showed a substantial increase between the pre-manipulation reading of 0.04139 Volts$^2$/Hz and the post manipulation reading of 0.092937 Volts$^2$/Hz. The theta waves then showed a significant increase to 0.178627 Volts$^2$/Hz 30 minutes later.

The alpha waves increased from 0.03115 Volts$^2$/Hz to a post-manipulation reading of 0.067405 Volts$^2$/Hz. This value further increased 30 minutes later to a value of 0.132075 Volts$^2$/Hz.

The beta waves recorded a baseline reading of 0.021703 Volts$^2$/Hz before increasing to an amount of 0.046352 Volts$^2$/Hz immediately after the manipulation. This value increased to a larger extent 30 minutes later and was captured at 0.091617 Volts$^2$/Hz.

Refer to Figure 31 for a graphical representation of the above data.
Figure 31: Temporal Lobe (Channel 2): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Temporal Lobe: Eyes Closed**

All waves experienced an increase, increase trend.

The delta waves increased from an initial reading of 0.062488 Volts$^2$/Hz to a post-manipulation reading of 0.087527 Volts$^2$/Hz. This value was seen to increase 30 minutes post-manipulation to a reading captured at 0.184958 Volts$^2$/Hz.

The theta waves increased to 0.077733 Volts$^2$/Hz directly after the manipulation from a baseline value of 0.05948 Volts$^2$/Hz. This value also went on to increase further and 30 minutes post-manipulation this value was captured at 0.140632 Volts$^2$/Hz.

The alpha waves increased following the manipulation from a value of 0.044587 Volts$^2$/Hz to 0.059272 Volts$^2$/Hz. This value continued its incline and at 30 minutes post-manipulation it reached 0.10122 Volts$^2$/Hz.

The beta waves had an initial baseline value of 0.031108 Volts$^2$/Hz and increased to 0.041455 Volts$^2$/Hz immediately after the chiropractic manipulation. This value also continued to increase and by 30 minutes post-manipulation this value was captured at 0.069405 Volts$^2$/Hz.

Refer to Figure 32 for a graphical representation of the above data.
Figure 32: Temporal Lobe (Channel 2): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Parietal Lobe: Eyes Open

The delta waves began at a baseline reading of 0.147747 Volts$^2$/Hz. This value increased post-manipulation to a value of 0.172645 Volts$^2$/Hz. 30 minutes later this value was captured at 0.182987 Volts$^2$/Hz. The delta waves followed an increase, increase trend.

The theta waves had an initial baseline value of 0.119637 Volts$^2$/Hz. Following the chiropractic manipulation a value of 0.14912 Volts$^2$/Hz was noted which was a significant increase. 30 minutes later, this value was seen to decrease but stabilise and an amount of 0.141707 Volts$^2$/Hz was extracted from the data. The theta waves followed an increase, decrease trend.

The alpha waves recorded a pre-manipulation reading of 0.087412 Volts$^2$/Hz. This value increased post-manipulation to a value of 0.111298 Volts$^2$/Hz. 30 minutes post-manipulation this value decreased but seemed to stabilise closer to the post-manipulation value and was captured at 0.103665 Volts$^2$/Hz. The alpha waves also followed an increase, decrease trend.

The beta waves had an initial reading of 0.060347 Volts$^2$/Hz. This had a similar pattern to that seen in the alpha waves. An increase post-manipulation to 0.07666 Volts$^2$/Hz was followed by a decrease which steadied the final value at 0.071003 Volts$^2$/Hz.

Refer to Figure 33 for a graphical representation of the above data.
Figure 33: Parietal Lobe (Channel 3): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Parietal Lobe: Eyes Closed**

All waves in this category followed an increase, increase trend.

The delta waves captured a pre-manipulation value of 0.1423 Volts\(^2\)/Hz. This value increased post-manipulation but it was the reading 30 minutes later that showed the most dramatic change. A value of 0.17105 Volts\(^2\)/Hz was recorded post-manipulation. This value increased 30 minutes later and was captured at 0.214817 Volts\(^2\)/Hz, which was a massive difference of 0.043137 Volts\(^2\)/Hz.

The theta waves made a steadier increase and increased from a baseline reading of 0.126837 Volts\(^2\)/Hz to a post-manipulation reading of 0.140367 Volts\(^2\)/Hz. 30 minutes post-manipulation a value of 0.167427 Volts\(^2\)/Hz was captured.

The alpha waves made only a slight increase throughout. A baseline reading of 0.093093 Volts\(^2\)/Hz increased to 0.093093 Volts\(^2\)/Hz immediately post-manipulation and then further increased to 0.120345 Volts\(^2\)/Hz 30 minutes later.

The beta waves also made a gradual increase throughout. A pre-manipulation reading of 0.063947 Volts\(^2\)/Hz increased to 0.071037 Volts\(^2\)/Hz. This value further increased and at 30 minutes post-manipulation a value of 0.08134 Volts\(^2\)/Hz was captured.

Refer to Figure 34 for a graphical representation of the above data.
Figure 34: Parietal Lobe (Channel 3): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

4.2.5 Participant 5

4.2.5.1 History and physical examinations
Participant 5 was a 21-year-old female student. She had not previously been treated by a chiropractor and therefore complied with the inclusion criteria for the study. Her general health was good at the time. Her history revealed that she had chicken pox and shingles as a child. The participant revealed that she had a traumatic shoulder injury sustained during cross fit 3 years previously. Her surgical history consisted of wisdom teeth removal. She exercises three times per week.

The participant’s family history revealed that her grandfather suffered from diabetes and pancreatic cancer before passing away. Her father has a heart condition and her mother suffers from depression. A review of systems revealed no abnormalities and the physical examination was unremarkable. A right sided talocrural long axis extension restriction.

4.2.5.2 Data analysis
Frontal Lobe: Eyes Open
The waves in this category all showed a decrease, increase trend.
The delta waves had a baseline reading of 0.147582 Volts²/Hz. This value decreased to 0.122583 Volts²/Hz immediately post-manipulation. 30 minutes post-manipulation this value increased substantially to 0.159005 Volts²/Hz.

The theta waves captured a pre-manipulation reading of 0.121535 Volts²/Hz. Immediately post-manipulation this value dropped to 0.10725 Volts²/Hz. The 30 minutes post-manipulation showed an increase that was captured at 0.132575 Volts²/Hz.

The alpha waves recorded a pre-manipulation value of 0.09062 Volts²/Hz. This value decreased slightly to 0.080867 Volts²/Hz immediately after the chiropractic manipulation. This value increased to 0.098782 Volts²/Hz 30 minutes later. This value was slightly higher but also very similar to the initial baseline reading.

The beta waves in a similar fashion saw an increase to 0.05685 Volts²/Hz from a pre-manipulation reading of 0.061667 Volts²/Hz. 30 minutes later this value increased to 0.068583 Volts²/Hz, which was also slightly higher than the initial baseline reading.

Refer to Figure 35 for a graphical representation of the above data.

Figure 35: Frontal Lobe (Channel 1): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Frontal Lobe: Eyes Closed

All waves in this category showed a trend where there was a slight increase between pre- and post manipulation values. 30 minutes post-manipulation there was a further increase.
The delta waves showed a steady increase from a pre-manipulation recording of 0.31445 Volts²/Hz to a post-manipulation reading of 0.158623 Volts²/Hz. 30 minutes post-manipulation this value increased significantly to a value of 0.190093 Volts²/Hz.

The theta waves recorded an initial baseline reading of 0.112275 Volts²/Hz. This value increased slightly to 0.128773 Volts²/Hz. 30 minutes post-manipulation a greater increase was seen and a final value of 0.16103 Volts²/Hz was captured.

The alpha waves made a steadier increase throughout, beginning with an initial baseline reading of 0.083758 Volts²/Hz. This value increased to a value immediately post-manipulation of 0.095543 Volts²/Hz. This value continued to climb steadily and was captured 30 minutes post-manipulation as 0.117848 Volts²/Hz.

A value of 0.05834 Volts²/Hz was taken pre-manipulation for the beta waves. This value only showed a slight increase to 0.066103 Volts²/Hz. 30 minutes post-manipulation this value was seen to increase to a greater degree and an amount of 0.081222 Volts²/Hz was taken.

Refer to Figure 36 for a graphical representation of the above data.

![Graph of Participant 5 Frontal Lobes (Eyes Closed)](image)

**Figure 36**: Frontal Lobe (Channel 1): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Temporal Lobe: Eyes Open**

All waves in this category also showed only a very slight increase between pre-, immediate post and 30 minutes post-manipulation. An increase, increase trend was seen throughout.
The delta waves had an initial baseline reading of $0.146507 \text{ Volts}^2/\text{Hz}$. This value steadily increased and was taken at $0.157408 \text{ Volts}^2/\text{Hz}$ immediately post-manipulation. This value continued to increase but not to a huge degree and 30 minutes later $0.167432 \text{ Volts}^2/\text{Hz}$ was extracted as a value from the data. The theta waves made a gradual increase from an initial baseline reading of $0.114588 \text{ Volts}^2/\text{Hz}$ to a post-manipulation reading of $0.129758 \text{ Volts}^2/\text{Hz}$. This was a slight increase and 30 minutes post-manipulation it continued to increase but with minimal impact. A final value of $0.134255 \text{ Volts}^2/\text{Hz}$ was noted.

The alpha waves also made a steady increase throughout. Pre-manipulation a value of $0.082623 \text{ Volts}^2/\text{Hz}$ was noted and this increased to $0.09625 \text{ Volts}^2/\text{Hz}$ immediately following the manipulation. This value also further increased and was taken as $0.104087 \text{ Volts}^2/\text{Hz}$ 30 minutes later.

The beta waves in a similar fashion made a minimal increase between an initial baseline reading of $0.056518 \text{ Volts}^2/\text{Hz}$ to a post-manipulation value of $0.066793 \text{ Volts}^2/\text{Hz}$. This value was seen to further increase and we were left with a final reading of $0.074818 \text{ Volts}^2/\text{Hz}$ 30 minutes post-manipulation.

Refer to Figure 37 for a graphical representation of the above data.

![Participant 5 Temporal Lobe (Eyes Open)](image)

**Figure 37:** Temporal Lobe (Channel 2): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Temporal Lobe: Eyes Closed**

All the waves in this category followed an increase, increase trend.

The delta waves had an initial baseline reading of $0.125265 \text{ Volts}^2/\text{Hz}$. This value increased to $0.151768 \text{ Volts}^2/\text{Hz}$ immediately following the manipulation. This value soared 30 minutes later and was finally taken at $0.225393 \text{ Volts}^2/\text{Hz}$.
The theta waves show a small increase between pre- and post-manipulation. 0.108445 Volts$^2$/Hz increased to 0.128443 Volts$^2$/Hz. 30 minutes post-manipulation this value made a far more significant increase to end off with a value of 0.170072 Volts$^2$/Hz.

The alpha waves made a general increase from a pre-manipulation value of 0.07972 Volts$^2$/Hz to 0.094763 Volts$^2$/Hz. This value further increased to a final amount of 0.125913 Volts$^2$/Hz 30 minutes post-manipulation.

The beta waves showed a similar pattern to their counterparts with an increase to 0.065468 Volts$^2$/Hz from a pre-manipulation value of 0.054967 Volts$^2$/Hz. A greater increase could be seen 30 minutes post-manipulation to end off with a value of 0.086133 Volts$^2$/Hz.

Refer to Figure 38 for a graphical representation of the above data

![Figure 38: Temporal Lobe (Channel 2): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation](image)

**Parietal Lobe: Eyes Open**

All waves showed a small increase immediately post-manipulation. This was followed by significant decreases all round that gave final measurements 30 minutes later which were slightly lower than their initial baseline values.

The delta waves increased from an initial baseline value of 0.142442 Volts$^2$/Hz. Immediately post-manipulation this increased to 0.157798 Volts$^2$/Hz. This value was seen to decrease 30 minutes later to a value captured at 0.135153 Volts$^2$/Hz.

The theta waves had a pre-manipulation reading of 0.11868 Volts$^2$/Hz. This value increased gradually to 0.133038 Volts$^2$/Hz. 30 minutes later this value dropped to just below the initial baseline reading, to 0.112567 Volts$^2$/Hz.
The alpha waves in keeping with a similar trend increased to 0.099095 Volts$^2$/Hz from a pre-manipulation recording of 0.087887 Volts$^2$/Hz. This value decreased to just below the baseline value and was noted at 0.083665 Volts$^2$/Hz.

The beta waves didn’t show a huge change, increasing only slightly from 0.060385 Volts$^2$/Hz to 0.068557 Volts$^2$/Hz. This value also dropped like its counterparts to a value lower than its initial baseline and was taken at 0.05822 Volts$^2$/Hz.

Refer to Figure 39 for a graphical representation of the above data.

![Participant 5 Parietal Lobe (Eyes Open)](image)

Figure 39: Parietal Lobe (Channel 3): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Parietal Lobe: Eyes Closed**

The waves in this category followed a similar trend to that of the parietal lobe with eyes open. All waves showed an increase immediately post-manipulation which was followed by only a slight increase to a final value which was significantly higher than the initial baseline value.

The delta waves increased drastically from the pre-manipulation reading of 0.105927 Volts$^2$/Hz to a post-manipulation reading of 0.185118 Volts$^2$/Hz. This value decreased only slightly 30 minutes later to end off with a reading of 0.173347 Volts$^2$/Hz.

The theta waves in a similar fashion increased drastically from 0.102615 Volts$^2$/Hz to a post-manipulation value of 0.157347 Volts$^2$/Hz. This value dropped only slightly 30 minutes later to give a post-manipulation reading of 0.144567 Volts$^2$/Hz.
The alpha values increased from a pre-manipulation reading of 0.077533 Volts$^2$/Hz to a post-manipulation reading of 0.113782 Volts$^2$/Hz. This value decreased 30 minutes later to an amount of 0.108525 Volts$^2$/Hz.

The beta waves had an original baseline value of 0.053272 Volts$^2$/Hz. This value increased to 0.078095 Volts$^2$/Hz immediately following the manipulation. In keeping with the same trend as above, this value only decreased slightly to give a final value of 0.07474 Volts$^2$/Hz.

Refer to Figure 40 for a graphical representation of the above data.

![Figure 40: Parietal Lobe (Channel 3): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation](image)

### 4.2.6 Participant 6

#### 4.2.6.1 History and physical examinations

Participant 6 was a 20-year-old male BA visual communications student. He had previously been treated by a chiropractor but he had not been manipulated in the preceding 3 months leading up to the study and therefore complied with the inclusion criteria for the study.

His general health was good at the time. His history revealed that he had chicken pox and malaria as a child. The patient revealed that he broke his left clavicle as a child and damaged his right anterior cruciate ligament (ACL) and medial meniscus during a school rugby game. His surgical history revealed a knee repair of the medial meniscus, ACL and medial collateral ligament (MCL) in his right knee. He exercises three times per week and has recently struggled to fall asleep at night with no explanation. The participant smokes 3 cigarettes per day and drinks alcohol socially.
A review of systems revealed no abnormalities besides the participant complaining of a slight cough. The physical examination was unremarkable. A right sided talocrural long axis extension restriction was found.

4.2.6.2 Data analysis

Frontal Lobe: Eyes Open

The waves in this category showed very significant changes. This began with substantial increases immediately following the chiropractic manipulation before dropping down to values similar to those of the initial baseline readings.

The delta waves made a dramatic increase immediately post-manipulation, going from an initial baseline value of 0.12347 Volts^2/Hz and increasing by a massive 0.083752 Volts^2/Hz. This gave a value immediately post-manipulation of 0.207222 Volts^2/Hz. 30 minutes post-manipulation this value decreased almost all the way back to the initial baseline value to capture a value of 0.127385 Volts^2/Hz.

The theta values in a similar fashion made a huge increase between pre- and post-manipulation recordings. 0.108732 Volts^2/Hz increased to 0.170757 Volts^2/Hz before dropping 30 minutes later to a value lower than the initial baseline reading at 0.099567 Volts^2/Hz.

The alpha waves increased to a much smaller degree from a pre-manipulation reading of 0.080293 Volts^2/Hz to a post-manipulation reading of 0.124965 Volts^2/Hz. 30 minutes later this value dropped to below the initial baseline value to give a final amount of 0.074732 Volts^2/Hz.

The beta waves made a significant increase from 0.056285 Volts^2/Hz pre-manipulation to a value of 0.084953 Volts^2/Hz. 30 minutes post-manipulation saw a decrease to a value below but also very near the initial baseline reading - 0.050048 Volts^2/Hz.

Refer to Figure 41 for a graphical representation of the above data.
Frontal Lobe: Eyes Closed

All waves followed a pattern where post-manipulation the values increased significantly. This was followed 30 minutes later by drops to values that were well below the initial baseline value.

The delta waves made a significant increase. They had an initial baseline value of 0.153467 Volts²/Hz which increased substantially to 0.192238 Volts²/Hz post-manipulation. This value dropped significantly 30 minutes later to a value far below the baseline reading. A final value of 0.100575 Volts²/Hz was captured.

The theta waves followed a similar trend. An initial baseline reading of 0.123265 Volts²/Hz increased post-manipulation to 0.154283 Volts²/Hz. 30 minutes later this value was also seen to drop below the pre-manipulation baseline reading of 0.083675 Volts²/Hz.

The alpha waves recorded an initial baseline reading of 0.088458 Volts²/Hz. This value increased to 0.116148 Volts²/Hz immediately post-manipulation, dropped significantly below the initial baseline reading and was noted at 0.061812 Volts²/Hz.

The beta waves followed the same trend. They increased from an initial baseline value of 0.060677 Volts²/Hz to a post-manipulation reading 0.08001 Volts²/Hz. This value dropped way below the initial baseline reading 30 minutes later and was captured at 0.043455 Volts²/Hz.

Refer to Figure 42 for a graphical representation of the above data.

Figure 42: Frontal Lobe (Channel 1): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation
**Temporal Lobe: Eyes Open**

All waves underwent an increase post-manipulation as well as a further increase 30 minutes post-manipulation.

The delta waves recorded a high pre-manipulation reading of 0.214455 Volts\(^2/\text{Hz}\). This further increased immediately following the manipulation to 0.232042 Volts\(^2/\text{Hz}\). 30 minutes later this value markedly increased and a final value of 0.32533 Volts\(^2/\text{Hz}\) was captured.

The theta waves had an original baseline reading of 0.20243 Volts\(^2/\text{Hz}\), which only increased slightly to 0.216447 Volts\(^2/\text{Hz}\) post manipulation. 30 minutes post-manipulation a further increase was noted and a final value of 0.263592 Volts\(^2/\text{Hz}\) was taken.

The alpha waves had a pre-manipulation value of 0.153313 Volts\(^2/\text{Hz}\), which increased by a small degree immediately post-manipulation to 0.166948 Volts\(^2/\text{Hz}\). This value showed a further and more substantial increase 30 minutes post-manipulation. This value was noted at 0.195827 Volts\(^2/\text{Hz}\).

The beta waves markedly increased from their original baseline reading of 0.108668 Volts\(^2/\text{Hz}\) to give a post-manipulation reading of 0.126912 Volts\(^2/\text{Hz}\). This value also continued to increase and at 30 minutes post-manipulation, the beta waves recorded a final value of 0.136247 Volts\(^2/\text{Hz}\).

Refer to Figure 43 for a graphical representation of the above data.

![Participant 6 Temporal Lobe (Eyes Open)](image)

Figure 43: Temporal Lobe (Channel 2): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Temporal Lobe: Eyes Closed**

All waves showed an increase, increase trend.
The delta waves recorded a high pre-manipulation reading of 0.250302 Volts²/Hz which increased significantly to 0.292415 Volts²/Hz immediately following the chiropractic manipulation. This value increased 30 minutes later to 0.327692 Volts²/Hz.

The theta waves underwent an increase from a pre-manipulation value of 0.203703 Volts²/Hz to a post-manipulation value of 0.27823 Volts²/Hz. 30 minutes post-manipulation this value increased drastically to 0.327692 Volts²/Hz.

The alpha waves showed a pre-manipulation reading of 0.148842 Volts²/Hz which increased significantly to 0.183722 Volts²/Hz immediately following the chiropractic manipulation. This number made a further increase 30 minutes later and a final reading of 0.210505 Volts²/Hz was captured.

The beta waves had an initial baseline reading of 0.101737 Volts²/Hz. This value increased to a value of 0.1306 Volts²/Hz post-manipulation. This value further increased 30 minutes later to a value of 0.144197 Volts²/Hz.

Refer to Figure 44 for a graphical representation of the above data.

Figure 44: Temporal Lobe (Channel 2): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

Parietal Lobe: Eyes Open

These were the only waves for participant 6 that showed a decrease, decrease trend. The delta waves had a pre-manipulation reading of 0.187515 Volts²/Hz. That value decreased to 0.165282 Volts²/Hz immediately following the manipulation. This value continued to decline and at 30 minutes post-manipulation this value had decreased to 0.134928 Volts²/Hz.
The theta waves made a smaller decline between pre- and post-manipulation readings. The pre-manipulation recorded a reading of 0.154982 Volts$^2$/Hz. This value decreased to 0.13487 Volts$^2$/Hz. 30 minutes post-manipulation this value decreased to almost 0.115223 Volts$^2$/Hz.

The alpha waves had an original baseline value of 0.11383 Volts$^2$/Hz. This value decreased to 0.098535 Volts$^2$/Hz immediately following the chiropractic manipulation. Following the 30 minute waiting period post-manipulation, this value had further decreased only slightly to give a final reading of 0.084542 Volts$^2$/Hz.

The beta waves began with a baseline reading of 0.076568 Volts$^2$/Hz. This value decreased to 0.067205 Volts$^2$/Hz post-manipulation. This value was also seen to make a decrease 30 minutes later before finally being noted at 0.057355 Volts$^2$/Hz.

Refer to Figure 45 for a graphical representation of the above data.

![Graph](image)

Figure 45: Parietal Lobe (Channel 3): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Parietal Lobe: Eyes Closed**

The delta waves had an initial baseline reading of 0.164787 Volts$^2$/Hz. This value decreased post-manipulation to a value of 0.156475 Volts$^2$/Hz. 30 minutes later this value decreased but stabilised at 0.15163 Volts$^2$/Hz. The delta waves were the only waves that followed a decrease, decrease trend.

The theta waves dropped from an original baseline reading of 0.146157 Volts$^2$/Hz to a post-manipulation value of 0.119325 Volts$^2$/Hz. 30 minutes later, the theta waves experienced a slight increase but also stabilised at a value of 0.123048 Volts$^2$/Hz. The theta waves followed a decrease, followed by a light increase but stabilising pattern.
The alpha waves had an initial baseline reading of 0.113688 Volts²/Hz. This value dropped to 0.088392 Volts²/Hz following the chiropractic manipulation. This value increased 30 minutes post-manipulation to 0.090182 Volts²/Hz. The alpha waves followed a decrease, increase trend.

The beta waves had a pre-manipulation value of 0.082127 Volts²/Hz which decreased to 0.060578 Volts²/Hz post-manipulation. This value stabilised 30 minutes following the chiropractic manipulation by only making a slight increase to 0.061335 Volts²/Hz. The beta waves followed a decrease, increase trend. Refer to Figure 46 for a graphical representation of the above data.

![Figure 46: Parietal Lobe (Channel 3): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation](image)

4.2.7 Participant 7

4.2.7.1 History and physical examinations

Participant 7 was a 23-year-old male financial planner. He had previously been treated by a chiropractor but he had not been manipulated in the preceding 3 months leading up to the study and therefore complied with the inclusion criteria for the study.

His general health was good at the time. He exercises five times per week. The participant smokes and drinks socially.

A review of systems revealed that the patient suffers from sinusitis. The physical examination was unremarkable. A left sided talocrural long axis extension restriction was found.
4.2.7.2 Data analysis

Frontal Lobe: Eyes Open

All waves in this category underwent a decrease, increase trend.

The delta waves had an initial baseline reading of 0.19162 Volts²/Hz. This value markedly decreased to 0.08425 Volts²/Hz, following the chiropractic manipulation. 30 minutes after the manipulation was executed, this number increased. A final value of 0.19528 Volts²/Hz was captured and this was only minimally higher than the initial baseline value.

The theta waves recorded a pre-manipulation reading of 0.15195 Volts²/Hz. This value was seen to decrease to 0.07112 Volts²/Hz immediately following the chiropractic manipulation. 30 minutes later this value was seen to increase markedly back to 0.17411 Volts²/Hz, which was very similar to the initial pre-manipulation reading.

The alpha waves had an initial baseline value of 0.1137 Volts²/Hz. This value decreased drastically to 0.05306 Volts²/Hz following the chiropractic manipulation. This value increased 30 minutes later to a final value of 0.12994 Volts²/Hz. This value was similar to but slightly higher than the initial baseline value.

The beta waves made a drastic decrease of 0.04115 Volts²/Hz from an original baseline value of 0.07751 Volts²/Hz. This gave a post-manipulation value of 0.03636 Volts²/Hz. 30 minutes later this value increased dramatically to give a post-manipulation reading of 0.08932 Volts²/Hz, which was higher than the initial baseline value.

Refer to Figure 47 for a graphical representation of the above data.

![Figure 47: Frontal Lobe (Channel 1): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation](image-url)
Frontal Lobe: Eyes Closed

All waves in this series recorded fluctuations in a decrease, increase pattern.

The delta waves recorded a very high pre-manipulation reading of 0.21441 Volts\(^2\)/Hz. This value dropped by a huge extent following the chiropractic manipulation and read as 0.13984 Volts\(^2\)/Hz. This value increased slightly 30 minutes later and was extracted from the relevant data at 0.16633 Volts\(^2\)/Hz.

The theta waves in a similar fashion made a significant drop post-manipulation, recording a value of 0.12082 Volts\(^2\)/Hz from a pre-manipulation reading of 0.17708 Volts\(^2\)/Hz. This value increased post manipulation and a final reading of 0.14319 Volts\(^2\)/Hz was taken down 30 minutes later.

The alpha waves decreased from a pre-manipulation reading of 0.12873 Volts\(^2\)/Hz to 0.09094 Volts\(^2\)/Hz directly following the chiropractic manipulation. This value was seen to increase slightly 30 minutes after the manipulation and a final reading of 0.10783 Volts\(^2\)/Hz was taken.

The beta waves recorded an initial baseline reading of 0.0869 Volts\(^2\)/Hz. Immediately following the manipulation, the beta waves experienced a substantial drop to be left with a value of 0.06431 Volts\(^2\)/Hz. This value increased 30 minutes later and was finally captured at 0.07602 Volts\(^2\)/Hz.

Refer to Figure 48 for a graphical representation of the above data.

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Temporal Lobe: Eyes Open

The delta waves recorded high readings in this category. They began with an initial baseline reading of 0.215733 Volts\(^2\)/Hz. Following the manipulation this reading made a significant increase and was noted at 0.24704 Volts\(^2\)/Hz. 30 minutes later this value was seen to decrease and a final value was taken at
0.236198 Volts$^2$/Hz, which is only a slight decrease from the pre-manipulation value. The delta waves followed an increase, decrease trend.

The theta waves increased from an initial pre-manipulation reading of 0.186853 Volts$^2$/Hz to a post-manipulation reading of 0.201722 Volts$^2$/Hz. This was a substantial increase which was then seen to drop again 30 minutes later, towards baseline value. It finally ended 30 minutes post-manipulation on 0.189598 Volts$^2$/Hz. The theta waves also followed an increase, decrease trend.

The alpha waves didn’t show a significant change between pre- and post-manipulation. The pre-manipulation value was 0.152717 Volts$^2$/Hz and only decreased slightly to 0.152443 Volts$^2$/Hz. 30 minutes post-manipulation this value decreased further but still only slightly, to give a final reading of 0.14228 Volts$^2$/Hz. The alpha waves followed a decrease, decrease trend.

The beta waves had an original baseline reading of 0.12019 Volts$^2$/Hz. This decreased significantly to give a value of 0.105537 Volts$^2$/Hz following the manipulation. 30 minutes later the value dropped minimally but stabilised at 0.101713 Volts$^2$/Hz.

Refer to Figure 49 for a graphical representation of the above data

![Figure 49: Temporal Lobe (Channel 2): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation](image)

**Temporal Lobe: Eyes Closed**

All waves showed a decrease, decrease trend for this category.
The delta waves recorded an initial baseline value of $0.33467$ Volts$^2$/Hz. Immediately post-manipulation, this value dropped to $0.248447$ Volts$^2$/Hz and continued to drop 30 minutes later. A final value of $0.205043$ Volts$^2$/Hz was captured.

The theta waves also recorded a high baseline reading at $0.258167$ Volts$^2$/Hz. This value decreased substantially following the manipulation and was noted at $0.213903$ Volts$^2$/Hz. 30 minutes post-manipulation this value continued to decrease and was finally captured at $0.175865$ Volts$^2$/Hz.

The alpha waves decreased from a baseline reading of $0.19929$ Volts$^2$/Hz to give a post-manipulation reading of $0.159245$ Volts$^2$/Hz. This value decreased to $0.136487$ Volts$^2$/Hz 30 minutes later. Overall there was a significant decline from the initial baseline reading.

The beta waves began at an initial pre-manipulation value of $0.14585$ Volts$^2$/Hz. This value only minimally decreased to $0.11488$ Volts$^2$/Hz immediately following the manipulation. 30 minutes following the manipulation this value decreased slightly again to give a reading of $0.102282$ Volts$^2$/Hz.

Refer to Figure 50 for a graphical representation of the above data

![Figure 50: Temporal Lobe (Channel 2): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation](image)

**Parietal Lobe: Eyes Open**

All waves fluctuated within a decrease, increase fashion but all tended to show minimal changes throughout.

The delta waves showed only a slight change between pre- and post-manipulation, going from $0.14592$ Volts$^2$/Hz to $0.13898$ Volts$^2$/Hz respectively. This value was seen to make a much more significant change 30 minutes later as it increased to $0.17898$ Volts$^2$/Hz.
The theta waves recorded an initial baseline reading of 0.12653 Volts$^2$/Hz. This value also minimally decreased to a post-manipulation value of 0.1215 Volts$^2$/Hz. 30 minutes later this value was seen to increase and a total value of 0.14562 Volts$^2$/Hz was noted.

The alpha waves recorded an initial baseline reading of 0.09449 Volts$^2$/Hz before also showing a minimal change following the manipulation. This value decreased to 0.0924 Volts$^2$/Hz. 30 minutes later there was a minimal increase which brought the waves to a value of 0.10717 Volts$^2$/Hz.

The beta waves in a similar fashion showed almost no change as it recorded a pre-manipulation reading of 0.06525 Volts$^2$/Hz. This value dropped only to 0.06377 Volts$^2$/Hz post-manipulation. Following the 30 minutes post-manipulation this value only increased slightly to 0.07404 Volts$^2$/Hz.

Refer to Figure 51 for a graphical representation of the above data

![Figure 51: Parietal Lobe (Channel 3): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation](image)

**Parietal Lobe: Eyes Closed**

The delta waves recorded an initial baseline reading of 0.16629 Volts$^2$/Hz. This was the only value to increase immediately after the manipulation. It increased slightly to 0.18559 Volts$^2$/Hz. 30 minutes post-manipulation, this value was seen to decrease substantially to 0.14126 Volts$^2$/Hz, which is below the initial baseline reading. The delta waves followed a slight increase, decrease trend.

The theta waves recorded a pre-manipulation value of 0.14564 Volts$^2$/Hz. This decreased negligibly following the chiropractic manipulation to a value of 0.1441 Volts$^2$/Hz. This value was once again taken 30 minutes post-manipulation, showing only a very slight decrease to 0.11752 Volts$^2$/Hz. The theta waves followed a decrease, decrease trend.
The alpha waves also showed a negligible change. Pre-manipulation a baseline reading of 0.1074 Volts$^2$/Hz was taken. Immediately following the manipulation, this value only decreased to 0.10441 Volts$^2$/Hz. 30 minutes later there was a further slight decrease to give a final value of 0.0907 Volts$^2$/Hz. The alpha waves showed a decrease, decrease trend.

The beta waves, in a similar fashion, showed a decrease between the pre-manipulation value of 0.07374 Volts$^2$/Hz and the post-manipulation value of 0.07094 Volts$^2$/Hz. 30 minutes post-manipulation this value also seemed to drop and an amount of 0.06308 Volts$^2$/Hz was taken.

Refer to Figure 52 for a graphical representation of the above data.

![Participant 7 Parietal Lobe (Eyes Closed)](image)

Figure 52: Parietal Lobe (Channel 3): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

### 4.2.8 Participant 8

#### 4.2.8.1 History and physical examination

Participant 8 was a 19-year-old female student. She had never been treated by a chiropractor and therefore complied with the inclusion criteria for the study.

Her general health was good at the time. Her history revealed that she had chicken pox as a child. She exercises three times per week and drinks socially.

According to participant heart disease runs in her family.

A review of systems revealed no abnormalities and the physical examination was unremarkable. A left sided talocrural long axis extension restriction was found.
4.2.8.2 Data analysis

Frontal Lobe: Eyes Open

All waves in this category followed an increase from the initial baseline value, directly after the manipulation was delivered. This value decreased 30 minutes later to almost the same as baseline levels. The delta waves recorded a pre-manipulation reading of 0.043232 Volts²/Hz. This value increased significantly post-manipulation and was noted at 0.073277 Volts²/Hz. Following the 30 minute waiting period post-manipulation, this value was seen to drop significantly to a value of 0.045493 Volts²/Hz, which was only slightly higher than the initial baseline value.

The theta waves underwent a sizeable increase from a pre-manipulation value of 0.039427 Volts²/Hz, to a post-manipulation value of 0.061389 Volts²/Hz. This value made a far more significant decrease 30 minutes post-manipulation to end at a final value of 0.038295 Volts²/Hz, which was slightly below baseline values.

The alpha waves captured a pre-manipulation reading of 0.029712 Volts²/Hz. This value increased considerably post-manipulation and was recorded at 0.044968 Volts²/Hz. 30 minutes later, this value was seen to decrease to just above the pre-manipulation value and was noted at 0.02918 Volts²/Hz.

The beta waves captured an initial baseline reading of 0.021348 Volts²/Hz. Following the manipulation, this value increased to 0.031593 Volts²/Hz. This wasn’t a major increase but was still noteworthy. 30 minutes post-manipulation this value decreased to a value of 0.021485 Volts²/Hz, which was almost exactly the same as the initial baseline value.

Refer to Figure 53 for a graphical representation of the above data.

![Figure 53: Frontal Lobe (Channel 1): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation](image-url)
Frontal Lobe: Eyes Closed

The delta waves were the only waves in this group that underwent an increase, decrease trend. From a pre-manipulation value of 0.04947 Volts²/Hz, the manipulation was delivered and a value of 0.055868 Volts²/Hz was captured immediately after. 30 minutes following this manipulation further data capturing took place. An amount of 0.055137 Volts²/Hz was taken. This value was still higher than the pre-manipulation value.

The theta waves underwent very insignificant changes. A pre-manipulation value of 0.047052 Volts²/Hz was taken. This value decreased insignificantly following the manipulation to an amount of 0.044787 Volts²/Hz. 30 minutes later there was still hardly any change, besides a minimal decrease to 0.046192 Volts²/Hz. The theta waves followed a decrease, decrease trend.

The alpha waves also showed irrelevant changes. Firstly a slight decrease was seen from a pre-manipulation reading of 0.03619 Volts²/Hz, to a post-manipulation reading of 0.03386 Volts²/Hz. 30 minutes later a minimal increase to 0.034755 Volts²/Hz was captured from the data. The alpha waves showed a decrease, increase trend.

The beta waves in a similar fashion showed changes of no consequence. An original baseline reading of 0.026883 Volts²/Hz decreased only slightly to 0.02413 Volts²/Hz following the manipulation. 30 minutes later this value hardly changed, to give a final value of 0.24417 Volts²/Hz. The beta waves followed a decrease, increase trend.

Refer to Figure 54 for a graphical representation of the above data

![Participant 8 Frontal Lobe (Eyes Closed)](image)

**Figure 54:** Frontal Lobe (Channel 1): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation
**Temporal Lobe: Eyes Open**

The delta waves recorded a baseline reading of 0.080573 Volts$^2$/Hz. Post-manipulation, this value dropped slightly to give an amount of 0.076785 Volts$^2$/Hz. 30 minutes later this value made a significant increase to a value of 0.095820 Volts$^2$/Hz. The delta waves followed a decrease, increase trend.

The theta waves followed a similar trend to delta waves. A pre-manipulation reading of 0.071198 Volts$^2$/Hz was taken. Following the manipulation there was relatively no change and a value of 0.070672 Volts$^2$/Hz was recorded. 30 minutes later there was an increase to 0.082892 Volts$^2$/Hz. The theta values followed a minimal decrease, increase trend.

The alpha waves were the only waves in this category to experience an increase, increase trend. They recorded an initial baseline reading of 0.40832 Volts$^2$/Hz. Post-manipulation this value increased to 0.053572 Volts$^2$/Hz. 30 minutes later it continued to increase to a final value of 0.064068 Volts$^2$/Hz.

The beta waves had a pre-manipulation reading of 0.046307 Volts$^2$/Hz. This value decreased to 0.038248 Volts$^2$/Hz immediately following the manipulation. 30 minutes later this value returned to baseline level and was recorded at 0.046545 Volts$^2$/Hz. The beta values followed a decrease, increase trend.

Refer to Figure 55 for a graphical representation of the above data

![Figure 55: Temporal Lobe (Channel 2): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation](image)

**Temporal Lobe: Eyes Closed**

The delta waves were the only waves to show an increase, increase trend. From a baseline reading of 0.054503 Volts$^2$/Hz, there was a small increase to 0.058773 Volts$^2$/Hz. This occurred following the manipulation. 30 minutes post-manipulation, there was a marked increase to 0.084445 Volts$^2$/Hz.
The theta waves showed a marked increase, going from a pre-manipulation value of 0.042558 Volts$^2$/Hz to a reading of 0.07977 Volts$^2$/Hz directly following the chiropractic manipulation. This value seemed to steady and drop only slightly to 0.076422 Volts$^2$/Hz 30 minutes post-manipulation. The theta waves followed an increase, decrease trend.

The alpha waves showed a substantial increase from the original baseline value of 0.032828 Volts$^2$/Hz to a post-manipulation value of 0.063957 Volts$^2$/Hz. This value only made a slight decrease which was seen 30 minutes later and captured at 0.059185 Volts$^2$/Hz. The alpha waves followed an increase, decrease trend.

The beta values recorded an initial baseline value of 0.02266 Volts$^2$/Hz. This value increased significantly post-manipulation to a value of 0.047905 Volts$^2$/Hz. This value was seen to decline only slightly to give a final value of 0.04344 Volts$^2$/Hz. The beta waves followed an increase, decrease trend.

Refer to Figure 56 for a graphical representation of the above data.

![Figure 56: Temporal Lobe (Channel 2): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation](image)

**Parietal Lobe: Eyes Open**

All waves showed an increase, increase trend.

The delta waves had an initial reading of 0.044402 Volts$^2$/Hz. Post-manipulation this value went up markedly to be captured as 0.069442 Volts$^2$/Hz. 30 minutes post-manipulation this value made a drastic increase and was finally captured at 0.092737 Volts$^2$/Hz.

The theta waves had a pre-manipulation reading of 0.034655 Volts$^2$/Hz. This value increased following the manipulation and was taken as 0.056167 Volts$^2$/Hz. 30 minutes following the manipulation, a further significant increase to 0.08885 Volts$^2$/Hz was seen.
The alpha waves had an initial baseline reading of 0.026897 Volts$^2$/Hz. Following the manipulation, an increase to 0.042483 Volts$^2$/Hz was experienced. A more substantial increase was seen 30 minutes post-manipulation and an amount of 0.071962 Volts$^2$/Hz was captured.

The beta waves recorded a pre-manipulation reading of 0.01933 Volts$^2$/Hz. Post-manipulation, this value increased significantly to 0.029947 Volts$^2$/Hz. This value increased 30 minutes post-manipulation by a larger extent to give a value of 0.051853 Volts$^2$/Hz.

Refer to Figure 57 for a graphical representation of the above data.

Figure 57: Parietal Lobe (Channel 3): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Parietal Lobe: Eyes Closed**

The delta waves recorded a pre-manipulation value of 0.086047 Volts$^2$/Hz. The delta wave was the only one that showed a decrease following the chiropractic manipulation. It decreased to 0.069205 Volts$^2$/Hz. 30 minutes following the manipulation, this value increased towards the initial baseline value and was finally captured at 0.083417 Volts$^2$/Hz. The delta waves followed a decrease, increase trend.

The theta waves recorded an initial baseline reading of 0.066707 Volts$^2$/Hz. There was a significant increase post-manipulation to a value of 0.076113 Volts$^2$/Hz. Following the 30 minute period post-manipulation this value decreased only slightly and steadied at 0.074222 Volts$^2$/Hz. The theta waves followed an increase, slight decrease pattern.

The alpha waves had a pre-manipulation value of 0.050228 Volts$^2$/Hz. Following the manipulation, there was only a slight increase which was recorded at 0.05958 Volts$^2$/Hz. This value stabilised but ultimately didn’t change to a great extent and dropped to 0.059183 Volts$^2$/Hz. The alpha waves followed an increase, slight decrease trend.
The beta values made a small increase following the manipulation, going from a pre-manipulation value of 0.035367 Volts$^2$/Hz to an amount of 0.043387 Volts$^2$/Hz. This value increased slightly following the 30 minute waiting period and a final value of 0.046105 Volts$^2$/Hz was captured. The beta waves followed an increase, increase trend.

Refer to Figure 58 for a graphical representation of the above data.

![Participant 8 Parietal Lobe (Eyes Closed)](image)

**Figure 58:** Parietal Lobe (Channel 3): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

### 4.2.9. Participant 9

#### 4.2.9.1. History and physical examinations

Participant 9 was a 26-year-old male golf instructor. He had previously been treated by a chiropractor but he had not been manipulated in the preceding 3 months leading up to the study and therefore complied with the inclusion criteria for the study.

His general health was good at the time. He exercises four times per week. This included golf, gym and soccer. Patient drinks socially.

A review of systems revealed no abnormalities and the physical examination was unremarkable. A right sided talocrural long axis extension restriction was detected.

#### 4.2.9.2. Data analysis

**Frontal Lobe: Eyes Open**

The delta waves recorded an initial baseline reading of 0.046448 Volts$^2$/Hz. This value was seen to decrease following the chiropractic manipulation to give a value of 0.033767 Volts$^2$/Hz. 30 minutes
following the manipulation, this value increased to almost the exact value of the baseline reading and was captured at 0.046335 Volts²/Hz. The delta waves followed a decrease, increase trend.

The theta waves had a pre-manipulation value of 0.07549 Volts²/Hz. This value was seen to decrease following the manipulation to a value of 0.040613 Volts²/Hz. 30 minutes post-manipulation the theta values stabilised and an amount of 0.040882 Volts²/Hz was noted. The theta waves noted a decrease with minimal increase trend.

The alpha waves recorded an initial baseline reading of 0.062185 Volts²/Hz. This value decreased markedly following the manipulation and was finally taken at 0.032237 Volts²/Hz. 30 minutes post-manipulation this value made a further decrease but stabilised at 0.031875 Volts²/Hz. The alpha waves followed a decrease, decrease trend.

The beta waves recorded a pre-manipulation reading of 0.051332 Volts²/Hz. This value dropped dramatically following the chiropractic manipulation and was extracted from the data as 0.023537 Volts²/Hz. This value stabilised 30 minutes later and only made a minimal decrease which was taken at 0.022282 Volts²/Hz.

Refer to Figure 59 for a graphical representation of the above data

![Figure 59: Frontal Lobe (Channel 1): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation](image)

**Frontal Lobe: Eyes Closed**

All waves in this category showed a decrease, increase trend.

The delta waves showed an initial baseline reading of 0.035682 Volts²/Hz. This value decreased minimally with almost no change following the chiropractic manipulation and was taken as a value of
0.034237 Volts$^2$/Hz. 30 minutes later this value increased and a total value of 0.056492 Volts$^2$/Hz was captured.

The theta values recorded an initial baseline reading of 0.067805 Volts$^2$/Hz. Post-manipulation, a drop to 0.049122 Volts$^2$/Hz was experienced. This value was seen to increase 30 minutes later and stabilise at 0.052258 Volts$^2$/Hz.

The alpha waves recorded a pre-manipulation reading of 0.054648 Volts$^2$/Hz. This value decreased significantly following the chiropractic manipulation and was captured at 0.036525 Volts$^2$/Hz. 30 minutes later there was a gradual increase and a final value of 0.040388 Volts$^2$/Hz was taken.

The beta waves in a similar fashion decreased to 0.026138 Volts$^2$/Hz post-manipulation, from an initial baseline reading of 0.038855 Volts$^2$/Hz. This value seemed to steady and 30 minutes later was seen to increase slightly to 0.028708 Volts$^2$/Hz.

Refer to Figure 60 for a graphical representation of the above data

![Graph](image)

Figure 60: Frontal Lobe (Channel 1): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Temporal Lobe: Eyes Open**

All the waves showed an increase, increase trend directly after the chiropractic manipulation and 30 minutes thereafter.

The delta waves recorded a low pre-manipulation reading of 0.004783 Volts$^2$/Hz. A marked increase was seen following the manipulation and a value of 0.02988 Volts$^2$/Hz was captured. 30 minutes post-manipulation this value was seen to increase further and was captured at a final value of 0.036755 Volts$^2$/Hz.
The theta waves had a pre-manipulation reading of 0.02350 Volts²/Hz. Post-manipulation there was only a slight increase which was taken at 0.028063 Volts²/Hz. 30 minutes later a much more significant change was seen as the post-manipulation value increased to 0.047087 Volts²/Hz.

The alpha waves produced a pre-manipulation reading of 0.018868 Volts²/Hz. This value was seen to increase slightly in a similar fashion to those of the theta waves. An initial increase to 0.02291 Volts²/Hz immediately following the manipulation was a mild increase when compared with the increase 30 minutes later. This value was captured at 0.039283 Volts²/Hz.

The beta values in a similar fashion increased from an initial baseline value of 0.013735 Volts²/Hz to a post-manipulation value of 0.016972 Volts²/Hz. Once again a further substantial increase was seen and 30 minutes post-manipulation a value of 0.0292 Volts²/Hz was taken.

Refer to Figure 61 for a graphical representation of the above data.

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**Figure 61: Temporal Lobe (Channel 2): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation**

**Temporal Lobe: Eyes Closed**

The delta waves recorded a pre-manipulation reading of 0.006998 Volts²/Hz. This value increased drastically following the chiropractic manipulation and was noted at 0.020732 Volts²/Hz. Following the 30 minute waiting period, another dramatic increase to 0.052023 Volts²/Hz was experienced. The delta waves followed an increase, increase trend.

The theta waves had an initial baseline reading of 0.030565 Volts²/Hz. Following the manipulation, this value dropped to 0.028582 Volts²/Hz. 30 minutes following the manipulation this value increased significantly to 0.041648 Volts²/Hz. The theta waves followed a decrease, increase trend.
The alpha waves recorded an initial baseline reading of 0.024692 Volts\(^2\)/Hz. This value hardly changed and only dropped to 0.028582 Volts\(^2\)/Hz following the chiropractic manipulation. A more significant change was seen 30 minutes post-manipulation when a value of 0.032638 Volts\(^2\)/Hz was noted. The alpha waves followed a very slight decrease, increase trend.

The beta waves recorded an initial baseline reading of 0.018128 Volts\(^2\)/Hz. This value was seen to decrease slightly following the chiropractic manipulation and was extracted as 0.01738 Volts\(^2\)/Hz. Following the 30 minutes post-manipulation, this value was seen to increase above the initial baseline reading and was taken down as 0.023435 Volts\(^2\)/Hz.

Refer to Figure 62 for a graphical representation of the above data.

![Figure 62: Temporal Lobe (Channel 2): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation](image)

**Parietal Lobe: Eyes Open**

All waves showed an increase, increase trend in this category.

The delta waves made a substantial increase from a pre-manipulation value of 0.008928 Volts\(^2\)/Hz to a post-manipulation value of 0.02036 Volts\(^2\)/Hz. 30 minutes following the manipulation this value increased dramatically to an amount of 0.053305 Volts\(^2\)/Hz.

The theta waves recorded an initial baseline reading of 0.045203 Volts\(^2\)/Hz. This value increased to 0.051343 Volts\(^2\)/Hz immediately following the manipulation. Following the 30 minute time-lapse, this value increased to 0.061182 Volts\(^2\)/Hz.
The alpha waves recorded a pre-manipulation reading of 0.036165 Volts$^2$/Hz. This value increased to 0.042518 Volts$^2$/Hz. 30 minutes post-manipulation, a further increase to an amount of 0.051068 Volts$^2$/Hz was captured.

The beta waves had an initial baseline reading of 0.025373 Volts$^2$/Hz. This value experienced a dramatic increase immediately following the manipulation and was taken at 0.030137 Volts$^2$/Hz. This value followed another dramatic increase 30 minutes later and was taken as 0.05766 Volts$^2$/Hz.

Refer to Figure 63 for a graphical representation of the above data

![Graph](image)

Figure 63: Parietal Lobe (Channel 3): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Parietal Lobe: Eyes Closed**

The delta waves made a minimal increase from a baseline reading of 0.011605 Volts$^2$/Hz to a post-manipulation reading of 0.01947 Volts$^2$/Hz. 30 minutes following the manipulation, a notifiable increase to a total value of 0.063085 Volts$^2$/Hz was taken. The delta waves showed an increase, increase trend.

The theta waves showed relatively little change, decreasing from a pre-manipulation value of 0.054877 Volts$^2$/Hz to a post-manipulation value of 0.050877 Volts$^2$/Hz. Following the 30 minute waiting period this value increased to an amount slightly higher than the initial baseline reading and was captured at 0.057625 Volts$^2$/Hz. The theta waves followed a slight decrease, slight increase trend.

The alpha waves increased from a pre-manipulation value of 0.044652 Volts$^2$/Hz to a value of 0.04505 Volts$^2$/Hz. This showed an insignificant change as the value hardly changed. 30 minutes later, only a slight increase to an amount of 0.047605 Volts$^2$/Hz was extracted. The alpha waves followed an increase, increase trend.
The beta waves also showed irrelevant changes, decreasing from a pre-manipulation value of 0.031457 Volts$^2$/Hz to a post-manipulation value of 0.031207 Volts$^2$/Hz. This value only increased slightly 30 minutes later and was captured at 0.034667 Volts$^2$/Hz. The beta waves followed a decrease, increase trend.

Refer to Figure 64 for a graphical representation of the above data

![Participant 9 Parietal Lobe (Eyes Closed)](image)

Figure 64: Parietal Lobe (Channel 3): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**4.2.10 Participant 10**

**4.2.10.1 History and physical examinations**

Participant 10 was a 20-year-old female dentistry student. She had previously been treated by a chiropractor but she had not been manipulated in the preceding 3 months leading up to the study and therefore complied with the inclusion criteria for the study.

Her general health was good at the time. Her history revealed that she had chicken pox as a child. She exercises twice week and she drinks socially.

Family history revealed that her uncle is in remission for colon cancer. Her aunt suffers from alcoholism. A review of systems revealed that the participant is prone to ear infections. The physical examination was unremarkable. A right sided talocrural long axis extension restriction was found.
4.2.10.2 Data analysis

**Frontal Lobe: Eyes Open**

All waves followed a decrease, increase pattern for this series.

The delta waves had a pre-manipulation reading of 0.04233 Volts$^2$/Hz. This value dropped dramatically following the manipulation and was captured at 0.022257 Volts$^2$/Hz. 30 minutes post-manipulation, this value increased to 0.030115 Volts$^2$/Hz.

The theta waves recorded an initial reading of 0.039407 Volts$^2$/Hz. Immediately following the manipulation, this value dropped to 0.021817 Volts$^2$/Hz. This value seemed to stabilise and only increased to 0.02624 Volts$^2$/Hz, 30 minutes post-manipulation.

The alpha waves decreased significantly from a pre-manipulation reading of 0.03219 Volts$^2$/Hz to a post-manipulation reading of 0.01856 Volts$^2$/Hz. This value increased substantially following the 30 minute waiting period but ended off at a value of 0.021102 Volts$^2$/Hz, which was still below the initial baseline value.

The beta waves recorded an initial baseline reading of 0.023527 Volts$^2$/Hz. A significant decrease to 0.0136 Volts$^2$/Hz occurred following the manipulation. 30 minutes later, this value steadied but increased slightly to 0.14957 Volts$^2$/Hz.

Refer to Figure 65 for a graphical representation of the above data.

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**Figure 65: Frontal Lobe (Channel 1): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation**

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**Frontal Lobe: Eyes Closed**

All waves in this category experienced a decrease, increase pattern.
The delta waves showed an initial baseline reading of 0.030407 Volts²/Hz, which decreased substantially to 0.024972 Volts²/Hz immediately following the manipulation. 30 minutes post-manipulation, this value increased to 0.037745 Volts²/Hz, which was a value slightly higher than baseline readings.

The theta waves recorded a pre-manipulation reading of 0.02963 Volts²/Hz. This value decreased minimally following the chiropractic manipulation to an amount of 0.024643 Volts²/Hz. 30 minutes post-manipulation, this amount increased significantly to give a value of 0.03366 Volts²/Hz.

The alpha waves produced a baseline reading of 0.24483 Volts²/Hz. This value decreased to a great extent following the manipulation and was noted at 0.010733 Volts²/Hz. This value, in a similar fashion mentioned above, ended off with a final value of 0.026835 Volts²/Hz. This was higher than the initial baseline value.

The beta waves recorded a pre-manipulation reading of 0.018318 Volts²/Hz. This value decreased following the manipulation and was captured at 0.1421 Volts²/Hz. Following the 30 minute waiting period, this value returned to baseline value but was captured slightly higher at 0.018992 Volts²/Hz.

Refer to Figure 66 for a graphical representation of the above data.

Figure 66: Frontal Lobe (Channel 1): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Temporal Lobe: Eyes Open**

All waves in this series underwent a decrease following the manipulation from initial baseline values and an increase 30 minutes later.
The delta waves made a significant decrease from a pre-manipulation value of 0.026387 Volts$^2$/Hz, to a post-manipulation value of 0.023308 Volts$^2$/Hz. 30 minutes following the manipulation, this value seemed to return toward baseline value but was captured at 0.023308 Volts$^2$/Hz.

The theta waves had a pre-manipulation reading of 0.25193 Volts$^2$/Hz. This value decreased following the manipulation and was noted at a similar reading to the delta waves at 0.11437 Volts$^2$/Hz. 30 minutes following the manipulation this value had increased substantially and was noted at 0.02109 Volts$^2$/Hz.

The alpha waves began with a baseline reading of 0.019183 Volts$^2$/Hz. This value decreased significantly to 0.009427 Volts$^2$/Hz immediately following the manipulation. 30 minutes thereafter, this value was seen to increase to 0.015757 Volts$^2$/Hz.

The beta waves recorded a baseline reading of 0.013695 Volts$^2$/Hz. This value decreased drastically following the manipulation and was noted at 0.007068 Volts$^2$/Hz. This value was seen to increase and was ultimately extracted from the data at 0.011523 Volts$^2$/Hz.

Refer to Figure 67 for a graphical representation of the above data

![Figure 67: Temporal Lobe (Channel 2): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation](image)

**Temporal Lobe: Eyes Closed**

All the waves in this series underwent a decrease in value following the manipulation. An increase 30 minutes later was experienced.

The delta waves recorded an initial baseline reading of 0.032375 Volts$^2$/Hz. Immediately following the manipulation, this value was seen to decrease drastically. A value of 0.01555 Volts$^2$/Hz was captured. 30 minutes post-manipulation, this value climbed and was noted at 0.027565 Volts$^2$/Hz.
The theta values recorded an initial baseline reading of 0.029898 Volts\(^2/\text{Hz}\). Following the manipulation, this value was seen to make a marked decrease to 0.01544 Volts\(^2/\text{Hz}\). 30 minutes following the manipulation, this value increased towards the baseline value but was captured below at 0.023778 Volts\(^2/\text{Hz}\).

The alpha waves recorded a pre-manipulation reading of 0.02245 Volts\(^2/\text{Hz}\). Following the manipulation, a significant decrease was experienced and a value of 0.011903 Volts\(^2/\text{Hz}\) was noted. This value seemed to stabilise and 30 minutes following the manipulation this value increased to only 0.017913 Volts\(^2/\text{Hz}\).

The beta waves recorded a pre-manipulation reading of 0.016568 Volts\(^2/\text{Hz}\). Following the manipulation, a drastic decrease to 0.008497 Volts\(^2/\text{Hz}\) was seen. This value increased 30 minutes later and an amount of 0.01253 Volts\(^2/\text{Hz}\) was noted.

Refer to Figure 68 for a graphical representation of the above data.

![Graph](image)

**Figure 68:** Temporal Lobe (Channel 2): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation

**Parietal Lobe: Eyes Open**

All waves in this category experienced a decrease, increase trend.

The delta waves recorded an initial baseline reading of 0.03147 Volts\(^2/\text{Hz}\). This value dropped significantly following the manipulation and was captured at 0.015238 Volts\(^2/\text{Hz}\). 30 minutes following the manipulation, the value increased dramatically and a result of 0.037952 Volts\(^2/\text{Hz}\) was taken, which was higher than that of the initial baseline reading.

The theta waves had a pre-manipulation reading of 0.030465 Volts\(^2/\text{Hz}\) which decreased to 0.01678 Volts\(^2/\text{Hz}\) directly following the manipulation. 30 minutes following the manipulation, this value increased back towards baseline reading and was captured at 0.030982 Volts\(^2/\text{Hz}\).
The alpha waves recorded an initial baseline value of 0.02567 Volts²/Hz, which decreased substantially before being captured at 0.014502 Volts²/Hz. This value was seen to increase 30 minutes later and was taken at just below baseline readings at a value of 0.024243 Volts²/Hz.

The beta waves had a pre-manipulation value of 0.018907 Volts²/Hz. This decreased to a smaller degree but was extracted from the data at 0.010982 Volts²/Hz. This value was seen to increase 30 minutes later and was eventually extracted at 0.017113 Volts²/Hz.

Refer to Figure 69 for a graphical representation of the above data.

Figure 69: Parietal Lobe (Channel 3): Eyes Open at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation.

Parietal Lobe: Eyes Closed

All waves in this series produced a decrease, increase pattern.

The delta waves produced an original baseline reading of 0.028867 Volts²/Hz. This value was seen to markedly decrease to 0.014935 Volts²/Hz immediately following the manipulation. 30 minutes later, a massive increase was noted that took the value to a final amount of 0.036288 Volts²/Hz.

The theta waves showed a pre-manipulation reading of 0.029615 Volts²/Hz. This value decreased to a large extent following the manipulation and was captured at 0.015815 Volts²/Hz. 30 minutes post-manipulation, this value increased back towards baseline value and was captured at 0.029538 Volts²/Hz.

The alpha waves had a pre-manipulation recording of 0.023208 Volts²/Hz. This value was seen to decrease significantly to 0.012757 Volts²/Hz following the manipulation. 30 minutes post-manipulation, the value climbed back towards baseline value before being noted as 0.022238 Volts²/Hz.
The beta waves recorded an initial baseline reading of 0.01658 Volts$^2$/Hz. This value decreased to 0.009455 Volts$^2$/Hz immediately following the manipulation. 30 minutes later, this value increased and was captured at 0.015572 Volts$^2$/Hz.

Refer to Figure 70 for a graphical representation of the above data.

Figure 70: Parietal Lobe (Channel 3): Eyes Closed at pre-manipulation, immediately post-manipulation and at 30 minutes post-manipulation.
4.3 Results

4.3.1 Group average results

4.3.1.1 Delta waves
Delta wave changes were detected across all of the lobes, while the eyes were open and closed. The most frequent trend observed was an increase immediately after the manipulation. This was observed in the frontal lobe with the eyes open and the parietal lobe with the eyes open. This was followed by a further noteworthy increase at 30 minutes post-manipulation. The parietal lobe with eyes closed showed the most significant increase following the manipulation and in keeping with the trend, also noted a significant increase 30 minutes post-manipulation. Participant 1 followed the exact same trend throughout. See figure 71 for an overview of all the group trends across all waves. Frontal lobe activity when the eyes were closed also increased significantly following the manipulation but steadied 30 minutes later at a value higher than the baseline value. Participant 3 and 8 followed a similar trend. Activity in the temporal lobe for eyes both open and closed showed a decrease immediately after the manipulation was delivered. Delta wave activity in the temporal lobe then made an increase 30 minutes post-manipulation and both values were shown to be higher than the initial baseline values respectively. Participant 1, 2 and 10 followed a similar trend but the final value captured was below initial baseline readings.

4.3.1.2 Theta waves
Observed changes in theta readings occurred in all three lobes. The most common trend was an increase immediately following the manipulation and a further, marked increase 30 minutes later. This trend was observed during the eyes open and closed periods of both the frontal and parietal lobes. The greatest change observed following manipulation was seen in the parietal lobe with eyes open. The greatest increase 30 minutes post-manipulation was seen in the parietal lobe with the eyes closed. Participants 4 and 5 reported similar trends to frontal theta activity and participants 1, 3, 4, 8 and 9 all had similar trends to those seen in the parietal lobe. The temporal lobe with the eyes open and closed showed a decrease after the manipulation. However, this was obscured by a drastic increase in activity 30 minutes later, to a value higher than the initial baseline value. Participants 1, 2, 3, 8, 9 and 10 all followed similar trends.
4.3.1.3 Alpha waves
The alpha waves did exhibit certain changes all round. The most frequent trend was a decrease following the manipulation which was displayed by the frontal lobe with eyes open, the temporal lobe with eyes open and closed and the parietal lobe with the eyes closed. The biggest change following the manipulation was seen in the temporal lobe when the eyes were closed. This decrease was followed by a more significant increase in brain activity in all four of the above-mentioned, 30 minutes after the manipulation was delivered. The parietal lobe with the eyes closed had an almost negligible change throughout. The greatest increase 30 minutes post-manipulation was seen in the temporal lobe with the eyes open. Participants 4, 5, 7 and 10 exhibited similarities to the frontal lobe with the eyes open. Participants 1, 2, 3, 9 and 10 demonstrated similarities to the trends seen in the temporal lobe’s activity. There was a negligible decrease observed in the frontal lobes’ activity immediately following the manipulation when the eyes were closed. Alpha wave activity in the parietal lobe when the eyes were open showed a significant rise following the manipulation and only a slight increase 30 minutes later. Participant 3 and 9 exhibited similar patterns.

4.3.1.4 Beta waves
Immediately post-manipulation there was an overall decrease in beta wave activity over all three lobes. The parietal lobe activity with the eyes open was the only section to show an increase following the manipulation. As the 30 minute period went by, all wave activity increased back towards normal and were captured at higher readings than the initial baseline values. The frontal lobe with the eyes closed noted a value just below its original baseline reading. Participant 1 exhibited the most accurate representation of the above trend.
Figure 71: Graphs Showing the Group Averages for Delta, Theta, Alpha and Beta Wave Activity in the Frontal, Temporal and Parietal Lobes while the Eyes were Open and Closed
4.3.2 Group modal results
The most prevalent trend observed throughout the participants was the decrease, increase trend. Out of a possible 240 recordings, this trend appeared 94 times. That is 39.17% of the data. The double increase trend was next highest, claiming 30.83% of the data. It was seen 74 times. The increase, decrease trend was noted 47 times out of the 240 total readings. It captured 19.58% of the data. Lastly, the double decrease trend was seen 25 times and made up 10.42% of the data. For more detailed graphs and tables please refer to (Appendix H).

![Modal Percentages]

Figure 72: Pie graph demonstrating the distribution of the trends seen throughout all 10 participants’ testing.

4.4 Group Average Results in the Brain Lobes
4.4.1 Frontal lobe

Eyes Open
Following the manipulation, the delta waves made a small increase. This further increased slightly but not to a significant extent 30 minutes later.
Frontal theta waves followed a similar trend. They increased to a slightly larger extent post-manipulation and increased minimally 30 minutes post-manipulation.
Alpha wave activity in the frontal lobe decreased post-manipulation. 30 minutes after the manipulation was delivered, a marked increase in alpha wave activity was observed. This value was higher than the initial baseline reading.
Beta waves decreased by a significant extent following the manipulation. Following the 30 minutes thereafter, beta wave activity increased beyond the initial baseline value.

**Eyes Closed**
Immediately following the manipulation, a marked increase in delta wave activity was observed. Delta wave activity decreased to a negligible degree 30 minutes post-manipulation. Theta waves minimally increased following the manipulation. This value also stabilised but instead of decreasing, theta wave activity increased considerably. Alpha wave activity was the only one to observe a double decrease trend. On further examination, the decrease following the manipulation was trivial. However, 30 minutes following the manipulation the greatest decrease in alpha wave activity in the frontal lobe with the eyes closed was observed. Scrutinizing beta wave activity, a significant decrease occurred following the manipulation. This activity increased 30 minutes later, to a value just below the initial baseline value.

**4.4.2 Temporal lobe**

**Eyes Open**
There was an irrelevant increase in delta wave activity following the manipulation. However, it was the reading 30 minutes later that showed a long term, marked increase in delta wave activity. Theta wave activity also decreased following the manipulation, but this was also minimal when compared to the increase 30 minutes later. Alpha waves decreased negligibly following the manipulation. 30 minutes later, alpha wave activity increased markedly beyond initial baseline readings.

Beta activity underwent a considerable decline following the extremity manipulation but ultimately increased 30 minutes later.

**Eyes Closed**
Delta wave activity showed the most significant change following the manipulation and 30 minutes post-manipulation. Initially, a large decrease was observed following the manipulation. This is the only time this phenomenon occurred throughout all the lobes. 30 minutes post-manipulation, the delta wave activity had increased beyond the initial baseline reading. Theta, alpha and beta wave activity followed the exact same decrease, increase trend as for the eyes open.
4.4.3 Parietal Lobe

**Eyes Open**
This was the only time a lobe showed an increase, increase trend throughout.

**Eyes Closed**
Delta wave activity increased to the highest extent in the parietal lobe following the manipulation as well as 30 minutes post-manipulation.
Theta wave activity increased marginally following the manipulation and to a larger extent 30 minutes later.
Alpha wave activity made an insignificant decrease following the manipulation. This was followed by an increase in alpha wave activity 30 minutes later, which brought alpha wave activity to a value slightly higher than the baseline values.
Beta wave activity followed a similar trend to that of alpha wave activity, although the decrease following the manipulation was more considerable. This value also increased slightly beyond baseline values following the 30 minute post-manipulation waiting period.
CHAPTER FIVE - DISCUSSION

5.1 Introduction
Chapter 4 detailed the changes seen in all four waves across the frontal, temporal and parietal lobes for all ten participants. The aim of this chapter will be to interpret the results presented previously.

The aim of the study was to determine whether chiropractic manipulation to an extremity joint (in this case the talocrural joint) would produce any descriptive change to brain wave readings. The brain waves were measured by the qEEG. An examination of the results showed that there were certain changes noted in brain wave readings throughout all three lobes.

The participants’ individual qEEG readings have been assembled into group graphs (Figure 71). This has been accomplished by calculating the average voltage readings for pre-manipulation, immediately following the manipulation and 30 minutes following the manipulation of all participants. Each of these graphs demonstrate a change in qEEG recordings. These averages for the trial group form the basis of the discussion below.

The observed changes in the brain waves following the chiropractic manipulation followed one of four patterns, namely: increase, decrease; decrease, increase; double increase or double decrease. The modal trend of these reactions was also analysed across each of the stages of the trial (Appendix H).

5.2 Neurology of the Brain Lobes
As seen in the above results, all three lobes typically demonstrated changes. The literature below describes the pathway from the stimulus to each brain lobe.

5.2.1 Parietal lobe
Chapter 2 described how mechanoreceptors in the talocrural joint travel via the dorsal column-medial meniscal system and terminate in the somatosensory cortex of the parietal lobe. As the manipulation was completed on the talocrural joint, mechanoreceptors in the joint capsule were activated.

Axons of the 1st order neurons (originating from the mechanoreceptors) travel via large myelinated nerve fibres to arrive at the dorsal roots of the spinal nerves. Without synapsing, axons from the inferior half of the body ascend within the fasciculus gracilis before synapsing in the nucleus gracillii of the medulla oblongata (Hall, 2011; Martini & Nath, 2009). Axons of the 2nd order neurons in the nucleus gracillii decussate to the other side of the brainstem and ascend within the medial lemniscus (Hall, 2011; Martini & Nath, 2009).

These 2nd order neurons then synapse on 3rd order neurons in the ventrobasal complex of the thalamus (Hall, 2011). Once information has been processed at these nuclei, it is projected to the primary
somatosensory cortex. Due to the decussation at the medulla, sensation from the left hand side of the body is represented by the right hand side of the thalamus (Hall, 2011; Martini & Nath, 2009). The anterior parietal lobe is where somatosensory areas are found (Hall, 2011).

5.2.2 Temporal lobe
Auditory stimuli result in stimulation of hair cell receptors within the cochlea and in turn, activate sensory neurons. The cochlear branch of cranial nerve VIII is formed by the afferent branches of these neurons. Auditory sensations are then relayed to the cochlear nuclei of the medulla oblongata. These signals are then directed to the inferior colliculus before ascending to the medial geniculate nucleus in the thalamus. Finally, this information is received by the auditory cortex of the temporal lobe (Hall, 2011; Martini & Nath, 2009). No change is expected, as besides the researcher’s instructions and the sound produced during the manipulation, there should be silence during the trials.

5.2.3 Frontal Lobe
Frontal SEP’s represent early somatosensory input into non-primary motor areas. They provide insight into the sensory processing of motor control. Research supports the role of the prefrontal cortex in the modulation of these SEP’s (Brown, MJ, Staines, WR, 2015). The prefrontal association area receives pre-analysed sensory information from the parieto-occipitotemporal association area via a substantial bundle of subcortical nerve fibres (Hall, 2011).

The frontal lobe’s connections to the parietal lobe are defined by a chain of U-shaped connections between the adjacent lobes. These include the paracentral lobe, the hand knob region and the ventral group of connections (Catani et al., 2012). It is through these connections that activations in the parietal lobe will cause a resultant change in frontal lobe qEEG readings.

5.3 Results
5.3.1 Group average results
Up until now, no research has investigated the effects of peripheral joint manipulation on brain EEG. Research has predominantly focused on the effects of spinal manipulation. The results that will be described showed similar patterns of change following the manipulation that was noted in the spinal studies. This could suggest that alternative reasons were responsible for the changes noted.

5.3.1.1 Delta waves
The marked changes in delta wave activity seen throughout the frontal and parietal lobe is indicative of the participants increased relaxed/ resting state immediately following the manipulation. However, delta
wave activity followed the largest increases 30 minutes post-manipulation across all the lobes. We therefore have to wonder how much of that increase in delta wave activity is as a result of the participant’s quiet and motionless state.

5.3.1.2 Theta waves
The largest amount of activity was observed in the parietal lobe. This could imply that the extremity manipulation may have had the largest effect on the somatosensory area of the brain although an effect on decreasing mental processing and alertness of the participant was also noted, (Hall, 2011). The increase in theta wave activity is supported by the increase in delta wave activity discussed above. The inactive state of the participants during the trial must also be considered.

5.3.1.3 Alpha Waves
The results obtained for the alpha waves show no correlation to the delta or theta counterparts described above. A decrease seen after the manipulation is indicative of either a decrease in the resting state of the participant or “alpha blockage.” This can occur with the participant being suddenly alerted (Pizzagalli, 2007). This may also suggest that the manipulation decreases this relaxed/learning state of mind in the participant. Ultimately, as 30 minutes went by, the participant found themselves in a more relaxed/meditative state with the increase in alpha wave activity (Tatum, 2014). This does coincide with alpha and delta wave patterns and therefore suggests that either as a result of the manipulation over time, the participant’s immobile state, alternative factors or a combination of all, may be responsible for the increased relaxed state of the participant (Tatum, 2014).

5.3.1.4 Beta Waves
If the participant experienced a state increased drowsiness as previously stated, this would explain the decrease in beta values immediately post-manipulation (Pizzagalli, 2007). The increased values following the 30 minute waiting period may indicate that the participant a state of increased information processing, which can further be supported (but only to a small degree) by the increase in mental activation seen in frontal theta activity (Tatum, 2014; Pizzagalli, 2007).

5.4 Interpretation of the Brain Waves within each Lobe
From the group averages, an attempt will now be made to analyse and interpret the trends and fluctuations in the brain waves within each lobe and state (eyes closed and eyes open). The explanations of the waves were described in chapter 2 and these were used to describe and add meaning to the trends. For an overview of all the trends please see figure 71.
5.4.1 Frontal lobe

Eyes Open
The undisturbed environment or alternative reasons may have been responsible for the increased effect on the deep relaxation state of the individual, owing to the increases in delta wave activity presented in the results following the manipulation (Pizzagalli, 2007). It can be assumed that the further increase in delta wave activity seen 30 minutes post-manipulation could be as a result of the manipulation as well as the unperturbed state of the participant during the trial.
The increase in frontal theta activity showed that the participant experienced a slight increase in focused mental attention.
A decrease in alpha wave activity could be as a result of “alpha blockage” when the eyes were open, with an increase in cognition occurring (Pizzagalli, 2007). The notable increase could correspond with an increased state of rest and reflection (Edge, 2015). It can be assumed that the manipulation or alternative reasons had a long term effect on this meditative state of the participant, although the quiet state of the participant during the trial must also be considered.
Beta waves decreased by a significant extent following the manipulation. This corresponds to the theory of an increased effect of relaxation seen also by the delta waves (Pizzagalli, 2007). Following the 30 minutes thereafter, beta wave activity increased beyond the initial baseline value. This may indicate that the participant was in a state of increased mental activation and information processing as time went on (Pizzagalli, 2007; Edge, 2015).
Trends were observed in the frontal lobe as a result of its connections to the parietal lobe (Catani M., 2012). The greatest change following the manipulation occurred in beta wave activity. This may indicate that the largest effect seen was an increase in the relaxed resting state of participants, with a decrease in focused attention (Pizzagalli, 2007). This can be supported by the increase in delta wave activity. Following the 30 minutes post-manipulation, delta wave activity increased by the largest degree, further supporting the above effects.

Eyes Closed
The marked increase in delta wave activity following the manipulation may indicate that the participant was in an increased deep sleep/resting state (Pizzagalli, 2007). Once again research does not support that an extremity manipulation could have such an effect but as the study is proving to have changes similar to that of spinal studies, further investigation is required.
As for eyes open, an increase in frontal theta activity is linked to increased mental alertness. This implies that the participant experienced a state increased mental attention in the frontal lobe (Tatum, 2014).
As seen by theta activity mentioned above, the participant decreased a state of relaxed wakefulness to allow a state of greater mental activeness (Tatum, 2014; Pizzagalli, 2007). Beta wave activity decreased following the manipulation, this supports the trend observed immediately post-manipulation in delta wave activity of an increased resting/quiescent state of the participant (Edge, 2015). The increase in beta wave activity supported that either the manipulation or alternative factors ultimately had an effect on increased information processing in the frontal lobe (Edge, 2015). Delta wave activity was by far the greatest following the chiropractic manipulation. This suggests that the participant was in a state of increased relaxation. It was the 30 minute post-manipulation value that was the most interesting. Theta, alpha and beta activity all pointed to an increase in the mental acumen as well as the increase in information processing of the participant (Edge, 2015; Pizzagalli, 2007).

5.4.2 Temporal lobe

Eyes Open
The long term increase in delta wave activity implied that the participant experienced an increased state of relaxation following the manipulation and 30 minutes post-manipulation (Edge, 2015). The temporal lobe showed to be in a state of decreased mental processing and alertness (Tatum, 2014). The temporal lobe showed signs of being in an increased reflective/meditative state 30 minutes post-manipulation (Tatum, 2014). It can be assumed that the chiropractic manipulation played a role, although we must not forget that alternative reasons are likely to be responsible as well as the participants’ docile state throughout the trial.

Beta activity underwent a considerable decline following the extremity manipulation. This supports the theory of an increase in the relaxed state of the individual (Tatum, 2014). Beta activity ultimately increased 30 minutes later, promoting a greater degree of attention and level of information processing (Edge, 2015).

The greatest degree of activity in the temporal lobe when the eyes were open was seen in the decline of beta wave activity following the manipulation. The participant likely underwent an increased reflective state (Tatum, 2014). This reflects similar changes to the changes seen post spinal manipulation therefore perhaps alternative reasons including the docile state of the participant are responsible for the changes being recorded. The largest difference after 30 minutes post-manipulation was seen in delta wave activity, which increased hugely. We must still consider that this effect may be influenced by the participants’ inactive position throughout the trial.
Eyes Closed
This single noted event of a decrease in delta activity following the manipulation implied that the participant felt a decrease in the resting state of the individual (Tatum, 2014). The ultimate increase in delta wave activity suggests that the individual was ultimately in a state of relaxation. The decrease, increase trend followed by theta, alpha and beta wave activity implies that the temporal lobe was in an increased state of peaceful relaxation. (Tatum, 2014). The largest difference after the 30 minutes post-manipulation was seen in delta wave activity, which increased hugely. This coincides once again with changes seen following a spinal manipulation that supports the relaxation potential of the manipulation (Barwell et al., 2004). We must still consider that these changes are occurring post TCJM and therefore alternative reasons or the participants’ motionless position throughout the trial may be responsible.

5.4.3 Parietal Lobe

Eyes Open
The increase in delta wave activity was suggestive that the patient was experiencing an increase in their resting state (Pizzagalli, 2007).
An increase in theta wave activity is suggestive of the participants decreased mental alertness and increase in the state of light sleep (Tatum, 2014.)
The increase in beta wave activity is suggestive of the participants possible increase in mental attention and information processing (Edge, 2015).
The tactile stimulus of the manipulation should theoretically activate the somatosensory area of the brain. So changes should ideally be expected in this category. Alpha wave activity in the parietal lobe made the most significant increase following the manipulation. This implies that following the manipulation the participant experienced an increased relaxed, learning state of mind (Tatum, 2014). The greatest increase 30 minutes thereafter was seen in delta wave activity. This once again notes similar changes to that seen in spinal studies and therefore alternative factors including the silent environment that the individual was exposed to throughout the trial may have influenced these changes (Pizzagalli, 2007).

Eyes Closed
Delta wave trends showed the largest increases immediately following the manipulation and 30 minutes later and therefore this is suggestive that the participant was in an amplified deep passive state (Tatum, 2014).
The theta wave trend was indicative that the participants’ position and alternative factors may have influenced a situation of decreased mental attentiveness and a position of light drowsiness (Edge, 2015).
Alpha trends showed that the chiropractic manipulation had no significant effect. Beta wave trends may indicate that following the manipulation the participant was in an increased tranquil state and that this state as well as alternative reasons may be responsible for the long term effect on increasing thought processing in the participants (Edge, 2015.)

5.5 Trends and Correlations
Out of the 10 participants, the following was observed with regards to their history. The age range of the participants was between 19 and 26 years old. There were three participants who had never received a chiropractic manipulation before and seven who had. There were four female and six male participants. On closer inspection of the participants’ histories, five participants had previously sustained some form of traumatic injury; two had previously sustained shoulder injuries, two had sustained a knee pathology and two participants had injured their wrists. One had sustained a soft tissue wrist injury two weeks prior to the trial during a rugby game. All participants were involved in some form of exercise. The most inactive participant only exercised twice per week, while the most active participant exercised six times per week. The participants were involved in a variety of activities including; gym, soccer, equestrian, golf and cycling. Some participants exercised in more than one discipline. An in depth look at the above mentioned data indicates that the participant group is not large or diverse enough to extract any meaningful conclusions when it comes to deciding whether trauma, exercise, gender, age or first time chiropractic treatment, had any discernible influence on the results.
CHAPTER SIX – CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The objective of this research was to compile a case series describing whether extremity chiropractic manipulations had any discernible influence on qEEG readings.

After scrutiny of chapter 4 and 5, there is most certainly an observable change to the qEEG readings post-manipulation. This consisted of either an increase or decrease in delta, theta, alpha and beta wave activity across one or all of the lobes immediately after the manipulation was carried out.

The study also attempted to understand and interpret the significance of the results, using group averages and modes. Many postulations and attempted links were made, but without a larger group of participants the results will remain inconclusive. Further study is warranted to prove that the effects observed are purely chiropractic related.

6.2 Recommendations

The following recommendations are made pertaining to future research:

1. A study with a bigger group of participants would allow for a more accurate interpretation of the trends.
2. A research which compares upper and lower limb extremity manipulations and their effects on qEEG readings.
3. A research study which focuses on participants with an ankle pathology as opposed to asymptomatic participants.
4. A comparative study between lumbar spine manipulation and lower limb extremity manipulation and any associated changes to qEEG readings.
References


1. DESCRIPTION OF STUDY: The aim of the study is to compile case series describing whether chiropractic manipulations on an extremity have any detectable influence on Electroencephalogram readings.

Your participation will take about one hour. Chiropractic manipulations will be performed while a qEEG monitors your brain wave activity.

This study will take place between June 2016 and November 2016

To participate: You must be between the ages of 18 – 45

To learn more, contact the principal investigator of the study, Devlin Randal-Smith,

On 084 503 7608 or drandalsmith12@gmail.com

Ethics clearance number: ______________
DEPARTMENT OF CHIROPRACTIC
RESEARCH STUDY INFORMATION SHEET

2 May 2016

Good Day

My name is Devlin Randal-Smith I would like to invite you to participate in a research study describing the effect of extremity manipulation on brain waves.

Before you decide on whether to participate, I would like to explain to you why the research is being done and what it will involve for you. I will go through the information sheet with you and answer any questions you have. This should take about 10 to 20 minutes. The study is part of a research project being completed as a requirement for a Masters Degree in Chiropractic through the University of Johannesburg.

The purpose of this study is to compare pre and post adjustment readings that will be taken by a Quantitative Electroencephologram (qEEG). The study will use the data gathered to describe weather Chiropractic manipulations on extremity joints have an effect on the qEEG readings.

Below, I have compiled a set of questions and answers that I believe will assist you in understanding the relevant details of participation in this research study. Please read through these. If you have any further questions I will be happy to answer them for you.
DO I HAVE TO TAKE PART?
No, you don’t have to. It is up to you to decide to participate in the study. I will describe the study and go through this information sheet. If you agree to take part, I will then ask you to sign a consent form.

WHAT EXACTLY WILL I BE EXPECTED TO DO IF I AGREE TO PARTICIPATE?
- If you agree to participate the following will occur:
- You will have a qEEG cap placed on your head and your baseling qEEG readings will be taken (i.e. your brainwaves will be measured). Gel will need to be used to aid conduction. This will be done for 2 minutes with your eyes open and 2 minutes with your eyes closed.
- Thereafter your ankle restriction will be manipulated by myself, the researcher. This will entail me distracting your foot. It is a painless procedure and you may hear an audible click.
- You will then have your brain waves remeasured using the qEEG.
- You will then need to remain in the room for a further 30 minutes after the manipulation. Thereafter you will have your final measurements taken.

WHAT WILL HAPPEN IF I WANT TO WITHDRAW FROM THE STUDY?
If you decide to participate, you are free to withdraw your consent at any time without giving a reason and without any consequences. If you wish to withdraw your consent, you must inform me as soon as possible.

IF I CHOOSE TO PARTICIPATE, WILL THERE BE ANY EXPENSES FOR ME, OR PAYMENT DUE TO ME:
You will not be paid and you will not bear any expenses.

RISKS INVOLVED IN PARTICIPATION:
There may be mild discomfort post ankle manipulation. The application of the conductive gel is generally well tolerated, but there is a possibility of irritation, pain, bleeding, and infection. This will be limited by sterilizing the cap with alcohol swabs as well as excluding participants with open wounds. Also, repeated EEG measurements pose a higher risk, in this study the cap will only be put on and removed once or possibly twice if it moves during the manipulation.

BENEFITS INVOLVED IN PARTICIPATION:
The restriction to your ankle joint will be treated. You will be aiding in the addition of knowledge of the extent of the neurological effect that the chiropractic manipulation has. The direct benefit to you is limited.
**WILL MY PARTICIPATION IN THIS STUDY BE KEPT CONFIDENTIAL?**
Yes. Names on the questionnaire/data sheet will be removed once analysis starts. All data and back-ups thereof will be kept in password protected folders. Only I or my research supervisor will be authorised to use and/or disclose your anonymised information in connection with this research study.

**WHAT WILL HAPPEN TO THE RESULTS OF THE RESEARCH STUDY?**
The results will be written into a research report that will be assessed. In some cases, results may also be published in a scientific journal. In either case, you will not be identifiable in any documents, reports or publications. You will be given access to the study results if you would like to see them, by contacting me.

**WHO IS ORGANISING AND FUNDING THE STUDY?**
The study is being organised by me, under the guidance of my research supervisor at the Department of Chiropractic in the University of Johannesburg. The study has received the supervisor linked bursary.

**WHO HAS REVIEWED AND APPROVED THIS STUDY?**
Before this study was allowed to start, it was reviewed in order to protect your interests. This review was done first by the Department of Chiropractic, and then secondly by the Faculty of Health Sciences Research Ethics Committee at the University of Johannesburg. In both cases, the study was approved.

**WHAT IF THERE IS A PROBLEM?**
If you have any concerns or complaints about this research study, its procedures or risks and benefits, you should ask me. You should contact me at any time if you feel you have any concerns about being a part of this study. My contact details are:
Devlin Randal-Smith
(+27)845037608
drandalsmith12@gmail.com

You may also contact my research supervisor:
Dr. Charmaine Bester
charmained@uj.ac.za
If you feel that any questions or complaints regarding your participation in this study have not been dealt with adequately, you may contact the Chairperson of the Faculty of Health Sciences Research Ethics Committee at the University of Johannesburg:

Prof. C Stein  
Tel: 011 559-6686  
Email: cstein@uj.ac.za

FURTHER INFORMATION AND CONTACT DETAILS:
Should you wish to have more specific information about this research project information, have any questions, concerns or complaints about this research study, its procedures, risks and benefits, you should communicate with me using any of the contact details given above.

Researcher:

Devlin Sean Randal-Smith
DEPARTMENT OF CHIROPRACTIC
RESEARCH CONSENT FORM

A Case Series Describing the Effect of Extremity Manipulation on qEEG

Please initial each box below:

☐ I confirm that I have read and understand the information sheet dated 2 May 2016 for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

☐ I understand that my participation is voluntary and that I am free to withdraw from this study at any time without giving any reason and without any consequences to me.

☐ I agree to take part in the above study.

_______________________  __________________________  _____________
Name of Participant      Signature of Participant    Date

_______________________  __________________________  _____________
Name of Researcher       Signature of Researcher     Date
To whom it may concern

Mr Devlin Randal-Smith

Mr Randal-Smith is planning research for the purposes of a master's degree. For the purpose of his research, he needs access to EEG equipment and approached me in this regard. I have given him permission to use the EEG equipment. There are no costs involved in the use of the equipment and the logistics of access will be negotiated once he has been given clearance to continue with the research.

Yours sincerely

Alban Burke (Ass-Prof)
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| **Educational qualifications:** | B.A. (Social Sciences), RAU, 1983  
|                     | B.A. Hons (Psychology), RAU, 1984  
|                     | M.A. (Psychology) *cum laude*, RAU, 1986  
|                     | D.Litt et Phil. (Psychology), RAU, 1993 |
| **Professional registration:** | Clinical Psychologist (HPCSA): Feb. 1988 – Dec 2002 |
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| **Fax:**           | (+2711) 559 3174 |
**Professor Burkes EEG Articles**


Were both Neuro studies, of which the Williams et al one was EEG based.

**Articles in preparation that are EEG based:**


2. Sklar, R., & Burke, A. Hyperfocus in adult ADHD: an EEG study of the differences in cortical activity in resting and arousal states

**Chapter in book that was EEG based:**


**Conference presentations that were EEG based:**


Workshop presentation that was EEG based:


MA dissertations that were EEG based:

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MA minor dissertations that were EEG based:

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<td>Ferreira, Q.</td>
<td>A comparison of frontal lobe cortical arousal between ADHD and Anxiety Disorders</td>
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If you would like more details please contact the supervisor Dr. Charmaine bester for the full CV.
Dear Prof Fourie

I would like to request permission to conduct research on the DFC campus. My study is **A Case Series Describing the Effect of Extremity Manipulation on qEEG**. It has been accepted by both the University of Johannesburg Ethics and Higher degrees committees.

Ethics clearance number: ______________
Higher degrees clearance number: ______________

Kind regards
Devlin Randal Smith
APPENDIX F

qEEG Equipment

Image 1: MP150 DATA ACQUISITION SYSTEM
GLP - WIN - MP150WSW-G

Image 2: The electrical cap.

Image 3: Electrode placement on the scale
APPENDIX G

FACULTY OF HEALTH SCIENCES
RESEARCH ETHICS COMMITTEE
NHREC Registration no: REC-241112-035

REC-01-62-2016
14 June 2016

TO WHOM IT MAY CONCERN:

STUDENT: RAHDAAL-SMITH, DS
STUDENT NUMBER: 201102820

TITLE OF RESEARCH PROJECT: A Case Series Describing the Effect of Extremity Manipulation on cEEG

DEPARTMENT OR PROGRAMME: CHIROPRACTIC
SUPERVISOR: Dr C Baxter
CO-SUPERVISOR: 

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,

Prof M Poggenpoel
Chair: Faculty of Health Sciences REC
Tel: 011 559 6689
## APPENDIX H

### Eyes Open

#### Frontal Lobe

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