THE IMMEDIATE EFFECT OF A CHIROPRACTIC MANIPULATION OF THE SPINE ON THE HITTING SPEED IN SQUASH

A research presented to the Faculty of Health Science, University of Johannesburg, as partial fulfilment for the Masters Degree in Technology: Chiropractic by

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DECLARATION

I, Mark van Dongen, declare that this dissertation is my own, unaided work. It is being submitted as partial fulfilment for the Masters Degree in Technology, in the Program of Chiropractic, at the University of Johannesburg. It has not been submitted before for any degree or examination in any other University or Technikon.

____

Mark van Dongen

On this day the ____ of the month of ________2019

DEDICATION

I would like to dedicate this dissertation to my maternal grandmother and my paternal grandfather who both passed away early in 2019 and so were not able to see me graduate. I hold you both dear to my heart.

I would also like to dedicate this to my family and friends who provided support and made the entire journey of this course enjoyable. To the friends I made at university, you guys made the six years and a bit fly. I will always treasure those six years of memories.

I would like to dedicate this to my mother, who spent countless hours helping me with editing and tinkering of my dissertation, although I didn't always show it, I am very grateful to you for all your love and support.

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To my family that supported me throughout the course and certainly throughout the study, you have done so much for me and I will never be able to fully express how much that means to me, so thank you all so much.

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To Anesu Kuhudzai at STATKON. Thank you for your fast and accurate work, as well as the guidance shown to better understand the statistics within this study.

ABSTRACT

Purpose: The aim of this study was to determine whether chiropractic manipulation has an immediate effect on the hitting speed of a squash ball in competitive squash players and to determine whether manipulation could be beneficial in increasing the ball speed post hit in the squash forehand drive.

Method: Both male and female participants between the ages of 35 and 65 (n=100), who met the inclusion criteria of being active league squash players, were selected. The participants were split into two groups, a control group and an intervention group, each consisting of 50 participants.

Procedure: Each participant, after consenting to be on this study, had a single consultation during which a patient history, physical examination and a cervical spine regional assessment were completed. Participants were given a standardised warmup which was followed by the first round of measurements for ball speed and cervical spine range of motion. Following the initial measurements, the intervention group received chiropractic manipulation via diversified techniques to any restrictions found within the cervical spine. The control group remained rested and received no treatment. A second round of measurements for ball speed and cervical spine range of motion were then taken following the intervention period for both groups. The average speed was determined for each participant and cervical range of motion difference was also noted.

Results: Analysis of the results revealed an increase in the ball speed for both groups. The intervention group showed a larger increase in ball speed with a larger number of participants seeing an improvement as compared to the control group. The control group also noted an increase in ball speed but this was significantly less than that of the intervention group. Similarly, with the range of motion results, the intervention group had a large number of participants seeing an enhancement compared to that of

the control group, with larger differences in the range of motion being observed in the intervention group as compared to the control group.

Conclusion: This study concluded that chiropractic manipulation was effective in providing an immediate increase in hitting speed in league squash players and shows that it could be used in a sporting environment to help enhance performance.

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CHAPTER 1 – INTRODUCTION

1.1 Introduction

When playing a fast-paced close quarters game like squash, ball speed can play a significant role in winning points by reducing the time players have to return the ball or playing it to the back of the court quickly to gain a positional advantage. Although the entire body is involved in playing squash, a powerful shot comes from well-coordinated interactions between the trunk, cervical spine and shoulder. The kinematic chain of a forehand drive involves the cervical spine, thoracic spine, shoulder, elbow and wrist (Elliott, Marshall & Noffal,1996). Any dysfunction along the kinematic chain may lead to a reduction in power and therefore decrease the potential velocity of a ball.

Chiropractic manipulations are thought to be able to restore normal biomechanical movement to dysfunctional motion segments. Some immediate effects seen include joint range of motion increases, pain reduction, increased blood flow, increased muscle strength and reduced muscle tension (Yeoman, 2001). In theory, these factors could have an impact on a squash players' hitting speed, as range of motion, muscle strength, blood flow and muscle tension could have an impact on the normal biomechanical swing of a player.

1.2 Aim of the Study

The aim of this study was to determine the effectiveness of chiropractic manipulation on the hitting speed of a squash ball in competitive squash players and to determine if it could be beneficial in increasing the ball speed post hit in the squash forehand drive.

1.3 Benefits of the Study

The benefit of this study was to determine whether chiropractic could impact a squash players game, thereby possibly influencing the preparation taken before important squash matches. Not only this, but it could also show the effects of chiropractic manipulation before a sporting event, especially in the squash community and possibly how the use of it may enhance performance before major matches.

CHAPTER 2 - LITERATURE REVIEW

2.1 Introduction

Squash is a fast-paced close quarters game that requires skill, speed and fitness. In a game of squash, the ball could reach speeds of around 273 kilometers per hour (km/hr) in the matches of elite squash players (BBC, 2006). In order to attain a high-speed squash forehand drive, there needs to be a coordinated movement that occurs between the neck, trunk and upper limb without any disruptions along its kinematic chain (Elliott et al., 1996). Disturbances of the upper kinematic chain could alter the overall strength of the upper limb and the more dysfunctional the joints are in the kinematic chain, the weaker it would be and the harder the muscles would have to work (Charschan, 1998). With proper utilisation of the kinematic chain, maximal force could develop in the core, which is considered to be the most proximal component of the kinematic chain, and would be able to efficiently transfer to the arm, but for this to happen there needs to be optimal muscle flexibility, strength, proprioception and endurance, thus allowing a task to be performed at maximum force. When looking at restoring a kinematic chain, the core, plays a vital role in the development and transfer of energy, and must therefore be looked at initially (Sciascia & Cromwell, 2012).

2.2 Anatomy

2.2.1 Cervical spine anatomy

There are seven vertebrae (Figure 2.1) that make up the cervical spine, of those seven there are three atypical vertebrae, being C1, C2 and C7. Together the articulation of the seven vertebrae work in an open kinematic chain with the segments above and below, being the skull and thoracic spine. Due to the structure of the cervical vertebrae and the large intervertebral disc height the cervical spine has a large range of motion (Moore, Dalley & Agur, 2014).

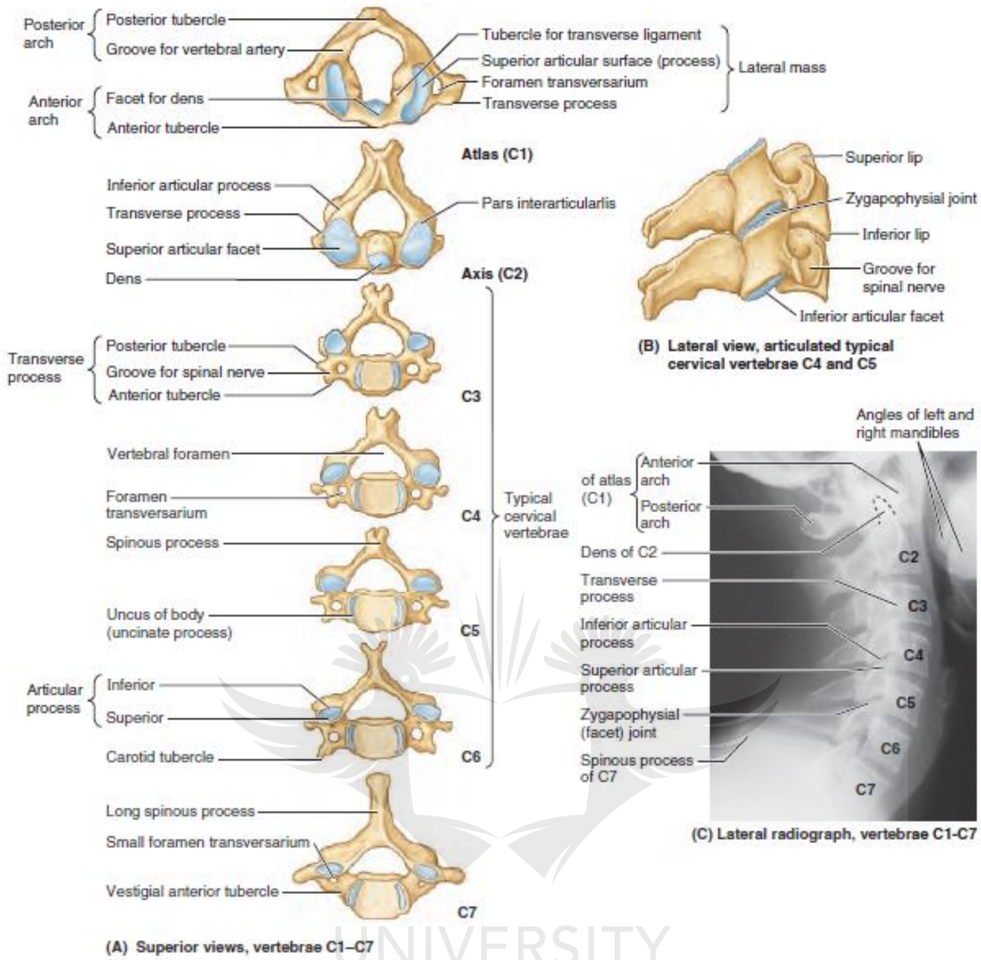


Figure 2.1: Cervical spine anatomy (Moore et al., 2014)

Of the entire vertebral column, the cervical spine vertebrae are among the smallest. The cervical spine has a lordotic curve that is created through the interlinking of the intervertebral discs, spinal laminae and articular processes of adjacent vertebrae (Moore et al, 2014).

Typical vertebrae consist of several components: a vertebral body, a vertebral arch and then seven processes which are the two superior articular processes, two inferior articular processes, two transverse processes and one spinal process. There is a gradual increase in size of the vertebral bodies from superior to inferior. The vertebral canal, otherwise known as the spinal canal, contains the spinal cord and is made up of the vertebral arch and the posterior aspect of the vertebral body. A large portion of the arch is created by the lamina, which is a bilateral and flat bony structure. The arch is also made up of bilateral pedicles which are responsible for connecting the arch to the vertebral body (Waxenbaum & Futterman, 2018).

The superior and inferior articular processes previously mentioned, articulate with the adjacent superior and inferior articular processes respectively, creating a facet joint, also known as a zygapophyseal joint. The facet joints are responsible for various important functions of the spine, such as maintaining alignment, controlling range of motion and bearing weight in certain positions. The articulation happens with the superior articular processes of the inferior segment with the inferior articular process of the superior segment. The orientation of the superior and inferior articular facets changes depending on what region of the spine one is looking at. In the cervical spine the orientation of these facets directs them superoposteriorly while the inferior facets are directed more in an infero-anterior orientation (Jaumard, Welch & Winkelstein, 2011).

The two lateral projections from the vertebral arch are the transverse processes, they project in a similar fashion on either side of vertebrae. In the cervical spine, the transverse processes each contain one foramen within them. These foramina encircle the vertebral arteries and veins, barring the foramina on the 7^{th} vertebra, which only contains small accessory veins (Waxenbaum & Futterman, 2018).

Finally, the spinous process extends posteriorly, and depending on the level, may also project inferiorly from the vertebral arch. In the cervical spine there is a unique feature of the spinous processes as they are bifid in shape. This can be seen from vertebrae 2 to 6. Vertebrae 3 to 6 are bifid and have short spinous processes. The thought behind the bifid vertebrae is that they may serve to increase the surface area for muscle attachments of cervical muscles. As one descends the cervical vertebrae, it can be noted that the spinous processes increase in size, up to the point where the 7th cervical vertebrae is long and known as the vertebra prominens (Bogduk, 2016).

There are 3 atypical vertebrae in the cervical spine. C1 is the first unique one and is also commonly known as the atlas. The atlas, as seen in figure 2.1, does not have a vertebral body nor a spinous process. Instead, replacing the body, are two lateral masses that are kidney shaped and concave in shape and face superiorly. These lateral masses bare the weight of the head as they articulate with the occipital condyles (Moore et al., 2014). The atlas has a modified lamina on the posterior arch, which is grooved on the superior surface to allow the vertebral arteries to pass through as they enter the foramen magnum. The atlas appears as a ring in shape and because of the lack of the vertebral body and location of the lateral masses, most of the flexion and extension in the cervical spine occurs at the atlanto-occipital joint. These masses are responsible for carrying the load the body of the vertebrae would usually carry. Each mass articulates with one occipital condyle, which is found on the skull. The inferior facets articulate with the superior facets of C2, which is commonly known as the axis (Bogduk, 2016).

The axis is the 2nd atypical vertebra and is distinct and could be recognised easily because of its odontoid process, labelled in figure 2.1 above, also referred to as the dens, located on the superior aspect of the body. The dens articulates with the posterior surface of the arch of the atlas and acts as an axis that C1 rotates around. C2 is considered to be the strongest cervical vertebra of them all. Another feature distinct to C2 are the 2 bilateral masses that articulate with the atlas, through this, weight can be distributed through C3 and lower (Waxenbaum & Futterman, 2018).

Lastly, C7 could be considered typical or atypical. The reasoning behind this is that unlike the other cervical vertebrae, C7 does not have the vertebral artery running through the transverse foramen. The second reason is that C7 has a long spinous process (Waxenbaum & Futterman, 2018).

2.2.2 Intervertebral discs

Intervertebral discs are part of the intervertebral joint. These discs consist of two parts, the annulus fibrosis and the nucleus pulposus. The annulus fibrosis is made up of concentric layers of fibrocartilage and forms the circumference of the intervertebral discs. The annuli attach to the epiphyseal rings on the vertebral bodies. The concentric layers of collagen fibres are known as lamellae. The orientation of these fibres alternates between each layer, limiting the rotation between adjacent vertebrae. As the annulus moves more centrally, the vascularity of it decreases and only the outer 3rd of the annulus has sensory innervation (Raj, 2008).

The nucleus pulposus is a gel like mass found at the centre or core of the intervertebral disc. It is mostly comprised of water and proteoglycans thus permitting the flexibility and resilience of the intervertebral disc as well as the dissipation of vector forces making it essentially a shock absorber as well. During movements, and depending on the type of movement, the nuclei can be compressed or stretched or a combination of both during certain movements. The nucleus pulposus receives nutrition via diffusion from blood vessels at the periphery of the annulus fibrosis and vertebral body as it is avascular (Raj, 2008).

2.2.3 Spinal nerves

There are 31 pairs of spinal nerves that are broken down as follows: 8 cervical, 12 thoracic, 5 lumbar and one coccygeal (Nógrádi & Vrbová, 2013). These nerves are formed from the joining of a posterior spinal root, which is sensory, and an anterior spinal root that is motor. The anterior nerve root consists mostly of motor fibres that pass from nerve cell bodies to effector organs located at the periphery via the anterior horn of the spinal cord grey matter. The posterior nerve root contains mostly sensory fibres from the cell bodies in the spinal or posterior root ganglion. These extend to sensory endings peripherally and to the posterior horn in the grey matter of the spinal cord centrally. Each of these spinal nerve roots join at an intervertebral foramen. From that point the nerve divides creating an anterior and posterior ramus. These mixed spinal nerves now carry both sensory and motor fibres as they split after both roots joined creating that posterior and anterior ramus. Most of the ganglia are located within the intervertebral foramen, however, cranial nerves 1 and 2 are located on the vertebral arches of C1 and C2 (Moore et al., 2014).

Normal spinal nerves are made up of visceral and somatic fibres. The somatic fibres then contain efferent and afferent fibres. The function of the somatic efferent fibres is to innervate skeletal muscle, whilst the somatic afferent fibres carry impulses from receptor joints, tendons, ligaments, muscles, the skin and subcutaneous tissue to the spinal cord. The visceral component of spinal nerves is again a combination of efferent and afferent fibres, but this time they are autonomic fibres (Ellis, 2009).

2.3 Chiropractic in Sports

Chiropractic appears to have several proposed roles in sport (Stump, 2001). One of which is, by correcting the deficiencies found on examination, an athlete could improve their performance and reduce their frustration levels, when the cause of their decreased performance is unclear (Kelsick, 2010).

A study done on the utilisation of chiropractic care at the World Games in 2013, showed 537 of 2964 accredited athletes and 401 of 4131 accredited non-athletes utilised the chiropractic services provided. Various regions were treated through various methods but there was an overall reduction of pain in 86.9% of the patients following treatment (Nook, Nook & Nook, 2016).

Another study, done to determine the use and roles of chiropractors within the National Football League (NFL) showed that chiropractors played a significant role with treating lower back pain and musculoskeletal injuries. A notable number of NFL trainers have cooperative relationships with chiropractors. Currently, 31% of the NFL teams having a chiropractor as a permanent staff member and a further 12% referring players to chiropractors but do not have their own (Stump & Redwood, 2002).

Other research, conducted to determine the effect that chiropractic treatment has on athletic ability and musculoskeletal performance has revealed increased athletic ability in golf club head speed (Sery, Losco & Pritchard, 2005), tennis serving speed (Palmer & Moodley, 2011) and cricket bowling speed (Levine, Moodley & Smilkstein, 2017).

When looking at the squash ball speed, there is a notably greater average ball speed seen in club squash players that win to those that lose (Hughes & Franks, 1994). Squash is also a very tactical game where movement to and from the "T" area of the court plays an important role in winning. This is because it gives the player an advantageous position and positions them for a wider shot selection to potentially win the rally (Vučković, Perš, James & Hughes, 2009).

Chiropractic focuses on the correction of pathomechanical faults within the spine and extremity joints, thereby restoring normal joint biomechanics and neurology. In doing so there would be a reduction in pain as well as the severity of the injury, potentially leading to an increase in an athlete's performance (Nook & Nook, 1997).

2.4 The Effects of Chiropractic Manipulation on Athletic Performance

It was postulated that the main objective of a chiropractic manipulation is to restore a joint to normal pain-free motion, allowing motor control and coordination to be in a state of postural balance. By doing so it allows an athlete to perform at the highest possible level (Prokop & Wieting, 1996).

In elite athletes, a 30 minute chiropractic session with manipulations has been shown to increase lower limb strength. This was found after just one session of spinal manipulation of dysfunctional spinal and pelvic joints. Spinal manipulation was shown to increase cortical drive, which persisted for about 60 minutes following the manipulation (Christiansen, Niazi, Holt, Nedergaard, Duehr, Allen & Haavik, 2018).

The effect of chiropractic manipulation could be used in various sports. In a study on elite judo athletes, grip strength was tested before and after chiropractic spinal manipulation was delivered. In the results, it was found that there was a significant increase in grip strength of those that had chiropractic manipulations compared to those that got a false intervention. It was also found that the subjects in the manipulation group, received an increase in grip strength as the amount of interventions increased (Botelho & Andrade, 2012).

An investigative study was done in 2009 to check the effect of spinal manipulation therapy with stretching compared with stretching alone in golfers' full swing performance. The spinal manipulation therapy group were assessed for any dysfunctions in the lower-back, thoracic and cervical areas, with any dysfunctions found being treated. The result showed a statistically significant difference between the 2 groups, with a decrease in performance in the stretching group alone, confirming the influence of spinal manipulation therapy in athletic golfers (Costa, Chibana, Giavarotti, Compagnoni, Shiono, Satie & Bracher, 2009).

The effect of chiropractic care in asymptomatic athletes' physical performance, found there to be an improvement in all 11 of the tests that were performed by a greater margin than the control group. The control group in the study had minor improvement in 8 of the 11 tests performed. Within the first 6 weeks, the control group exhibited an improvement of less than 1% in the reaction speed test of the hand in response to a visual stimulus, while the chiropractic group showed an improvement of more than 18% in the same time frame (Lauro & Mouch, 1991).

2.5 The Strength Velocity Principle

The strength velocity principle is an inverse curve that describes the relationship between force and velocity. Essentially, it states that exercises that produce a high level of force, would be done at a low velocity and exercises that have a quick velocity would produce relatively low amounts of force (Walker, 2016).

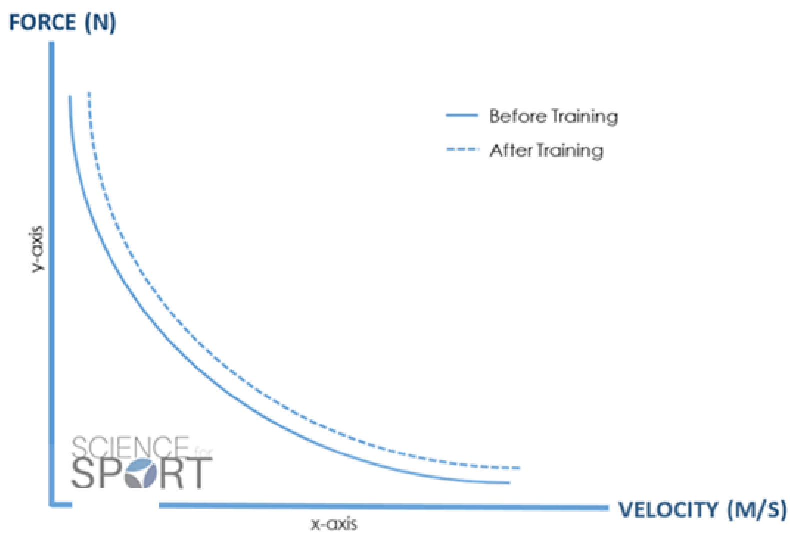


Figure 2.2: The force velocity relationship curve after an effective training programme (Walker, 2016).

When looking at the relationship of this curve to racket sports such as squash or tennis, it is seen that both components are utilised in the sports. In the racket sports having a high maximum strength allows for absorption of high forces as well as the generation of high forces. This is seen especially when decelerating to a shot or accelerating in a burst to run, whereas the serves and ground strokes require large levels of speed at low levels of force (Walker, 2016).

The aim of athletes that compete is to train in exercises that would cause the graph to shift in a manner that would allow the athlete to access the same force at a greater velocity as seen in figure 2.2, allowing them to compete at a higher athletic level. This, however, requires the athlete to train both in power (strength) as well as speed (velocity) allowing the athlete to become more explosive in their sport and to muster greater force in a shorter amount of time (Walker, 2016).

2.6. Chiropractic Manipulation on Muscle Strength

Chiropractic has been seen to have influences on muscle strength through various studies. Chiropractic manipulation has been shown to alter central sensory motor integration, the relationship between the sensory and motor system, as well as the motor cortical drive to voluntary muscles of both the upper and lower limbs (Haavik, Özyurt, Niazi, Holt, Nedergaard, Yilmaz & Türker, 2018).

Cervical spine manipulation has also been shown to immediately increase the biceps brachii muscles resting electromyographic activity. The high velocity low amplitude manipulation was done at the level of C5/6 to the facet joint, to both the right and left biceps. Irrespective of whether a cavitation was present or not, there was an increase in the resting motor activity in both biceps (Dunning & Rushton, 2009).

It has also been reported that subjects with muscle imbalances in the lower limb attain an increase in muscle strength in their weak leg hip abductors. A single lumbar spinal manipulation was able to decrease a relative strength difference between limbs. This could be beneficial both for older people with functional impairments and even for high performance athletes (Chilibeck, Cornish, Schulte, Jantz, Magnus, Schwanbeck & Juurlink, 2011).

2.7 The Biomechanical Analysis of the Forehand Drive

The forehand drive is the shot the players were required to play for this study. It consists of 5 phases: the preliminary movement, the backswing, the force producing movement, the critical instant and finally the follow through movement (Bacon, 2003).

During the preliminary movements the player is positioned at the “T” awaiting the ball as their opponent plays their shot. Once the shot has been played the player quickly moves into a suitable position to play the ball. This could be achieved by a split-step or stab-step in the direction of the ball and the player then stands ready to enter the backswing phase (Bacon, 2003).

The backswing phase is initiated by rotation of the upper body and hips towards the back-right corner of the court. The racket follows the rotation of the upper body and is held high above the head, whilst the knees bend and the non-racket hand points to the front or side wall (Machar, Elliott & Crespo, 2013).

The force producing movement occurs as the player steps towards the ball with their front foot, swinging the racket so that the contact between the ball and racket occurs on the inside of the front foot. The swing starts as the legs push against the ground followed by rotation of the hips, trunk, shoulder, arm and wrist (Machar, Elliott & Crespo, 2013).

The critical instant is the moment the ball leaves the racket and is the point where the arm is fully extended (Bacon, 2003).

The follow through movements are as the player pushes back off the leading front foot and begins to move back towards the centre of the squash court (“T”) to prepare for the opponents next shot (Machar, Elliott & Crespo, 2013).

2.8 Muscles Involved in the Production of a Full Forehand Swing

The average squash shot has become more forceful, requiring a better transference of forces from the lower body to the upper body. This is achieved through a sequence of well-coordinated muscle actions. There are several muscles that have been noted in creating this effect and allowing for good performance while protecting joints during each shot, working together to provide an optimal swing as well as providing the necessary stability that is needed. The muscles involved include the trapezius, posterior and anterior deltoid muscle, triceps brachii, biceps brachii, flexor carpi radialis, extensor carpi radialis, pectoralis major, serratus anterior, rectus abdominis, external abdominal muscle, gluteus maximus, gluteus medius, biceps femoris, rectus femoris, tibialis anterior, gastrocnemius and soleus (Alaaeldien & Akl, 2016) (which can be seen in Figure 2.3). Appendix M provides the anatomy of these muscles, and includes their origin, insertion, function and innervation.

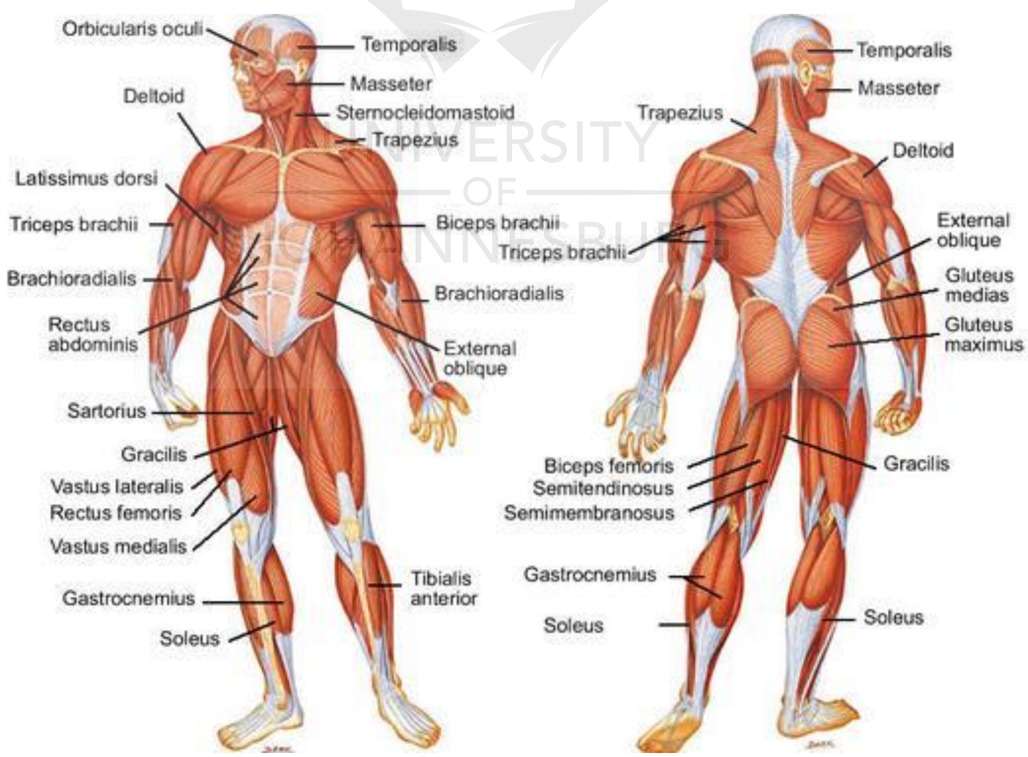


Figure 2.3: Muscles used during a squash shot (HSC PDHPE, 2019)

2.9 The Chiropractic Vertebral Subluxation Complex

The subluxation is a hotly debated term used by chiropractors. However, the principle and notion of the word is central to chiropractic by the fact that there is an articular lesion that chiropractors are able to treat (Gatterman & Meridel, 2009).

The subluxation complex is a theoretical model that describes the widespread effects of subluxations. This model is of motion segment dysfunction that includes the complex interaction of pathologic changes in nerve, muscle, ligamentous, vascular and connective tissues. Further, a chiropractic subluxation/restriction is commonly defined as a motion segment in which alignment, movement integrity and physiologic function has been altered, even though the contact between the joints remains intact. There are then manipulable subluxations/restrictions, which are dysfunctional segments that, through the use of manual thrust procedures, altered alignment, movement or function could be improved. It is also important to improve practitioner's treatment and diagnostic abilities and develop a full understanding on biomechanics (Senzon, 2018).

The vertebral subluxation complex is, as previously mentioned, a theoretical model that is not a definite entity but rather, it only exists when all the components that form it are present. The pathologies that are incorporated into this model are those that are related to anatomy, physiology, biochemistry and biomechanics. These few pathologies may then lead to various other symptoms such as autonomic dysfunction, visceral dysfunction and pain. The theoretical model is made up of 5 components: neuropathophysiology, kinesiopathology, myopathology, histopathology, and biochemical pathology. These components each separately represent a pathophysiological process contributing to dysfunction, but also interact with each other and not solely independently (Gatterman & Meridel, 2009).

Neuropathophysiology describes the neurological pathology of the vertebral subluxation complex. It looks at neurological components that could affect the subluxation complex such as hypertonia, muscular atrophy and dysaesthesia (Gatterman, 2005).

Kineosiopathophysiology refers to altered movements of the vertebral subluxation complex, leading to or resulting in hyper or hypomobility of a joint motion segment and in the joint play of that same segment. The result of altered movement may lead to the redistribution of mechanical stresses to various other structures like intervertebral discs, other articular surfaces, muscles and ligaments (Gatterman, 2005).

Myopathology refers to the change in muscle tone, like hypertonicity for example. This may be as a result of the compensatory mechanism of altered movement or due to a secondary mechanism from a neuropathological component (Gatterman, 2005).

Histopathology refers to the process of inflammation and the cellular response to it. Inflammation brings in inflammatory cells and fluids which in turn may lead to an oedema which may have the potential to compress neural structures, resulting in neurophysiological side effects (Haschek, Rousseaux, & Wallig, 2013).

Biochemical pathology refers to the accumulation of chemicals and inflammatory mediators in stressed or otherwise damaged tissues. These can include things such as prostaglandins, bradykinin, histamine and more (Haschek, Rousseaux, & Wallig, 2013).

2.10 Chiropractic Manipulation

The definition of a chiropractic manipulation is the administering of a high velocity, low amplitude thrust to a joint, with the aim of moving it beyond the physiological limit and into the paraphysiological space whilst staying within the anatomical integrity limits, which could produce an audible release. Chiropractic manipulative therapy is thought to reduce or correct chiropractic restrictions that are affecting normal biomechanical movement of a joint motion segment (Gatterman, 2005).

The chiropractic restriction is an entity that may have an effect on biomechanical and neural integrity. The basis of chiropractic treatment is that, through the use of chiropractic manipulative therapy, this dysfunctional entity may be corrected or at least reduce the severity of the dysfunction or restriction, and therefore improve the negative biomechanical and neurophysiological effects the restriction has on the body; as well as aiming to restore postural balance, through the corrections of restricted motion segments (Miners, 2010). Palpatory procedures are used to assess these joint dysfunctions. A smooth motion with an end feeling of play or spring is considered to be a normal joint range of motion. The term restriction or abnormal joint motion is given to joints that stop before the expected range of motion or have a hard end feel during motion palpation (Vernon & Mrozek, 2005).

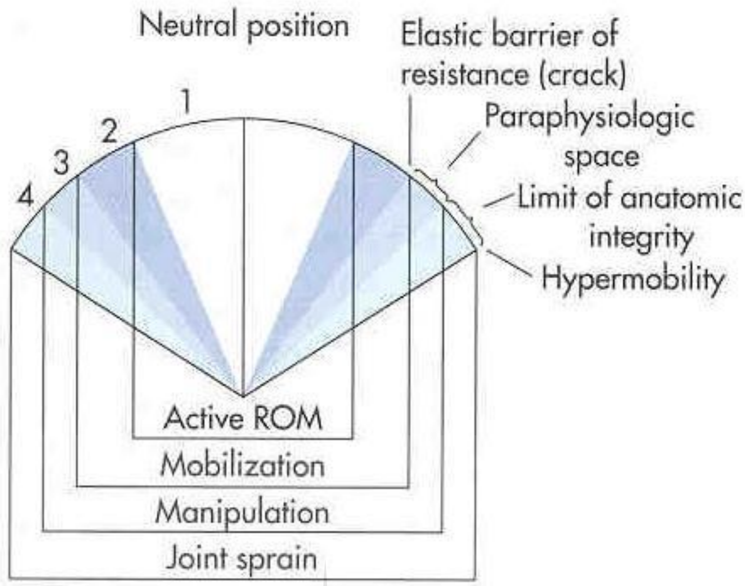


Figure 2.4: Sandoz chart (Gatterman, 2005)

According to the Sandoz chart, figure 2.4, diarthrodial joints have 4 stages through the range of movement. The chart identifies several phases of a joint's complete motion (Vernon & Mrozek, 2005).

The 1st stage describes the active range of motion, being the motion that can voluntarily be produced by a person, through the use of muscular action. The 2nd stage is that of passive range of motion. This is movement that is produced passively by an external agent or force, that being from themselves or a therapist. It is the motion that occurs between the end of active range of motion and up to the elastic barrier of resistance. It is commonly seen during mobilization of the joint. The 3rd stage is a space that is present beyond the elastic barrier, or past the passive range of motion, yet does not exceed the anatomical barrier. It is the zone or stage in which the chiropractic manipulation occurs. The anatomical barrier is the limit to any movement of a joint. The 4th stage is when movement occurs past the anatomical barrier, it is described as pathological motion and is therefore motion beyond the anatomical integrity. This causes damage to soft tissue constraints. Joint sprains, medical subluxations and strains occur in this stage (Vernon & Mrozek, 2005).

2.11 The Effect of the Chiropractic Manipulation

The chiropractic manipulation is said to have an effect on the altered segments' biomechanics. This may be through the releasing of trapped meniscoids, releasing adhesions or even by reducing annulus fibrosis deformation (Pickar & Wheeler, 2001). It also has a relaxation effect on the hypertonic muscles around the region of the treatment area as well as elicits a reflex response that is not necessarily localised to the region, affecting locations that are more remote from the actual treatment site (Herzog, 2010). Herzog stated that scar tissues and adhesions within joints would also be broken, which could account for the changes in the motion segments.

It is proposed that there is an activation of mechanoreceptors in zygapophyseal joint capsules, spinal ligaments, intervertebral discs, cutaneous receptors, muscles spindles and Golgi tendon organs within associated muscle bellies and tendons following high velocity low amplitude thrusts. It is thought that, following the chiropractic manipulation, there is a change in afferent input due to the receptor's stimulation, as well as causing a change in the alpha motor neuron excitability levels, with a change in the muscle activity (Dunning & Rushton, 2009).

By correcting the biomechanics through chiropractic manipulation, there is a resultant reduction in the inflammatory exudates and mechanical stresses present on a joint. This results in a decrease in pain experienced as well as increasing the referred joint's mobility. Although it could reduce pain and inflammation in a joint, chiropractic manipulation is not able to undo any damage that has already been done to the joint and the surrounding tissues (Huiskes & Mow, 2005).

2.12 Chapter Overview

Squash is a high impact sport that requires a fully functional spine allowing each segment in the biomechanical chain to freely move in order to bring about coordinated movement, promoting high speed squash shots in order to beat the opponent (Elliot et al., 1996).

Any disruption that occurs within the biomechanical chain could disrupt the potential for playing a powerful forehand drive (Charschan, 1998). This dysfunction may lead to a decrease in the efficiency of movement during the shot or decrease the muscle strength needed for the shot (Gatterman, 2005)

A dysfunctional spinal segment leads to altered distribution of mechanical stresses on joints and surrounding muscles (Gatterman, 2005). In the correction of these dysfunctional segments through chiropractic manipulation, range of motion, muscle strength and athletic ability may all be improved. Chiropractic manipulation is also seen to have immediate positive effects on athlete's muscle strength (Christiansen et al., 2018). Chiropractic treatment given to squash players should therefore see similar results immediately on their hitting speed following chiropractic manipulation.

CHAPTER 3 - METHODOLOGY

3.1 Introduction

This chapter discusses the methods and materials that were used in this study. It also describes the methods used to collect data, the subjects involved in the study, the tools and instruments that were used in the data collection process as well as the statistical analysis of the data. This study aimed to determine the immediate effects of chiropractic spinal manipulation on the hitting speed of squash players. Figure 3.1 presents a flow chart of the procedure used in this study.

3.2 Method of Research Used

The data was collected by the researcher using a Jugs Pro-Sport Radar gun, which is an American product used to measure ball speeds, and a cervical spine range of motion device (CROM device).

The data analysis

The analysis included descriptive statistics. The Kolmogorov-Smirnov Test was used to check the normality of the variables.

The intra-group analysis used Wilcoxon Signed Rank Tests to check statistically significant changes between two-time periods depending on the outcome of the normality test (Pallant, 2013).

The inter-group analysis used Mann-Whitney U-Tests to check statistically significant differences between the two groups depending on the outcome of the normality test (Pallant, 2013).

The data was analysed by the researcher with the assistance of the University of Johannesburg's STATKON and was interpreted by the researcher.

3.3 Participants

For this study, 100 participants were recruited. The participants fell within the age range of 35 to 65 and were a player in at least 1 of the 9 squash leagues for a club. Both genders were accepted in this study and the majority of the participants were made up of Modderfontein Squash Club and Bryanston Squash Club players.

3.3.1 Participant recruitment

Participants were recruited via advertisements (appendix A) which were placed at various squash clubs in central Gauteng (appendix B) and around the University of Johannesburg's Doornfontein and Auckland Park campuses. Participants were also recruited via word of mouth.

Participants were screened prior to the testing phase of the study by taking a full case history and assessing this against the inclusion and exclusion criteria in order to ensure consistency and that the criteria was met.

3.4 Sample Selection

Once the participant had satisfied all the inclusion criteria, they were able to participate in the study. The participants were asked to read the information letter (appendix C) and then sign the consent form (appendix D) prior to participating in the study, thereby acknowledging that they agreed to the procedure and were aware of any risks involved with the study. The player's skill level was determined if they were in a team for one of the squash leagues.

In order to ensure that the selection of the 2 groups was randomised, each participant was asked to draw a piece of paper from a black hat that contained 100 pieces of paper, 50 with the number 1 written on it and 50 with the number 2 written on it. The participants that drew the number one were allocated to the control group (group A) whilst the others that drew number 2 were allocated to the intervention group (group B).

3.5 Data Collection Procedure

Research sessions were held at Modderfontein Squash Club (appendix H) and were overseen by Dr. Gareth Hardie. The session consisted of a patient history, a physical assessment and a cervical spine regional assessment to eliminate any contra-indications to chiropractic manipulation (appendix E). These tests were all performed prior to the start of the trial and the findings and treatments were all recorded on a Subjective Objective and Examination Assessment Plan (SOAP) note. Participants were given a standardized 5-minute warm up with the warmup ball, after they completed their warmup, their cervical spine range of motion was measured and recorded (appendix F).

The warm up each participant was required to perform consisted of 1 minute of light jogging from the back wall to the front wall and back, repeating that for an entire minute followed by high knee pick up running for 30 seconds, followed by heel to bum running for 30 seconds. They were then given a warm up ball to play forehand drives down the wall to get their eye in and warm up for the shot for the remaining 3 minutes.

Once their range of motion had been recorded, the participant stood in a demarcated zone on the court, which was at the “T”. This was done in order to standardise the hitting distance for participants. They then proceeded to hit 10 cold double yellow dot squash balls once each towards the glass back wall. The researcher stood with the Doppler radar gun on the other side of the glass and recorded the speed of each ball. Once all 10 balls had been hit, the initial data was recorded on the initial data sheet (appendix G1). The participants then had a 5-minute period between the 1st and 2nd phase of testing. For the control group, the 5-minute period entailed them resting on a seat for the entire period. For the intervention group, the 5-minute period was used to motion palpate for any chiropractic restrictions within the cervical and thoracic spine. Chiropractic manipulations were delivered to the restrictions found during motion palpation. At the end of the 5-minute period, both groups, control and intervention, had their cervical spine range of motion rechecked (appendix F) before proceeding to repeat the test of hitting the 10 cold squash balls towards the glass back wall, while the researcher stood on the other side of the glass recording each ball’s speed with the Doppler radar gun and record them on the final data sheet (appendix G2).

At the end of each testing phase, the 10 recorded ball speed values were added and divided by 10 to give an average speed before and after the 5-minute period.

3.6 Inclusion Criteria

Participants were included if:

- They were male or female between the ages of 30 and 65 years that play league squash.

- They were active league players for a squash club in any of the 9 leagues, thereby meeting the skill criterion.
- They had at least one cervical or thoracic spine restriction which was confirmed by chiropractic motion palpation of the cervical and thoracic spine.

3.7 Exclusion Criteria

Participants were excluded if:

- There were any contra-indications to chiropractic manipulation (appendix E).
- They had any injuries to their cervical or thoracic spine, shoulders, elbow or wrist which prohibited a normal forehand shot.
- They had not played league squash in the last 2 years.
- They were unable to play the forehand drive shot.

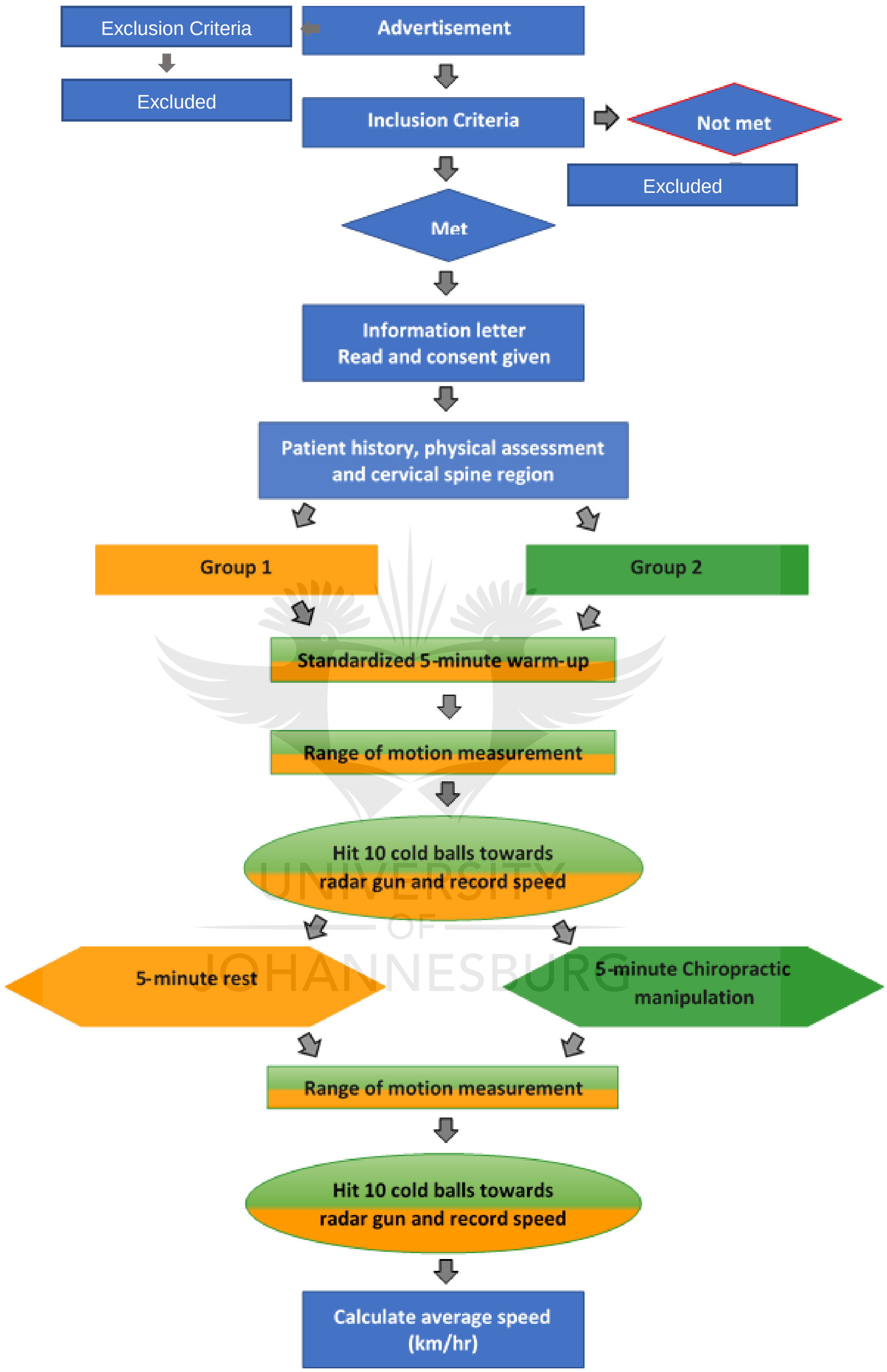


Figure 3.1: A flow chart of the procedure during trials

3.8 Research Materials

The materials that were used during the trial phase of this study were: 10 new black Dunlop Pro double yellow dot balls, a Cervical Spine Range of Motion device (CROM), a squash racket, a Doppler radar gun and the Modderfontein squash courts.

3.8.1 Radar gun

A Jugs Pro-Sport Radar Gun (Figure 3.2) was used to measure the ball speed in this study. The Jugs Pro-Sport Radar Gun is a Doppler radar unit that has the option of being mounted, hand held or static. It measures the speed of the object it is pointed at by detecting the change in the frequency of the returned radar signal caused by the Doppler Effect (Erkel, 2007). A trained professional was present to operate the radar gun ensuring the data captured was reliable and consistent.

The speed is taken using the frequency difference between the reflected signal and the transmitted signal, which is related to the relative speed of the ball and the radar. When there is an increase in the frequency of the reflected signal, it means the object is approaching. When there is a decrease in the frequency, it means the object is receding. Since the best possible position to get the most accurate reading, is at the receiving end of the ball and in the centre line (Robinson & Robinson, 2016) the researcher took measurements from behind the glass at the back of the court while the participant hit towards the radar gun in the centre line.

Figure 3.2: Jugs pro-sport radar gun (Amazon.com. 2019)

3.8.2 Squash Balls

The squash balls (Figure 3.3) that were used comply with the Professional Association of Squash's (PSA) standards according to the PSA World Tour's official website. The double yellow dot balls are used at a professional level in competitions as well as at a good club level (Psaworldtour.com. 2019)

Figure 3.3: Dunlop pro double yellow dot balls (Squashpoint, 2019)

3.8.3 Cervical spine range of motion

For measuring the cervical spine range of motion, a CROM device was used (Figure 3.4). This device has been used in numerous published studies proving it to be reliable and providing valid results thus showing it to be clinimetrically sound (Williams, McCarthy, Chorti, Cooke & Gates, 2010). The device was positioned on the participant’s heads. It was aligned to the bridge of the nose and ears while the Velcro strap secured it in position on the head. The movements of flexion, extension and lateral flexion to both sides were performed, and the data recorded from the meter values. Lateral flexion was recorded from the coronal plane meter and flexion and extension from the sagittal plane meter. The rotational component was used for the coronal meter to find the amount of rotational movement. To do so, a magnetic yoke was placed on the participants’ shoulders ensuring an accurate reading by zeroing the coronal meter as an initial baseline before movement occurred (Paton & Bester, 2012).

Figure 3.4: CROM device used to measure the cervical spine range of motion (Williams, Williamson, Gates & Cooke, 2011)

3.9 Chiropractic Manipulative Therapy

Standard diversified chiropractic techniques were performed on the dysfunctional segments/restrictions. The dysfunctional segments were identified through the use of specific orthopedic, neurological and chiropractic techniques. They were noted in the SOAP notes before any treatment occurred. Throughout the study, several chiropractic manipulative techniques were used in the treatment of the dysfunctional segments, the techniques selected were patient dependent.

The following techniques were used during the study:

- Lateral Atlas Pisiform – Used for lateral atlas restrictions
- Cervical Break – Used for lateral and rotational restrictions from the levels of C2-C7
- Reverse Thumb Movement – Used for lateral, rotational and lateral flexion restrictions from spinal levels C5-T3
- Anterior Thoracic Technique – Used for anterior or posterior restrictions of the thoracic spine, levels T1-T12
- Phalangeo-Metacarpal Technique – Used for posterior, rotational restrictions in the thoracic spine from levels T1-T12

CHAPTER 4 - RESULTS

4.1 Introduction

At the end of the trials, Data collected from 100 participants (control n=50; chiropractic manipulation n=50) comprised of 2 sets, the first was pre and post ball speed, the second was on the cervical spine range of motion. The ball speeds were measured in kilometers per hour whilst the range of motion was measured in degrees. All measurements were done for both groups of participants, with the only difference between the groups being the chiropractic manipulations that the intervention group (group B) received. Group A was assigned as the control group and did not receive any intervention during the study. This chapter will discuss and explain the data that was collected throughout the study.

4.2 Demographic Data

Both males and females were able to participate, providing they met the inclusion criteria and importantly were active league squash players.

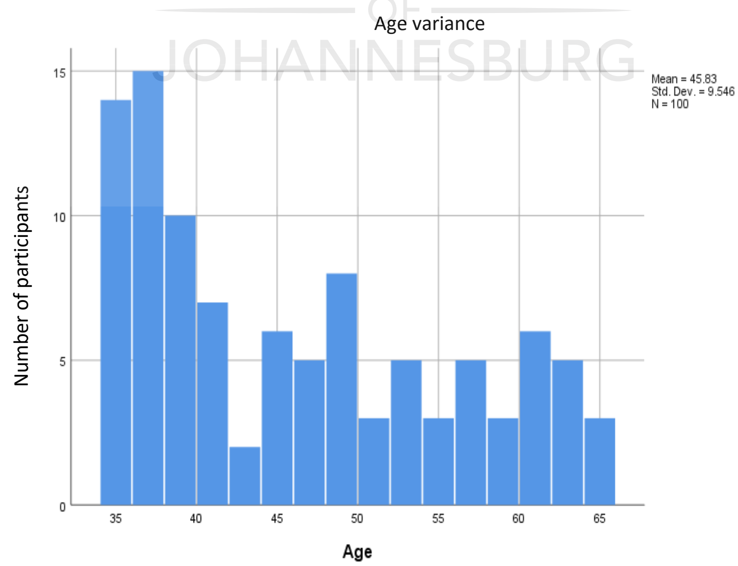


Figure 4.1: Histogram of the age variation of the participants

Figure 4.1 is a histogram that shows the distribution of age of the 100 participants that took part in the study. The vast majority of participants fell between the ages of 35-40. The average age of the participants was 45.83 years and of the 100 participants, 82% were male and 18% female.

Age and gender did not have much statistical relevance to the study as all the measurements taken were compared to their own readings and no other participant's readings.

Table 4.1 Kolmogorov-Smirnov test for normality in age

Tests for normality - Age			
	Kolmogorov-Smirnov		
	Statistic	df	Sig.
Age	0.159	100	0.000

The Kolmogorov-Smirnov test (Table 4.1) was used to determine the normality of age distribution in the study. This test was used as the number of participants was above 50. The significance value (Sig.) or p-value was 0.000, (far-right column) with the level for statistical significance being set at 0.05 indicating that the age distribution is significantly different meaning that the data is not normally distributed. Although this is not of any vital importance for age distribution, it does become more important when looking at the other values taken from the readings and measurements. The column labelled "df" pertains to the number of people used for that test and is seen throughout the rest of the Kolmogorov-Smirnov tests.

4.3 Pre and post ball speed descriptive statistics

When examining the normality of the data distribution for pre and post ball speed, the groups were split into A-Control and B-Intervention groups. For name sake group A will be reviewed first.

Table 4.2a: The descriptive statistics of group A ball speed pre-rest

Group A				
			Statistic	**Standard Error**
Ball Speed Pre	Mean		167.42	3.83
	95% Confidence Interval for Mean	Lower Bound	159.72	
		Upper Bound	175.11	
	Median		169.25	
	Standard Deviation		27.09	
	Minimum		98.40	
	Maximum		243.80	
	Range		145.40	

Table 4.2a shows a summary of the statistics collected for the first round of data collection for the control group. The average speed for all 50 participants was 167.42km/h, with a maximum speed reaching 243.80km/h and a minimum speed of 98.40km/h. The maximum and minimum speeds were taken from the participant with the highest average speed and the participant with the lowest average speed from group A. The 95% confidence interval's lower and upper bound values were 159.72km/h and 175.12km/h respectively.

Table 4.2b: The descriptive statistics of group A ball speed post-rest

Group A				
			Statistic	Standard Error
Ball Speed Post	Mean		169.07	3.81
	95% Confidence Interval for Mean	Lower Bound	161.41	
		Upper Bound	176.72	
	Median		170.85	
	Standard. Deviation		26.95	
	Minimum		96.40	
	Maximum		244.30	
	Range		147.90	

Table 4.2b shows a summary of the statistics collected for the second round of data collection for the control group. The average speed for all 50 participants was 169.07km/h, with a maximum average speed reaching 244.30km/h and an average minimum speed of 96.40km/h. The maximum and minimum speeds were taken from the participant with the highest average speed and the participant with the lowest average speed from group A. The 95% confidence interval's lower and upper bound values were 161.41km/h and 176.72km/h respectively. Both groups showed a low interval range.

Table 4.3a: The descriptive statistics of group B ball speed pre intervention

Group B				
			Statistic	Standard Error
Ball Speed Pre	Mean		167.00	4.43
	95% Confidence Interval for Mean	Lower Bound	158.10	
		Upper Bound	175.90	
	Median		166.35	

	Standard. Deviation	31.31	
	Minimum	97.40	
	Maximum	232.00	
	Range	134.60	

Table 4.3a gives the statistics of the first round of data collection for group B. For this group, the average speed for the first round of shots came to a mean of 167.00km/h with a maximum average speed of 232km/h and a minimum average speed of 97.40km/h. For this group the upper and lower bound values for the 95% confidence interval for the mean were 158.10km/h for the lower and 175.90km/h for the upper.

Table 4.3b: The descriptive statistics of group B ball speed post intervention

Group B				
			Statistic	**Standard Error**
Ball-Speed-Post	Mean		171.83	4.36
	95% Confidence Interval for Mean	Lower Bound	163.08	
		Upper Bound	180.59	
	Median		177.15	
	Standard. Deviation		30.81	
	Minimum		98.70	
	Maximum		237.00	
	Range		138.30	

Table 4.3b shows statistics from group B's second round of results. As seen above the mean value for post-test ball speed was 171.83km/h, with the maximum average speed coming to 237.00km/h and the average minimum ball speed coming to 98.70km/h. The upper and lower bound values for the 95% confidence interval came to 163.09km/h for the lower value and 180.59km/h for the upper value.

4.4 Normality Tests

4.4.1 Pre and post ball speed

Table 4.4: Kolmogorov-Smirnov Test results

Tests of Normality for group A						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Ball Speed Pre	0.086	50	0.200*	0.985	50	0.756
Ball Speed Post	0.085	50	0.200*	0.985	50	0.753

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

In the normality tests for pre and post ball speed, the Kolmogorov-Smirnov Test was performed (table 4.4) in order to determine if the data was normally distributed for ball speed. The Kolmogorov-Smirnov Test compares the observed values with a normal distribution, with the mean and standard deviation, giving a p-value. This p-value then determines whether the data has a normal distribution or not.

The value showing statistical significance was set to 0.05. Table 4.4 above shows a p-value of 0.200 ($p > 0.05$) for both the pre and post ball speeds indicating that the data was normally distributed for the control group.

Table 4.5: Kolmogorov-Smirnov test for normality in group B

Tests of Normality for group B						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Ball Speed Pre	.074	50	.200*	.982	50	.652
Ball Speed Post	.087	50	.200*	.986	50	.810

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

Table 4.5 shows the test for normality for the intervention group. The table reveals a p-value of 0.200 for both the pre and post ball speeds. The statistical significance value was set to 0.05, which signifies that the distribution of the data for the intervention group was normal.

4.4.2 Range of motion

The Kolmogorov-Smirnov Test was used to determine the normality for the control and intervention group data distribution for range of motion. Table 4.6 shows the results of the test for the control group and table 4.7 shows the results for the intervention group.

Table 4.6: Kolmogorov-Smirnov Test for normality in group A

Tests for normality Group A			
Range of motion	**Kolmogorov-Smirnov**		
	Statistic	**df**	**Sig.**
Extension Pre	0.143	50	0.012
Extension Post	0.166	50	0.001
Flexion Pre	0.178	50	0.000
Flexion Post	0.158	50	0.003
Left Lateral Flexion pre	0.244	50	0.000
Left Lateral flexion post	0.264	50	0.000
Right Rotation pre	0.176	50	0.001
Right Rotation post	0.155	50	0.004
Left Rotation pre	0.158	50	0.003
Left Rotation post	0.134	50	0.026

Table 4.6 shows the results for the normality test for the range of motion data for the control group. The p-values for all motions, namely, extension, flexion, lateral flexion both directions and rotation both directions, fall below the level set for statistical

significance (p = 0.05) indicating that the data collected for the range of motion for the control group was not normally distributed.

Table 4.7: Kolmogorov-Smirnov Test for normality in group B

Tests for normality Group B			
Range of motion	**Kolmogorov-Smirnov**		
	Statistic	**df**	**Sig.**
Extension Pre	0.135	50	0.024
Extension Post	0.111	50	0.166
Flexion Pre	0.130	50	0.034
Flexion Post	0.150	50	0.006
Left Lateral Flexion pre	0.154	50	0.005
Left Lateral flexion post	0.107	50	0.200
Right Rotation pre	0.202	50	0.000
Right Rotation post	0.149	50	0.008
Left Rotation pre	0.184	50	0.000
Left Rotation post	0.182	50	0.000

In table 4.7, the p-values for some of the motions of the intervention group fall below p = 0.05 showing that the data was not normally distributed, with the exception of extension post (p = 0.166) and left lateral flexion post (p = 0.200) which showed a normal distribution.

Table 4.8: Range of motion result for group A

Group A			
Motion	**Mean Pre (Degrees)**	**Mean Post (Degrees)**	**Difference**
Extension	58.40	58.74	0.34
Flexion	58.12	58.04	-0.08
Left Lateral flexion	31.44	31.44	0
Right Lateral flexion	30.86	31.12	0.26
Left Rotation	63.12	63.60	0.48
Right Rotation	63.24	63.72	0.48

Table 4.9: Range of motion results for group B

Group B			
Motion	**Mean Pre (Degrees)**	**Mean Post (Degrees)**	**Difference**
Extension	61.44	65.62	4.18
Flexion	58.6	60.22	1.62
Left Lateral flexion	32.12	35.08	2.96
Right Lateral flexion	32.68	35.28	2.6
Left Rotation	66.12	69.04	2.92
Right Rotation	66.48	70.20	3.72

Table 4.8 and 4.9 compare the average range of motion of all the participants before and after the rest period for all ranges of motion which included flexion, extension, left and right lateral flexion and left and right rotation. It also gives the average difference each range of motion had. This was done for both groups allowing a comparison to be made.

The values above show the changes that occurred which may or may not be statistically significant, which is why the Wilcoxon Signed Ranks Test and Kolmogorov-Smirnov Test were done to determine if there was a statistically significant change in each group.

4.5 Wilcoxon Signed Ranks Tests

This is a nonparametric test that has been used to determine whether two dependent samples were selected from populations having the same distribution. For this study the Wilcoxon Signed Ranks Test was used to ascertain whether there was a statistically significant difference between the pre-test and post-test results for the control group and the intervention group.

Table 4.10: Wilcoxon Signed Rank Test for group A

Group A				
Ranks				
Elements		Number	Mean Rank	Sum of Ranks
Ball Speed Post – Ball Speed Pre	Negative Ranks [a]	14	20.86	292.00
	Positive Ranks [b]	34	26.00	884.00
	Ties [c]	2		
	Total	50		
Flexion Post – Flexion Pre	Negative Ranks	8	10.69	85.50
	Positive Ranks	9	7.50	67.50
	Ties	33		
	Total	50		
Extension Post – Extension Pre	Negative Ranks	5	11.00	55.00
	Positive Ranks	13	8.92	116.00
	Ties	32		
	Total	50		
Left Rotation Post – Left Rotation Pre	Negative Ranks	5	10.50	52.50
	Positive Ranks	15	10.50	157.50
	Ties	30		
	Total	50		
Right Rotation Post – Right Rotation Pre	Negative Ranks	8	11.44	91.50
	Positive Ranks	16	13.03	208.50
	Ties	26		
	Total	50		
Left Lateral Flexion Post – Left Lateral Flexion Pre	Negative Ranks	7	11.07	77.50
	Positive Ranks	11	8.50	93.50
	Ties	32		
	Total	50		
Right Lateral Flexion Post – Right Lateral Flexion Pre	Negative Ranks	4	8.88	35.50
	Positive Ranks	11	7.68	84.50
	Ties	35		
	Total	50		

a Negative Ranks = The post condition is < the pre-condition
b Positive Ranks = The post condition is > the pre-condition
c Ties = The post condition = the pre-condition

Table 4.10 above, shows the results for the Wilcoxon Signed Rank Test for the control group. The various elements that were tested during the study are indicated in the far-left column, while the ranks show whether there was improvement, no improvement or no change. The table also provides a general statistic for the number of people that experienced changes and the type of changes they had. Number represents the "number" of participants which needed to total 50 (the sample amount for each group).

For the first element, pre and post ball speed, it is seen that out of the 50 participants, 14 had negative ranks, 34 had positive ranks and 2 had ties. This meant that of the 50 participants in the control group, 14 of the people had posttest speeds that were lower than the pretest speeds (negative ranks), 34 of the participants had posttest speed that were faster than the pretest speeds (positive ranks) and 2 participants had no change in their average speed. This information does not provide the significance of the change or the amount of change that occurred but rather indicates that there was a change.

- Similarly, this interpretation could be done for all the elements: In the flexion element, there were 9 positive ranks showing an increase in flexion before and after the waiting period, 8 negative ranks, showing a decrease in flexion before and after and 33 participants that had no change in flexion before and after. This meant that the majority of the participants had no change that occurred.

- For extension, there were 5 negative ranks, 13 positive ranks and 32 ties, showing that even though there were slightly more people that had changes compared to the flexion group, the majority of people still had no change in extension.

- Left rotation had 5 negative ranks, 15 positive ranks and 30 ties, still showing the majority of people having no change between pretest and post test results.

- Right rotation similarly showed the majority with ties at 26, 8 negative ranks and 16 positive ranks.

- Left lateral flexion had 32 ties, 7 negative ranks and 11 positive ranks.

- Right lateral flexion had 35 ties, 4 negative ranks and 11 positive ranks.

Table 4.11: Test statistics for Wilcoxon Signed Ranks Test for group A

Test Statistics – Wilcoxon Signed Ranks Test		
Group A		
Elements	**Z**	**Asymp. Sig. (2-tailed)**
Ball Speed Post- Ball Speed Pre	-3.036[a]	0.002
Flexion Post – Flexion Pre	-.456[b]	0.648
Extension Post – Extension Pre	-1.377[a]	0.169
Left Rotation Post – Left Rotation Pre	-2.090[a]	0.037
Right Rotation Post – Right Rotation Pre	-1.779[a]	0.075
Left Lateral Flexion Post – Left Lateral Flexion Pre	-.380[a]	0.704
Right Lateral Flexion Post – Right Lateral Flexion Pre	-1.441[a]	0.149
a Based on negative ranks b Based on positive ranks Asymp. Sig = Asymptotic Significance		

Table 4.11 shows the test statistics for the Wilcoxon Signed Ranks Test for group A. The test statistics give valuable information as to whether there is a statistically significant difference in the data and is determined by the p-value again. The level set for statistical significance is 0.05. P-values that fall below or are equal to the level of 0.05 ($p \leq 0.05$) are considered to be statistically significant.

From table 4.11, it can be seen that of the p-values for group A, ball speed and left rotation values were the only 2 that fell below the value of 0.05, at 0.002 for pre and post ball speed and 0.037 for left rotation pre and post. The remaining values were 0.648 for flexion, 0.169 for extension, 0.075 for right rotation, 0.704 for left lateral flexion and 0.149 for right lateral flexion. This meant that there was a statistically significant difference in the pre-test and post-test values for the ball speed and left lateral flexion elements. The other values were all well above 0.05 ($p > 0.05$) and therefore were not statistically significantly different.

Table 4.12: Test statistics for Wilcoxon Signed Rank Test for group B

Group A				
Ranks				
Elements		**Number**	**Mean Rank**	**Sum of Ranks**
Ball Speed Post – Ball Speed Pre	**Negative Ranks** [a]	9	12.00	108.00
	Positive Ranks [b]	39	27.38	1068.00
	Ties [c]	2		
	Total	50		
Flexion Post – Flexion Pre	**Negative Ranks**	5	6.50	32.50
	Positive Ranks	21	15.17	318.50
	Ties	24		
	Total	50		
Extension Post – Extension Pre	**Negative Ranks**	1	8.50	8.50
	Positive Ranks	42	22.32	937.50
	Ties	7		
	Total	50		
Left Rotation Post – Left Rotation Pre	**Negative Ranks**	0	.00	.00
	Positive Ranks	32	16.50	528.00
	Ties	18		
	Total	50		
Right Rotation Post – Right Rotation Pre	**Negative Ranks**	0	.00	.00
	Positive Ranks	39	20.00	780.00
	Ties	11		
	Total	50		
Left Lateral Flexion Post – Left Lateral Flexion Pre	**Negative Ranks**	1	8.50	8.50
	Positive Ranks	35	18.79	657.50
	Ties	14		
	Total	50		
Right Lateral Flexion Post –	**Negative Ranks**	0	.00	.00
	Positive Ranks	27	14.00	378.00
	Ties	23		

Right Lateral Flexion Pre	**Total**	50		
a Negative Ranks = The post condition is < the pre-condition b Positive Ranks = The post condition is > the pre-condition c Ties = The post condition = the pre-condition				

The results for the Wilcoxon Signed Rank Test for group B, can be seen in table 4.12 above. When compared to group A, the results show many more positive ranks with fewer negative ranks. However, this did not determine whether the data was statistically significant or not necessitating the need for the Wilcoxon Signed Ranks Test (data presented in table 4.13 below).

According to table 4.12 the following ranks were achieved for each element:

- Flexion had 5 negative ranks, 21 positive ranks and 24 ties
- Extension had 1 negative rank, 42 positive ranks and 7 ties
- Left rotation had 0 negative ranks, 32 positive ranks and 18 ties
- Right rotation had 0 negative ranks, 39 positive ranks and 11 ties
- Left lateral flexion had 1 negative rank, 35 positive ranks and 14 ties a
- Right lateral flexion had 0 negative ranks, 27 positive ranks and 23 ties.

Table 4.13: Test statistics for Wilcoxon Signed Ranks Test for group B

Test Statistics – Wilcoxon Signed Ranks Test		
Group B		
Elements	**Z**	**Asymp. Sig. (2-tailed)**
Ball Speed Post- Ball Speed Pre	-4.924[a]	0.000
Flexion Post – Flexion Pre	-3.684[a]	0.000
Extension Post – Extension Pre	-5.669[a]	0.000

Left Rotation Post – Left Rotation Pre	-4.994[a]	0.000
Right Rotation Post – Right Rotation Pre	-5.495[a]	0.000
Left Lateral Flexion Post – Left Lateral Flexion Pre	-5.164[a]	0.000
Right Lateral Flexion Post – Right Lateral Flexion Pre	-4.578[a]	0.000
a Based on negative ranks b Based on positive ranks Asymp. Sig = Asymptotic Significance		

The test statistics above indicate that there was a statistically significant difference in all the elements in group B ($p = 0.000$ for all elements; with $p \leq 0.05$ being the level set to show statistical significance).

CHAPTER 5 - DISCUSSION

5.1 Introduction

Chapter 5 links and discusses the results found in chapter 4 to the aim that was proposed in chapter 1. The following discussion was based on literature from chapter 2 to explain the results and understand the theories on the results. Results that had a statistical significance are explained as to how and why they occurred based on previous studies as well as evidence-based explanations with clinical reasoning. This chapter determined whether chiropractic manipulation had an immediate effect on squash players' hitting speed and how much more effective it may have been compared to the players who did not have chiropractic manipulation.

5.2 Demographic data analysis

5.2.1 Age distribution

Participants in the study were either male or female between the ages of 35-65 years. Figure 4.1 showed a histogram of the age distribution of the participants. The mean age of all the participants was 45.83 years and the participants consisted of 82% males and 18% females. The reason for the large difference in the gender split is based on the fact that there are a larger number of male leagues and therefore male players compared to female league players or female players in general. The split between males and females was markedly uneven and with the selection process being randomised the control group (n=50) comprised 16% females and 84% males while the intervention group (n=50) comprised 20% females and 80% males.

The age distribution according to the Kolmogorov-Smirnov Test for normality indicated that the data was not normally distributed. Although there is a statistically significant difference in the age distribution, the study was not greatly affected, as the readings taken from participants were compared to their own readings and no other participant's readings.

5.3 Objective Data

5.3.1 Pre and post ball speed analysis

Table 4.2a and 4.2b shows the descriptive data that was collected for the ball speed pre-test and post-test for the control group. According to the data, the control group started with a pre-test average speed of 167.42km/h and ended with a post-test overall average speed of 169.07km/h, equating to a change of 1.65km/h, an increase of 0.97%. Similar results were to be expected, as no intervention occurred with this group between testing sessions.

In tables 4.3a and 4.3b however, the intervention group was found to have slightly different results with the initial pre-test average speed at 167.00km/h and the final test post-test speed averaging 171.83km/h, a difference of 4.83km/h which is just under 3 times that of the control group. The Wilcoxon Signed Rank Tests revealed a positive improvement in ball speed pre- and post-test for both groups, with 68% of the control group participants showing an increase in ball speed whilst 78% of the intervention group showed an increase. This however, only tells us that there was an increase but does not give any set values which was why the mean speeds taken for both groups before and after were important. The Wilcoxon Signed Rank Test revealed that there was a statistical significance in the ball speed for both the pre and post ball speed averages, seen by the p-value being less than 0.05, the level set for statistical significance ($p \leq 0.05$). This could be attributed to the intervention of chiropractic manipulation of the cervical and thoracic spine between the 2 sets of shots. The chiropractic manipulations performed, were aimed at reducing any dysfunctions that were found within the cervical and thoracic spines, increasing the range of motion (Gatterman, 2009) and improving the functionality and strength of the active muscles needed to perform a good forehand drive with power (Dunning & Rushton, 2009). Chiropractic manipulation has been shown to have strengthening effects on muscles such as the biceps brachii (de Clercq & Landman, 2018). There are several muscles that work together in a well-coordinated manner to allow for good performance while protecting joints during a shot, providing the player with a chance to have an optimal swing (Alaaeldien & Akl, 2016). The chiropractic manipulative therapy performed was aimed at increasing range of motion as well as functionality to muscles that were used during a forehand drive. The range of motion and muscles were key contributors to ball speed thus, it can be deduced that the increase in ball speed could be attributed to chiropractic manipulative therapy.

5.3.2 Pre and post test range of motion

Tables 4.8 and 4.9 show the mean values for each range of motion pre-test and post-test. The differences that were seen between the two groups was notable. Within the control group the highest difference seen was 0.48 degrees for left and right rotation, with the other values lower at 0.34 for extension, -0.08 for flexion, 0 for left lateral flexion and 0.26 for right lateral flexion. These values are relatively low but were also to be expected as the control group had no intervention. The intervention group saw a varied amount of changes depending on the motion, with the largest difference being 4.18 degrees for extension, far more than the control group. The other changes were also all well above that of the control group with 1.62 degrees in flexion, 2.96 in left lateral flexion, 2.6 for right lateral flexion, 2.92 for left rotation and 3.72 for right rotation. For each range of motion within the intervention group, there was a statistical significance found with p-values for all elements being less than 0.05, the level set for statistical significance ($p \leq 0.05$). The chiropractic manipulation is a high velocity, low amplitude thrust to a joint aimed to correct chiropractic restrictions that alter the normal biomechanical movements of a joint segment thus allowing the biomechanical chain to function optimally again (Gatterman, 2005). It is with this manipulation that joint range of motion, blood flow and muscle activity were all increased (Yeoman, 2001). This could explain the statistically significant increases in cervical spine range of motion that was found in the intervention group. It could also explain why there was an increased speed seen in the intervention group compared to the control group and could be attributed to the chiropractic manipulations performed on the restricted segments found. This could also be backed by previous research showing that the chiropractic manipulation does have an impact on cervical spine range of motion (Paton & Bester, 2012).

The Wilcoxon Signed Rank Tests (table 4.10) also showed interesting results with the control group having a majority of the participants with no change. This could be seen in their respective percentages: flexion had 66% of the participants having no change, extension 64%, left rotation 60%, right rotation 52%, left lateral flexion 64% and right lateral flexion 70%. In the intervention group a large percentage of the participants showed positive ranks in the Wilcoxon Signed Rank Tests, with 84% of the participants showing an increase in extension, 64% in left rotation, 78% in right rotation, 70% in left lateral flexion and 54% in right lateral flexion. Flexion was the only motion which saw a higher percentage of people showing no change in range of motion at 54%. In a study done on the effect of spinal manipulative therapy on spinal range of motion, it was found that spinal manipulative therapy did have an effect on the range of motion in the cervical spine (Millan, Leboeuf-Yde, Budgell, Descarreaux & Amorim, 2012).

5.4 Final Thoughts

Squash shots require an efficient transfer of force from the lower body through to the upper body to produce a powerful and forceful shot. This is achieved through well-coordinated muscle actions which allow the body to perform an optimum swing whilst maintaining the stability needed (Alaaeldien & Akl, 2016). The chiropractic manipulation has been shown to have influences on muscle strength (Dunning & Rushton, 2009), which has been shown to alter central sensory motor integration, the relationship between the sensory and motor system, as well as the motor cortical drive to voluntary muscles of both the upper and lower limbs (Haavik et al., 2018). Athletes train to gain a greater advantage over their opponents as much as possible. Training effects the performance of the athlete by enabling them to gain more strength and speed allowing them to become more explosive in their respective sport by mustering a greater precise force in a shorter amount of time. This theory works on an inverse graph, seen in figure 2.2, where training in both strength and speed would shift the graph curve to the right. This shows that training allows athletes to access a greater velocity with the same force. In this, power would also be increased as power is determined by the product of force multiplied by velocity (Walker, 2016). Taking these into consideration, there were then chiropractic restrictions (dysfunctional segments) that may influence biomechanical and neural integrity. These dysfunctions may lead to an altered distribution of mechanical stresses on joints and surrounding muscles, potentially decreasing their ability to function at maximum capacity both in strength as well as motion (Gatterman, 2005). The chiropractic manipulations were aimed to reduce any dysfunctions found in the cervical and thoracic spine in this study, increasing the range of motion (Gatterman, 2009) and improving the functionality and strength of the active muscles needed to perform a precise forehand drive with power (Dunning & Rushton, 2009).

The results chapter gave insight into the immediate effect chiropractic manipulation had on hitting speed in squash. This was highlighted with all the p-values in the intervention group's results falling below 0.05, showing their statistical significance. This may be due to the correction of the unfavourable biomechanics and restrictions found within the participants' cervical and thoracic spine, which may have caused a decrease, be it slight, in the players' performance.

CHAPTER 6 - CONCLUSION

6.1 Conclusion

The aim of this study was to determine the immediate effect of chiropractic manipulation on the hitting speed in league squash players.

The results of this study showed the benefits the intervention group gained through chiropractic manipulation to the cervical and thoracic spine, resulting in an increase in hitting speed. This was seen in the statistical analysis when the p-value for the test came out to be less than 0.05. Although there was an increase in speed between the pre-test and post-test in both groups, the group that received the chiropractic manipulations during the rest period achieved a greater increase in speed compared to that of the control group by 2.9 times.

The benefit of this study was that it shows the potential chiropractic manipulation and treatment has within the squash and athletic community. This study also provides the groundwork for more research to be done on improving the hitting performance of squash players.

In conclusion, this study suggests that chiropractic manipulation can provide an immediate increase in hitting speed in league squash players.

6.2 Recommendations

Below is a list of recommendations that could be used in future studies to improve the results that were obtained:

- A larger study sample could be used to provide more statistically accurate results with more data.
- The participation of males and females could be equalized to provide a balanced gender sample.
- Chiropractic manipulation or treatment could be applied along the entire biomechanical chain for the shot, rather than just the spine, allowing for potentially greater performance results.
- A comparison could be done on hitting speed in people that frequently visit a chiropractor compared to those that have never been before.
- An addition of accuracy of the shot could be included into the study along with hitting speed as accuracy also plays a large role in matches.
- The warm up time could be increased by 5 minutes to allow the participants more time to get their "eye in".
- Multiple treatments could be done rather than just one to see the relatively longer-term effect it may have on the player's hitting speed.
- A placebo could be added to the study such as a sham adjustment, to provide a placebo effect and improve the psychosomatic effect.
- A sample group could be used that all have the same skill level and similar training regimes, for example, recruit only first league players.

REFERENCES

Alaaeldien, T. & Akl, A. (2016). Electromyographic comparison of squash forehand shot after midcourt and frontcourt traditional movement patterns. Sport Scientific And Practical Aspects. 13. 19-25.

Amazon.com. (2019). Jugs Wireless Battery Pack for the Pro-Sports Radar Gun. [online] Available at: https://www.amazon.com/Jugs-Wireless-Battery-Pro-Sports-Radar/dp/B003VFQXSY [Accessed 14 May 2019].

Bacon, T. (2003). Analysis of the Squash Forehand Drive. Biomechanical Lab Assignment. ESS 100.

Bahamonde, R. (2001). Biomechanics of forehand stroke. Coaching & Sport Science Review, 24, 7-8.

BBC Sport. (2006). Beginners guide to squash. BBC Sport. 5 May 2018. http://news.bbc.co.uk/sport2/hi/other_sports/squash/4748522.stm.

Bogduk, N. (2016). Functional anatomy of the spine. Neuroimaging Part II, 675–688. doi:10.1016/b978-0-444-53486-6.00032-6.

Botelho, M.B. & Andrade, B.B. (2012). Effect of Cervical Spine Manipulative Therapy on Judo Athletes' Grip Strength. Journal of Manipulative and Physiological Therapeutics, 35(1), 38–44.doi:10.1016/j.jmpt.2011.09.005).

Charschan, W. (1998). Evaluating Patterns of Function: Effects of Kinetic Chain Dysfunction of the Neck and Back. Dynamic Chiropractic, 16(1). Available from http://www.dynamicchiropractic.com/mpacms/dc/article.php?id=37005.

Chilibeck, P.D., Cornish, S.M., Schulte, A., Jantz, N., Magnus, C.R.A., Schwanbeck, S & Juurlink, B.H.J. (2011) The effect of spinal manipulation on imbalances in leg strength. Journal of the Canadian Chiropractic Association. 2011, 55, 183–192. [PubMed]).

Christiansen, T. L., Niazi, I. K., Holt, K., Nedergaard, R. W., Duehr, J., Allen, K. & Haavik, H. (2018). The effects of a single session of spinal manipulation on strength and cortical drive in athletes. European Journal of Applied Physiology, 118(4), 737–749.doi:10.1007/s00421-018-3799-x.

Costa, S.M.V., Chibana, Y.E.T., Giavarotti L., Compagnoni D.S., Shiono A.H., Satie J. & Bracher, E.S.B., (2009). Effect of spinal manipulative therapy with stretching compared with stretching alone on full-swing performance of golf players: a randomized pilot trial. Journal Chiropractic Medicine. 2009; 8:165–170. [PMC free article][PubMed] [Google Scholar].

De Clercq, C. & Landman, D.M. (2018) The effects of cervical manipulation alone versus cervical manipulation combined with dry needling on biceps brachii strength. Masters Dissertation. [Unpublished]: University of Johannesburg. Retrieved from: http://ujdigispace.uj.ac.za (Accessed: 15 May 2019).

Dunning, J. & Rushton, A. (2009). The Effects of Cervical High-Velocity Low-Amplitude Thrust Manipulation on Resting Electromyographic Activity of the Biceps Brachii Muscle. Manual Therapy, 15(5): 508-513. Available from http://www.ncbi.nlm.nih.gov/pubmed/19027344.

Elliott, B., Marshall, R. & Noffal, G. (1996). The role of upper limb segment rotations in the development of racket-head speed in the squash forehand. Journal of Sports Sciences, 14(2), pp.159-165.

Ellis, H. (2009). Anatomy of the spinal nerves and dermatomes. Anaesthesia & Intensive Care Medicine, 10(11), 536–537.doi:10.1016/j.mpaic.2009.08.004.

Erkel, J. (2007). The Changes In Pitching Mechanics and Pitch Velocity During a Seven-Inning Simulated Game in High School Baseball Pitchers: A Prospective Descriptive Study, 3-17. Masters Dissertation, West Virginia: West Virginia University.

Gatterman, M. (1991). Standards of practice relative to complications of and contraindications to spinal manipulative therapy. The Journal of the Canadian Chiropractic Association. 1991 Dec; 35(4): 232–236.

Gatterman, M. (2005). Foundations of Chiropractic: Sublaxation. 2nd Edition. St Louis, Missouri: Elsevier. pp. 136-143.

Gatterman, M. & Meridel, I. (2009) Subluxation – Historical Perspectives. Chiropractic Journal of Australia, Volume 39 issue 4. ISSN: 1036-0913

Haavik, H., Özyurt, M., Niazi, I., Holt, K., Nedergaard, R., Yilmaz, G., & Türker, K. (2018). Chiropractic Manipulation Increases Maximal Bite Force in Healthy Individuals. Brain Sciences, 8(5), 76.doi:10.3390/brainsci8050076.

Haschek, W., Rousseaux, C. & Wallig, M. (2013). Haschek and Rousseaux's handbook of toxicologic pathology. 3rd ed. Amsterdam: Elsevier, pp.3-7.

Herzog, W. (2010). The biomechanics of spinal manipulation. Journal of Bodywork and Movement Therapies, 14(3), 280–286.doi:10.1016/j.jbmt.2010.03.004.

Hughes, M. & Franks, I.M. (1994) Dynamic patterns of movement of squash players of different standards in winning and losing rallies, Ergonomics, 37:1, 23-29, DOI: 10.1080/00140139408963619.

Huiskes, R. & Mow, V. (2005). Basic orthopaedic biomechanics & mechano-biology. 3rd ed. Philadelphia: Lippincott Williams & Wilkins.

HSC PDHPE. (2019). Major muscles involved in movement. [online] Available at: https://www.pdhpe.net/the-body-in-motion/how-do-the-musculoskeletal-and-cardiorespiratory-systems-of-the-body-influence-and-respond-to-movement/muscular-system/major-muscles-involved-movement/ [Accessed 14 May 2019].

Jaumard, N.V., Welch, W.C., & Winkelstein, B.A. (2011). Spinal Facet Joint Biomechanics and Mechanotransduction in Normal, Injury and Degenerative

Conditions. Journal of Biomechanical Engineering, 133(7), 071010. doi:10.1115/1.4004493

Kelsick, W.E. (2010). The pre-participation examination. Canadian Chiropractor. 8(5):6, 8, 9, 33.

Lauro, A. & Mouch, B. (1991). Chiropractic effects on athletic ability. J Chiropractic Research and Clinical Investigation. 1991;6(4):84–87.

Levine, M., Moodley, M. & Smilkstein, S. (2017). The Acute Effects of Chiropractic Manipulation on the Accuracy and Bowling Speed of Male Bowlers, 20-28. Masters Dissertation. [Unpublished]: Johannesburg: University of Johannesburg.

Machar, A., Elliott, E. & Crespo, M. (2013). Mechanics and Learning Practices Associated with the Tennis Forehand: A Review. Journal of Sports Science and Medicine, 12,255-231.

Millan, M., Leboeuf-Yde, C., Budgell, B., Descarreaux, M., & Amorim, M.A. (2012). The effect of spinal manipulative therapy on spinal range of motion: a systematic literature review. Chiropractic & Manual Therapies, 20(1), *23*.doi:10.1186/2045-709x-20-23

Miners, A. (2010). Chiropractic Treatment and the Enhancement of Sport Performance: A Narrative Literature Review. Journal of Canadian Chiropractic Association, 54(4): 210-221.

Moore, K., Dalley, A. & Agur, A. (2014). Clinically oriented anatomy. 7th ed. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins Health.

Nógrádi A. & Vrbová G. (2013). Anatomy and Physiology of the Spinal Cord. In: Madame Curie Bioscience Database [Internet]. Austin (TX): Landes Bioscience; 2000-2013. Available from: https://www.ncbi.nlm.nih.gov/books/NBK6229/.

Nook, B.C. & Nook, D.D. (1997). Demographics of athletes and support personnel who used chiropractic physicians at the 6th All African Games. Journal Sports Chiropractic & Rehabilitation. 11(4):136–139.

Nook, D.D., Nook, E.C. & Nook, B.C. (2016). Utilization of Chiropractic Care at the World Games 2013. Journal of Manipulative and Physiological Therapeutics, 39(9), pp. 693-704.

Pallant, J. (2013). SPSS SURVIVAL MANUAL. 5ed. Open University Press: McGraw-Hill Education.

Palmer, P. & Moodley, M. (2011). A study to determine the effect of chiropractic treatment on the serving speed of male tennis players, 5-10, Masters Dissertation. [Unpublished]: Johannesburg: University of Johannesburg.

Paton, G.J. & Bester, C. (2012) The Effect of Chiropractic Cervical Spine Adjustment on Cervical Range of Motion, Beyond the Effect of Cavitation. Masters Dissertation. [Unpublished]: University of Johannesburg. Retrieved from: http://ujdigispace.uj.ac.za (Accessed: 30 July 2018).

Pickar, J.G., & Wheeler, J.D. (2001). Response of muscle proprioceptors to spinal manipulative-like loads in the anesthetized cat. Journal of Manipulative and Physiological Therapeutics, 24(1), 2–11.doi:10.1067/mmt.2001.112017

Prokop, L.L. & Wieting, J.M. (1996). The use of manipulation in sports medicine practice. Physical Medicine and Rehabilitation Clinics of North America. 1996;7(4):915–933.

Psaworldtour.com. (2019). Squash Balls - Explained | Professional Squash Association. [online] Available at: https://psaworldtour.com/news/view/3939/squash-balls-explained [Accessed 14 May 2019].

Raj, P.P. (2008). Intervertebral Disc: Anatomy-Physiology-Pathophysiology-Treatment. Pain Practice, 8(1), 18–44.doi:10.1111/j.1533-2500.2007.00171.x

Robinson, G. & Robinson, I. (2016). Radar speed gun true velocity measurements of sports-balls in flight: application to tennis. Physica Scripta, 91(2). Doi:10.1088/0031-8949/91/2/023008.

Sciascia, A. & Cromwell, R. (2012). Kinetic Chain Rehabilitation: A Theoretical Framework. Rehabilitation Research and Practice, 2012, pp.1-9.

Senzon, S.A. (2018). The Chiropractic Vertebral Subluxation Part 1: Introduction. Journal of Chiropractic Humanities, 25, 10–21. doi:10.1016/j.echu.2018.10.002.

Sery, R., Losco, B. & Pritchard, M.C. (2005). The Effects of Chiropractic Spinal Manipulation on Driver Club Head Speeds of Asymptomatic Amateur Golfers. Department of Chiropractic, University of Johannesburg. Dissertation submitted in compliance with the requirements for the Masters Degree in Technology in the Department of Chiropractic at the Technikon Witwatersrand.

Squashpoint. (2019). Buy Dunlop Pro Squash Ball (double yellow dot) - 3 -Pack. [online] Available at: https://www.squashpoint.com/dunlop-pro-squash-ball-3-pack.html [Accessed 14 May 2019].

Stump, J.L. (2001). Commentary: a perceived role of the Doctor of Chiropractic in sports health care. Journal Sports Chiropractic & Rehabilitation. 15(1):44–46.

Stump, J.L. & Redwood, D. (2002). The use and role of sport chiropractors in the National Football League: A short report. Pages A5.

Vernon, H., & Mrozek, J. (2005). A Revised Definition of Manipulation. Journal of Manipulative and Physiological Therapeutics, 28(1), 68–72. doi:10.1016/j.jmpt.2004.12.009.

Vučković, G., Perš, J., James, N. & Hughes, M. (2009). Tactical use of the T area in squash by players of differing standard. Journal of Sports Sciences, 27(8), pp.863-871.

Walker, O. (2016). Force-Velocity Curve. Science for Sports. Available at: https://www.scienceforsport.com/force-velocity-curve/#av_section_2 (Accessed: 15 September 2018).

Waxenbaum, J.A., Futterman, B. (2018). Anatomy, Back, Cervical Vertebrae. [Updated 2018 Dec 6]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2019 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK459200/.

Williams, M., McCarthy, C., Chorti, A., Cooke, M. & Gates, S. (2010). A Systematic Review of Reliability and Validity Studies of Methods for Measuring Active and Passive Cervical Range of Motion. Journal of Manipulative and Physiological Therapeutics, 33(2), pp.138-155.

Williams, M. A., Williamson, E., Gates, S., & Cooke, M. W. (2011). Reproducibility of the cervical range of motion (CROM) device for individuals with sub-acute whiplash associated disorders. European Spine Journal, 21(5), 872–878. doi:10.1007/s00586-011-2096-8.

Yeoman, S.G. (2001). Chiropractic Manipulation. Spinal Health Journal, 5(1): 1-2.

APPENDICES

Appendix A : Advertisement

RESEARCH

Participants needed for a research study:

"THE IMMEDIATE EFFECTS OF CHIROPRACTIC MANIPULATIONS ON THE HITTING SPEED OF SQUASH PLAYERS."

YOUR PARTICIPATION WILL TAKE ABOUT HALF AN HOUR FOR JUST ONE DAY. CHIROPRACTIC MANIPULATIONS WILL BE PERFORMED WHILE A DOPPLER RADAR GUN MONITORS YOUR HITTING SPEED!!!

This study will take place between August and September 2018 at Modderfontein Squash Club

To participate: You must be between the age of 18 and 65 years and be an active league squash player.

TAKE ONE IF INTERESTED	MARKALFREDVD@GMAIL.COM	MARKALFREDVD@GMAIL.COM	MARKALFREDVD@GMAIL.COM	MARKALFREDVD@GMAIL.COM	MARKALFREDVD@GMAIL.COM	MARKALFREDVD@GMAIL.COM	MARKALFREDVD@GMAIL.COM	MARKALFREDVD@GMAIL.COM

Appendix B : List of Gauteng squash clubs

Alberton

Bryanston

Chamber Exiles

Country Club Johannesburg

Crusaders

Pirates

Randburg

Southern Suburbs

Soweto

Dainfern

University of Johannesburg

Jeppe Quondam

Wanderers

Modderfontein

Northcliff

Western Rackets

Old Edwardians

Wits University

Appendix C : Information letter

DEPARTMENT OF CHIROPRACTIC

RESEARCH STUDY INFORMATION LETTER

Date:

Good Day

My name is Mark van Dongen **I WOULD LIKE TO INVITE YOU TO PARTICIPATE** in a research study on the effect of Chiropractic Manipulation on the hitting speed of squash players.

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 letter 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 measure the effect of Chiropractic Manipulation on the hitting speed of squash players.

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? You will start with a 5-minute warm up and stretch, after which your cervical spine range of motion will be measured. You will then proceed to hit 10 cold squash balls once each. Depending on the group you are placed in, you will either receive Chiropractic manipulative therapy to restricted segments found in the thoracic and cervical spine or

Participants initials:___________

rest for 5 minutes before for cervical range of motion is rechecked. You will then proceed to hit another 10 squash balls. Each of the 10 shots both before and after will be measured using a Doppler radar gun.

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 should 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 to participate in this study, and you will not bare any expenses.

RISKS INVOLVED IN PARTICIPATION: The risks involved with this study are post manipulation stiffness to your neck and upper back.

BENEFITS INVOLVED IN PARTICIPATION: Relief of stiffness and an increase in your hitting speed.

WILL MY PARTICIPATION IN THIS STUDY BE KEPT CONFIDENTIAL? Yes. During the testing phase of this study, privacy will be ensured to each individual that partakes. 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 and/or locked away as applicable. Only I and my research supervisor will be authorised to use and/or disclose your anonymised information in connection with this research study. Any other person wishing to work with your anonymised information as part of the research process (e.g. an independent data coder) will be required to sign a confidentiality agreement before being allowed to do so.

OR

WILL MY TAKING PART IN THIS STUDY BE ANONYMOUS? Yes. Anonymous means that your personal details will not be recorded anywhere by me. As a result, it will not be possible for me or anyone else to identify your responses once these have been submitted.

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.

Participants initials:___________

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. This study has received funding through the supervisor linked bursary distributed by the University of Johannesburg.

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 the participant is injured during the procedures of the study, they will be recommended to a local general practitioner for further assessment. 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:

Mark van Dongen

markalfredvd@gmail.com

You may also contact my research supervisor:

Dr Caroline Hay

carolineh@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. Christopher Stein

Tel: 011 559-6564

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.

Participants initials:___________

Appendix D : Consent form

UNIVERSITY OF JOHANNESBURG

DEPARTMENT OF CHIROPRACTIC

RESEARCH CONSENT FORM

THE IMMEDIATE EFFECT OF CHIROPRACTIC MANIPULATION ON THE HITTING SPEED OF SQUASH PLAYERS

Please initial each box below:

☐ I confirm that I have read and understand the information letter dated ____________________ 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

Appendix E : Contra-indications to manipulation (Gatterman, 1991)

Vascular complications

- Vertebral artery syndrome
- Aneurysms

Tumours

- Primary to the bone
- Secondary, a metastasis to the bone

Bone Infections

- Tuberculosis of the spine
- Osteomyelitis of the spine

Traumatic injuries

- Fractures
- Instability
- Dislocations
- Unstable spondylolisthesis

Arthritis

- Ankylosing spondylitis
- Rheumatoid arthritis
- Psoriatic arthritis
- Reiter's syndrome
- Osteoarthritis

Psychological considerations

- Malingering
- Hysteria
- Hypochondriasis
- Pain intolerance
- Dependent personality
- Disability syndromes

Neurological complications

- Cervical disc lesions and myelopathy
- Nerve root damage

Appendix F : C-Spine range of motion data sheet

Patient No. ________

Date: __________________

CROM READINGS

Movement	Initial Degrees	Final Degrees
Flexion		
Extension		
Left Rotation		
Right Rotation		
Left Lateral Flexion		
Right Lateral Flexion		

Appendix G1 : Radar data sheet

UNIVERSITY OF JOHANNESBURG - CHIROPRACTIC DEPARTMENT

PROJECT:	**The immediate effect of chiropractic manipulation on ball speed in squash players**

SQUASH CLUB	
PARTICIPANT No.	
DATE	
AGE	
MALE/FEMALE	

	INITIAL	
	SHOT	**BALL SPEED**
	1	
	2	
	3	
	4	
Group 1 / 2	**5**	
	6	
	7	
	8	
	9	
	10	
	Average	

Appendix G2 : Radar data sheet

UNIVERSITY OF JOHANNESBURG - CHIROPRACTIC DEPARTMENT	
PROJECT:	The immediate effect of chiropractic manipulation on ball speed in squash players

PARTICIPANT No.		
Group 1 / 2	FINAL	
	SHOT	BALL SPEED
	1	
	2	
	3	
	4	
	5	
	6	
	7	
	8	
	9	
	10	
	Average	
	Difference	

Appendix H : Modderfontein squash club confirmation letter

Modderfontein Squash Club

Mark van Dongen
University of Johannesburg
Faculty of Health Science

18 June 2018

Dear Mark,

This serves to confirm that the Modderfontein squash courts are made available to you in to complete your chiropractic dissertation.

It is understood that the research and the use of the facilities will be done in consultation with the court manager, Nkateko Hlatschwayo. You are requested to respect the club's booking restrictions during peak hours.

Piet van Dongen
Chairman
Modderfontein Squash Club

Appendix I : Case history forms

Research Copy

UNIVERSITY OF JOHANNESBURG

UNIVERSITY OF JOHANNESBURG
CHIROPRACTIC DAY CLINIC

CASE HISTORY

Date: ______________________________

Patient: ______________________________ **File No:** ______________________________

Occupation: ______________________________ **Age:** __________ **Sex:** ________

Student: ______________________________ **Signature:** ______________________________

FOR CLINICIAN USE ONLY:

Initial visit clinician: ______________________________ **Signature:** ______________________________:

Case History: ______________________________

Examination:	Previous:	UJ Other	Current:	UJ Other
X-ray Studies:	Previous:	UJ Other	Current:	UJ Other
Clinical Path. Lab:	Previous:	UJ Other	Current:	UJ Other

Case status: PTT: Conditional: Signed off: Final sign out:

Recommendations:

Students case history:

1. **Source of History:** ____________________________

2. **Chief Complaint in patients own words:**

____

____

____

____

____

3. PRESENT ILLNESS/PRIMARY COMPLAINT

Location	
Onset	
Duration	
Frequency	
Pain Character	
Progression	
Aggravating Factors	
Relieving Factors	
Ass Signs & Symptoms	
Previous Occurrence	
Past Tx and Outcomes	

4. PAST HISTORY

General Health Status	
Childhood Illnesses	
Adult Illnesses	
Psychiatric Illnesses	
Accidents	
Traumatic Injuries	
Surgeries	
Hospitalizations	

5. **ANY OTHER COMPLAINTS**

____

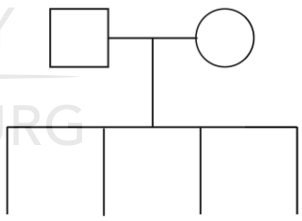
____

6. CURRENT HEALTH STATUS & LIFESTYLE

Allergies	
Immunizations	
Screening Tests	
Environmental Hazards	
Safety Measures	
Progression	
Exercise and Leisure	
Sleep Patterns	
Diet	
Current Mediation	
Tobacco	
Alcohol	
Social Drugs	
Other	

7. FAMILY HISTORY

Diabetes Mellitus	
Heart Disease	
TB	
HBP	
Stroke	
Kidney Disease	
Cancer	
Arthritis	
Anaemia	
Headaches	
Thyroid Diseases	
Epilepsy	
Mental Illness	
Alcoholism	
Drug Addiction	
Other	



8. PSYCHOSOCIAL HISTORY

Home Situation	
Daily Life	
Important Experiences	
Religious Beliefs	
Other	

9. REVIEW OF SYSTEMS

General	
Skin	
Head	
Eyes	
Ears	
Noses / Sinuses	
Mouth / Throat	
Neck	
Breasts	
Respiratory	
Cardiac	
Gastrointestinal	
Urinary	
Genital/Sexual Function	
Vascular	
Musculoskeletal	
Neurological	
Hematological	
Endocrine	
Psychiatric	
Other	

Appendix J : Physical examination form

Research Copy

UNIVERSITY OF JOHANNESBURG

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CHIROPRACTIC DAY CLINIC

PHYSICAL EXAMINATION

Underline abnormal findings in **RED** | **Date:** ______________________

Patient: ______________________ | **File No:** ______________________

Clinician : ______________________ | **Signature:** ______________________

Student: ______________________ | **Signature:** ______________________

VITAL SIGNS

Height	
Weight	
Temperature	
Heart Rate	
Pulse	
Respiratory Rate	

BLOOD PRESSURE

	Left	Right
Arms		
Legs		

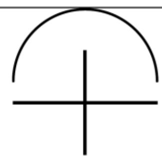
General Appearance

____

____

____

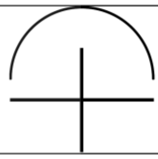
STANDING EXAMINATION

Minor's Sign	
Skin Changes	
Posture • Erect • Adams	
Romberg's Sign	
Pronator Drift	
Trendelenburg Sign	
Gait • Rhythm • Balance • Pendulousness • On toes • On heels • Tandem	
Half Squat	
Scapular Winging	
Muscle Tone	
Spasticity / Rigidity	
Chest measurement • Inspiration • Expiration	 __________ cm __________ cm
Visual Acuity	
Lumbar Spine ROM • Flexion (90°) • Extension (50°) • Lat. Flexion (30°) • Rotation (35°)	

SEATED EXAMINATION

Spinal Posture	
Head • Hair & Skin • Scalp • Skull • Face	
Eyes • Observation - Conjunctiva - Sclera - Eyebrows & Lids - Lacrimal Glands - Nasolacrimal Duct - Position - Alignment - Cornea / Lens • Corneal Reflex • Ocular Movements • Visual Fields • Accommodation • Ophthalmoscopy - Iris - Pupils - Red Reflex - Optic Disc - Macula - Vitreous - Lens	
Ears • Inspection - Auricle - Ear Canal - Drum • Auditory Acuity • Weber Test • Rinne Test	
Nose • External Inspection • Internal Inspection - Septum - Turbinate - Olfaction	
Sinuses • Tenderness • Transillumination	

SEATED EXAMINATION Cont.

Mouth & Pharynx • Lips • Buccal Mucosa • Gums & Teeth • Roof • Tongue - Inspection - Movements - Taste - Palpation • Pharynx – CN X	
TMJ • Inspection - ROM - Deviation • Palpation - Crepitus - Tenderness	
Neck • Posture • Size / Swellings • Scars • Discolorations • Hairline • Lymph Nodes • Tracheal Alignment • Thyroid & Carotids	
Cervical Spine ROM • Flexion (45º) • Extension (55º) • Lat. Flexion (40º) • Rotation (70º)	
Peripheral Vascular • Inspection - Pigmentation, Skin, Nailbeds, Hair loss • Palpation - Pulses, Lymph nodes, Skin Temp • Manual Compression • Retrograde Filling • Arterial Insufficiency • Allan's Test	

BREAST

Inspection • Skin • Size • Contour • Nipples • Arms Overhead • Hands Against Hips • Leaning Forward	
Palpation • Axillary Lymph Nodes • Breast • Breast tail	

THORAX – HEART AND LUNGS

Inspection • Skin • Shape • Respiratory Distress • Rhythm • Depth • Effort • Intercostal Retraction	
Palpation • Tenderness • Masses • Respiratory Expansion • Tactile Fremitus • JVP • PMI	
Percussion • Lungs (posterior) • Diaphgragmatic excursion • Kidney Punch	
Auscultation • Breath Sounds • Adventitious Sounds • Voice Sounds • Heart Auscultation • Heart Murmurs	

ABDOMINAL

Inspection • Skin • Umbilicus • Contour • Peristalsis • Pulsations • Hernias	
Auscultation • Bowel Sounds • Bruits	
Percussion • General • Liver • Spleen	
Palpation • Superficial Reflex • Cough • Light • Rebound Tenderness • Deep • Liver • Spleen • Kidneys • Aorta • Abdominal Masses • Shifting Dullness • Fluid Wave	
Acute Abdomen • Where pain began? • Moved to where? • Cough • Tenderness • Guarding / Rigidity • Rebound Tenderness	
Special Tests • Rovsing's Sign • Psoas Sign • Obturator Sign • Cutaneous Hyperaesthesia • Murphy's Sign • Rectal Examination	

MUSCULOSKELETAL

Shoulder • Observation - Skin - Symmetry • ROM - Glenohumeral - Scapulo-thoracic - Acromioclavicular - Elbow - Wrist		
Hip	Left	Right
• Flexion (90° / 120°)		
• Extension (15°)		
• Abduction (45°)		
• Adduction (30°)		
• Internal Rotation (40°)		
• External Rotation (45°)		
Knee	Left	Right
• Flexion (30°)		
• Extension (0° / 15°)		
Ankle	Left	Right
• Plantar Flexion (45°)		
• Dorsi Flexion (20°)		
• Inversion (30°)		
• Eversion (20°)		
Leg Length	Left	Right
• Apparent		
• Actual		

MENTAL STATUS

Appearance & Behavior • LOC • Posture • Motor Behavior • Dress, Grooming • Facial Expression • Affect	
Speed & Language • Quantity • Rate • Volume • Fluency • Aphasia (pm)	
Mood	
Memory • Orientation • Remote Memory • Recent Memory • New Learning Ability	
Higher Cognitive Function • Information • Vocabulary • Abstract Thinking	

CO-ORDINATION AND CEREBELLAR TESTING

Vertigo	
Ataxic Gait	
Nystagmus	
Intention Tremor	
Slurring/ Staccato Speech	
Hypotension	
Dysmetria (Point to point)	
Dysdiachokinesia	
Titubation	

CRANIAL NERVES

	Left	Right
CN I – Olfactory		
CN II – Optic		
CN III – Oculomotor		
CN IV - Trochlear		
CN V – Trigeminal • Motor • Sensory		
CN VI – Abducens		
CN VII – Facial • Motor • Sensory		
CN VIII - Vestibulocochlear		
CN IX – Glossopharyngeal		
CN X – Vagus		
CN XI – Spinal Accessory		
CN XII - Hypoglossal		

Appendix K : Cervical spine regional examination form

Research Copy

UNIVERSITY OF JOHANNESBURG

UNIVERSITY OF JOHANNESBURG
CHIROPRACTIC DAY CLINIC

REGIONAL EXAMINATION
CERVICAL SPINE

Date: ______________________

Patient: ______________________ **File No:** ______________________

Clinician: ______________________ **Signature:** ______________________

Student: ______________________ **Signature:** ______________________

OBSERVATION

Posture	
Size	
Swellings	
Scars	
Discolourations	
Hairline	
Bony Contours	
Soft Tissue Contours	
Shoulder Level	
Muscle Spasm	
Facial Expression	
Antalgic List	
Torticollis	
Plumb lines • Frontal plane • Sagittal Plane	

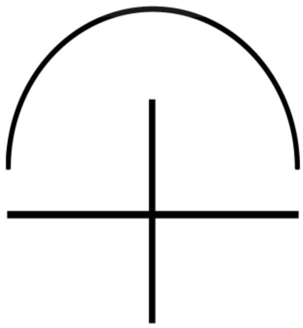
MYOFASCIAL – ACTIVE TRIGGER POINTS

	Left	Right
SCM		
Trapezius		
Scalene Anterior		
Scalene Posterior		
Scalene Medius		
Levator Scapula		
Posterior Cervicals		
Rhomboids		
Sub Occipitals		
Masseter		
Temporalis		

PALPATION

Lymph Nodes	
Trachea	
Thyroid Gland	
Pulses • Carotid • Subclavian • Brachial • Radial	
Tenderness	
Muscle Tone	

RANGE OF MOTION



RANGE OF MOTION

	Active ROM		Passive ROM		Resisted Isometric	
	Left	Right	Left	Right	Left	Right
Flexion (45º - 90º)						
Extension (55 º - 70 º)						
Lateral Flexion (20 º - 45 º)						
Rotation (70 º - 90 º)						

NEUROLOGICAL ASSESSMENT

DERMATOMES

	Left	Right
Cervical		
C2		
C3		
C4		
C5		
C6		
C7		
C8		
T1		
T2		

DISCRIMATIVE SENSATIONS

	Left	Right
Sterognosis		
Graphesthesia		
Two Point Discrimination		
Point Localisation		
Extinction		

NEUROLOGICAL ASSESSMENT

REFLEXES

	Level	Left	Right
Biceps	C5		
Brachioradialis	C6		
Triceps	C7		

REFLEX GRADING

- 4+ Very brisk, hyperactive. Perform ankle clonus.
- 2+ Average; normal
- 1+ Somewhat diminished; low normal.
- 0 No response

NEUROLOGICAL ASSESSMENT

CO ORDINATION

	Left	Right
Rapid Alternating Movements		
Point to Point Movements		

NEUROLOGICAL ASSESSMENT

MYOTOMES

	Level	Left	Right
Neck Forward Flexion	C1 / C2		
Neck Lateral Flexion	C3		
Shoulder Elevation	C4		
Shoulder Abduction	C5		
Elbow Flexion	C5		
Elbow Extension	C7		
Elbow Flexion	C6		
Forearm Pronation	C6		
Forearm Supination	C6		
Wrist Extension	C6		
Wrist Flexion	C7		
Finger Flexion	C8		
Finger Abduction	T1		
Finger Adduction	T1		

MUSCLE GRADING

- 0 - No contraction detected
- 1 - Barely detectable flicker or trace of contraction
- 2 - Active movement with gravity eliminated
- 3 - Active movement against gravity
- 4 - Active movement against gravity and some resistance.

NEUROLOGICAL ASSESSMENT

STANCE

	Left	Right
Romberg's		
Pronator Drift		
Arm Tapping		

CRANIAL NERVES

	Left	Right
CN I		
Smell		
CN II		
Visual acuity		
Optic fundi		
Visual fields by confrontation		
CN II and III		
Pupils		
Reactions to light		
Near response		
CN III, IV and IV		
Extraocular movements		
Ptosis		
CN V		
Sensory		
Motor		
Corneal reflex		
CN VII		
Muscles of face		
CN VIII		
Auditory acuity		
Weber		
Rinne		
CN IX and X		
Voice		
Movements of soft palate and pharynx		
Gag reflex		
CN XI		
Shoulder elevation		
Neck rotation		
CN XII		
Asymmetry/deviation of tongue		
Fasciculation's		
Strength		

MOTION PALPATION

	Left	Right
C0		
C0 / C1		
C1 / C2		
C2 / C3		
C3 / C4		
C4 / C5		
C5 / C6		
C6 / C7		
C7 / T1		
T1 / T2		
T2 / T3		
T3 / T4		
T4 / T5		
T5 / T6		
T6 / T7		

ORTHOPAEDIC TESTS

	Left	Right
Doorbell Sign		
Max Cervical Compression		
Spurling's Manoeuvre		
Lateral Compression		
Kemp's Test		
Cervical Distraction		
Shoulder Abduction Test		
Shoulder Depression Test		
Dizziness Rotation Test		
L'Hermitt's Sign		
Brachial Plexus Tension • Median • Radial • Ulna		
Carpal Tunnel Tests • Tinel's at the Wrist • Phalen's • Reverse Phalen's		
TOS Testing • Halstead's Test • Adson's Test • Eden's Traction Test • Wright's Test (Pec Minor) • Costoclavicular Test		

VASCULAR TESTING

	Left	Right
Blood Pressure		
Carotids Pulse		
Subclavian Pulse		
Brachial Pulse		
Radial Pulse		
JVP		
Auscultation of Carotid		
Auscultation of Subclavian		
Allen's Test		
Capillary Refill		
Examination of the Eye		
VBAI Testing		
Wallenberg's Test		
5 D's and 3 N's		
Dizziness / Disequalibrium		
Drop Attacks		
Diplopia		
Dysarthria		
Dysphagia		
Ataxia		
Nausea		
Nystagmus		
Numbness		

Appendix L : SOAP note

UNIVERSITY OF JOHANNESBURG
CHIROPRACTIC DAY CLINIC
SOAP NOTE

Research Copy

Patient:	Visit Number:
File Number:	Student:
Date:	Clinician:
S:	O:
A: Differential Diagnosis / ICD-10 Code	P: Procedure Codes
Home Advice:	Comments:

Patient:	Visit Number:
File Number:	Student:
Date:	Clinician:
S:	O:
A: Differential Diagnosis / ICD-10 Code	P: Procedure Codes
Home Advice:	Comments:

Appendix M : Table showing the anatomy of the muscles involved in a forehand swing (Moore et al., 2014)

Muscle	Origin	Insertion	Function	Nerve
Trapezius	Medial third of superior nuchal line, external occipital protuberance, nuchal ligament, spinous processes of C7-T12 vertebrae	Lateral 3rd of clavicle, acromion and spine of scapula	Elevates scapular Adducts scapula Helps serratus anterior rotate scapula	Spinal Accessory nerve (cranial nerve XI)
Deltoid	Lateral 3rd of clavicle, acromion and spine of scapular	Deltoid tuberosity of the humerus	Abduction of shoulder (middle fibres) Flexion, horizontal adduction and medial rotation of shoulder (anterior fibres) Extension, horizontal abduction and lateral rotation of shoulder (posterior fibres)	Axillary nerve (C5,6)
Triceps Brachii	Long head: Infraglenoid tubercle of the scapula Lateral head: Posterior surface of the humerus Medial head: Posterior surface of the humerus, inferior to radial groove	Proximal end of olecranon of ulna and fascia of forearm	Extension of the elbow	Radial nerve (C6,7,8)
Biceps Brachii	Short head: Tip of coracoid process of scapula Long head: Supraglenoid tubercle of scapula	Radial tuberosity and bicipital aponeurosis	Flexion and supination of forearm Slight flexion of shoulder	Musculocutaneo us nerve (C5,6)

Muscle	Origin	Insertion	Function	Nerve
Flexor Carpi Radialis	Medial epicondyle of humerus	Base of 2^{nd} metacarpal	Flexes and abducts the hand	Median nerve (C7,8)
Extensor Carpi Radialis	Brevis: Lateral epicondyl of humerus Longus: Lateral supra-epicondylar ridge of humerus	Brevis: Dorsal aspect of base of 3^{rd} metacarpal Longus: Dorsal aspect of base of 2^{nd} metacarpal	Extends and abducts the hand at the wrist joint Longus: Active during fist clenching	Radial nerve (C6,7)
Pectoralis major	Clavicular head: Medial half of clavicle (anterior surface) Sternocostal head: Surface of sternum (anterior surface), superior six costal cartilages and aponeurosis of external oblique	Lateral lip of bicipital groove of humerus	Adduction and medial rotation of shoulder Horizontal adduction of shoulder Flexion of shoulder (clavicular portion)	Medial and lateral pectoral nerves Clavicular head (C5,6) Sternocostal head (C7,8,T1)
Serratus anterior	Lateral surface of ribs 1-8	Medial border of scapula (anterior surface)	Protracts the scapula, holding it to thoracic wall Upward rotation of scapula	Long thoracic nerve (C5,6,7)
Rectus abdominis	Public crest and pubic symphysis	Costal cartilage of ribs 5-7 and xiphoid process	Flexion of trunk Posterior pelvic tilt Compression and stabilization of abdomen	Intercostal nerves (T5-T12)
External abdominal muscle	External surface of ribs 5-12	Linea alba, pubic tubercle and anterior half of iliac crest	Flexes and contralateral rotation of the torso Compresses and supports abdomen as well as abdominal viscera	Thoraco abdominal nerves (T7-T11) Subcostal nerve (T12)
Gluteus maximus	Posterior iliac crest, posterior surface of sacrum and coccyx and sacrotuberous ligament	Iliotibial band and gluteal tuberosity of femur	Extends thigh, assists in lateral rotation of hip	Inferior gluteal nerve (L5,S1,S2)

Muscle	Origin	Insertion	Function	Nerve
Gluteus medius	External surface of ilium, between anterior and posterior gluteal lines	Lateral surface of greater trochanter of femur	Abduction of the hip, medial rotation of thigh Prevents pelvis from tilting when ipsilateral limb is weight bearing	Superior gluteal nerve (L5,S1)
Biceps femoris	Long head: Ischial tuberosity Short head: Lateral lip of linea aspera and supracondylar line of femur	Head of fibular (lateral side)	Flexion of leg, and laterally rotates knee when knee is flexed Extension of thigh	Sciatic nerve: Long head (tibial division L5,S1,S2) Short head (Common peroneal division L5,S1,S2)
Rectus femoris	Anterior inferior iliac spine and ilium superior to acetabulum	Tibial tuberosity via the quadriceps tendon and patellar ligament	Extenion of the leg at knee Steadies hip joint Aids in hip flexion	Femoral Nerve (L2,3,4)
Tibialis anterior	Lateral condyle, proximal half of lateral surface of tibia and interosseous membrane	Medical cuniform and base of 1^{st} metatarsal (medial plantar surface)	Dorsiflexion and inversion of ankle	Deep peroneal nerve (L4,L5,S1)
Gastrocnemius	Medial head: Popliteal surface of femur, superior to medial condyle of femur Lateral head: Lateral aspect of lateral condyle of femur	Calcaneus via calcaneal tendon	Plantar flexion of the foot Flexes knee and inverts foot (weak actions)	Tibial nerve (S1,S2)
Soleus	Soleal line and middle border of tibia, posterior aspect of fibular head and superior ¼ of posterior surface of fibular	Calcaneus via calcaneal tendon	Plantar flexes food Steadies leg on foot	Tibial nerve (S1,S2)

Appendix N : Higher Degrees Committee letter

FACULTY OF HEALTH SCIENCES

HIGHER DEGREES COMMITTEE

HDC-01-101- 2018

29 October 2018

TO WHOM IT MAY CONCERN:

STUDENT: VAN DONGEN, MA
STUDENT NUMBER: 201309560

TITLE OF RESEARCH PROJECT: The Immediate Effect of a Chiropractic Manipulation on the Hitting Speed in Squash

DEPARTMENT OR PROGRAMME: CHIROPRACTIC

SUPERVISOR: Dr C Hay CO-SUPERVISOR: Dr G Hardie

The Faculty Higher Degrees Committee has scrutinised your research proposal and concluded that it complies with the approved research standards of the Faculty of Health Sciences; University of Johannesburg.

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

Yours sincerely,

Prof H Abrahamse
Acting Chair: Faculty of Health Sciences HDC
Tel: 011 559 6550
Email: habrahamse@uj.ac.za

Appendix O : Research Ethics Committee clearance letter

FACULTY OF HEALTH SCIENCES
RESEARCH ETHICS COMMITTEE

NHREC Registration: REC 241112-035

ETHICAL CLEARANCE LETTER
(RECX 2.0)

Student/Researcher Name	Van Dongen, MA	Student Number	201309560
Supervisor Name	Dr C Hay	Co-Supervisor Name	Dr G Hardie
Department	Chiropractic		
Qualification	367		
Research Title	The Immediate Effect of a Chiropractic Manipulation on the Hitting Speed in Squash		
Date	12 November 2018	Clearance Number	**REC-01-160-2018**

Approval of the research proposal with details given above is granted, subject to any conditions under 1 below, and is valid until 31 January 2019.

1. **Conditions:**

Registration of the research on the South African National Clinical Trial Register.

2. **Renewal:**

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

3. **Amendments:**

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

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

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

The REC wishes you all the best for your studies.

Yours sincerely,

Prof. Christopher Stein
Chairperson: REC
Tel: 011 559 6564
Email: cstein@uj.ac.za

Secretariat: Ms Raihaanah Pieterse
Tel: 011 559 6073 email: rpieterse@uj.ac.za

Appendix P : Turnitin report

turnitin

Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

The first page of your submissions is displayed below.

Submission author:	MA VANDONGEN
Assignment title:	Submit proposals, theses, disserta..
Submission title:	Full dissertation
File name:	Turnitin.docx
File size:	1.42M
Page count:	57
Word count:	11,947
Character count:	62,155
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CHAPTER 1 – INTRODUCTION