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How to cite this thesis
THE EFFECT OF POWER®BALL ON NON-SPECIFIC WRIST PAIN

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

Jacques Herman Maree
(Student number: 200700891)

Supervisor: _________________ Date: ______________________
Dr. I. Landman
DECLARATION

I, Jacques Herman Maree, declare that this dissertation is my own, unaided work. It is being submitted as partial fulfilment of the Master's 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 Technikon or University.

________________________________________
Jacques Herman Maree

On this day the _____ of the month of __________ 2015.
AFFIDAVIT

AFFIDAVIT: MASTER’S AND DOCTORAL STUDENTS

TO WHOM IT MAY CONCERN

This serves to confirm that I Jacques Herman Maree
ID number 8712075044083 Student number 200700891 enrolled student
for the Qualification MTECH: CHIROPRACTIC Faculty of Health
Sciences,

Herewith declare that my academic work is in line with the Plagiarism
Policy of the University of Johannesburg. I further declare that the work
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infringement in the work. I declare that no unethical research practices
were used or material gained through dishonesty. I understand that
plagiarism is a serious offence.

Signed at ___________________ on this ___ day of _____________ 2015.

_________________________                                _____________________
Signature                                                           Print name

STAMP COMMISSIONER OF OATHS
Affidavit certified by a Commissioner of Oaths
ABSTRACT

**Purpose:** The aim of this study was to determine the effect of using the Power®Ball gyroscope as a treatment device, with regards to pain and change in endurance in the wrist for participants with a non-specific wrist injury. The aim was determined by using the Jamar Dynamometer grip strength measuring instrument and the Patient Rated Wrist Evaluation Questionnaire.

**Method:** The study consisted of 40 participants that had an equal male to female distribution. The individuals had to be between the set ranges of 18 to 35 years of age to prevent any discrepancies regarding the participant’s grip strength and had to meet the inclusion and exclusions criteria before being accepted into the study. The participants had to use the Power®Ball gyroscope for 5 minutes per treatment session.

**Procedure:** Treatment consisted of 12 treatment sessions and was carried out 3 times per week so that the treatment time period occurred over a four week study period. Participants were required to complete the objective and subjective data before the 1st, 7th and 12th treatment sessions. The objective data were recorded by using the Jamar Dynamometer to record the change in grip strength for each participant throughout the study. The subjective data were gathered by using the Patient Rated Wrist Evaluation Questionnaire. Participants then used the Power®Ball gyroscope in the hand with the affected wrist. All data recorded were gathered under the supervision of the researcher and analysed by a statistician at the University of Johannesburg.

**Results:** Significant findings were present for both the Patient Rated Wrist Evaluation Questionnaire and the Grip strength measurements with the Jamar Dynamometer. A constant, significant decrease in pain was noted throughout the study but the most significant changes occurred between
the 7th and 12th treatment sessions. A significant increase in grip strength was also noted throughout the study with the greater increase in grip strength occurring during the first 7 treatments.

**Conclusion:** The results of this study suggest that the Power®Ball gyroscope has a positive effect on the treatment and rehabilitation of non-specific wrist pain. The possible effect/outcome for the chiropractic profession suggest that the Power®Ball may be used as an alternative, conservative treatment modality or in conjunction with an existing treatment protocol for treating sub-acute or chronic non-specific wrist pain. Additionally the results indicated that the Power®Ball may serve as a grip strengthening or endurance device to prevent future injury to the wrist.
DEDICATIONS

I would foremost like to thank my heavenly Father for the strength and wisdom He gave me to complete this dissertation. Every prayer was answered through this period and I am blessed by Your unconditional love and grace.

I dedicate this research to my soon to be wife, Maryke Botes, thank you for your endless faith in me, your continuous motivational speeches, love and support through my thoroughly dragged-out student career.

I would like to thank my parents, Derick and Sanet, for your continuous financial and emotional support and unconditional love throughout the past 27 years. Lastly I would also like to thank my friends for bearing with me throughout my student years; the journey was made much easier with all of you by my side.
ACKNOWLEDGEMENTS

I would like to thank Dr. Irmarie Landman for her boundless insight and guidance through the journey to completing my dissertation. You were always easily accessible and a pleasure to work alongside.

I would like to acknowledge Anesu Kuhudzai of STATKON at the University of Johannesburg for the data analysis of this study and Kelly Gilbertson for her professional input regarding the editing of this dissertation. You’re work ethics and light speed communication truly amazed me.

I would like to acknowledge Rory McLoughney, CEO of RPM Sports, who did not hesitate to supply me with the equipment needed to pursue this task. Thank you for your unwavering kindness and support.

Lastly I would like to acknowledge all the participants who gave me their precious time and full commitment to this study. Thank you for your unconditional dedication to this study.

Baie dankie.
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CHAPTER ONE:
INTRODUCTION
CHAPTER ONE - INTRODUCTION

1.1 The Problem Statement

Although hand and wrist injuries are not hazardous to a person’s wellbeing, they are of great importance in terms of our average daily living (Wang, Reed, Leone, Bhandari and Moro, 2001). Almost every professional career relies on the optimum function of the worker’s wrists to complete a certain function. Wrist pain may hinder athletes from lifting weights, throwing a javelin, swinging a tennis racquet or holding a bicycle handle. Wrist pain may also be an irritation in professions where hands are constantly used, such as in the case of chiropractors, physiotherapists, secretaries and typists.

Any anatomical structure under constant stress will often lead to injury. However, because of the complicated anatomy of the wrist, the close relationship of multiple bones and ligaments in the wrist and subtle imaging findings, the pathophysiology may appear vague and not related to a single structure (Vezeridis, Yhosioka, Han and Blazar, 2009). Abnormal biomechanics and repetitive motions across the wrist joint may lead to pain and dysfunction. Wrist pain may be a result of both traumatic and non-traumatic events. Traumatic wrist injuries may lead to possible fractures and dislocations, while non-traumatic wrist injuries may develop from muscle, ligament and tendon dysfunction, which may lead to injuries such as tenosynovitis, nerve entrapment and arthritis (Wang et al., 2001).

From a health clinician’s perspective, difficulty arises in the treatment and rehabilitation of the injury if the pathophysiology of the injury is not understood. A vast amount of conservative treatment options and devices are currently available for wrist pain, although research on the treatment of wrist pain is limited in the cases where fractures and surgery are excluded. One such conservative treatment device available is the Power®Ball gyroscope.
The Power®ball is based upon the principles of a gyroscope, which focus on exercising muscular build-up of the upper extremities. Research has shown that exercise with the Power®Ball increases the muscle endurance substantially over a one month period as well as highly increases the number of contractions of the forearm muscles. The Power®Ball acts as an eccentric exercise tool, generating forces in different directions and thus causing stimulation of the forearm, hand and wrist musculature (Balan and Garcia-Elias, 2008).

1.2 Aim
The aim of this study was to determine the effect of utilising the Power®Ball gyroscope as a treatment device, specifically for pain and change in endurance in the wrist for participants with a non-specific wrist injury.

1.3 Benefits of the Study
The study determined the proficiency and effectiveness of the Power®Ball as a treatment or rehabilitation tool for non-specific wrist pain. The outcomes of the study will provide healthcare clinicians with an alternative, conservative treatment protocol for treating non-specific wrist pain. Additionally, the results indicate that the Power®Ball may serve as a grip strengthening device to prevent future injury to the wrist.
CHAPTER TWO - LITERATURE REVIEW

2.1 Introduction
The primary focus of this study was to determine the effects of using the Power®Ball as a treatment device for patients with non-specific wrist pain.

In order to provide a clear background and understanding of this study, the following will be discussed in this literature review: the anatomy and biomechanical behaviour of the wrist, Power®Ball, proprioception of the wrist and the pathophysiology behind non-specific wrist injuries, such as:

- Lunotriquetral-, schapholunate-, and ulnatriquetral-instability
- Repetitive stress injuries (RSI)
- Triangular fibrocartilage complex (TFCC) sprains
- Hyperextended and hyperflexion wrist injuries
- Chronic tenosynovitis
- Hypermobile wrists
- Muscle atrophy.

The human hand has been characterised as a symbol of power, an extension of intellect and the seat of the will. The symbiotic relation of the mind and hand is exemplified by sociologists’ claim that while the brain is responsible for the design of civilisation, the hand is responsible for its formation (Levangie and Norkin, 2011).

The upper limb is defined by its capability to embrace and move objects, and control fine motor dexterity. These attributes of the hand are specifically convenient while performing manual, fine motor activities, such as picking up keys or unbuttoning a shirt. The hand, together with the forearm, forms part of the most distal aspect of the upper limb. It consists of the carpal, metacarpal and phalangeal bones and is divided into the dorsum of hand, palm, wrist and digits. The hand and wrist are abundantly supplied with sensory nerve endings for pain, temperature and touch (Moore, Dalley and Agur, 2014).
The wrist complex is formed by eight carpal bones, aligned in two chains of four bones. The two chains of carpal bones fundamentally form two compound joints, namely the radiocarpal and midcarpal joints. These two joints collectively form the wrist complex. These carpal bones and compound joints allow for flexibility of the wrist complex. The posterior aspect of the wrist is markedly convex and the anterior aspect markedly concave. The two chains of carpal bones synchronise and glide in unison with each carpal bone adjacent to it thus enhancing the movement at the wrist complex (Moore, Dalley and Agur, 2014).

Wrist pain is a serious condition in terms of morbidity, since it often leads to functional disability (Wang et al., 2001). Injuries to the hand amount to 10% of all Emergency Department visits and up to 20% of all traumatic or non-traumatic injuries treated (De Jong, Nguyen, Sonnema, Nguyen, Amadio and Moran, 2014). In addition, 3% to 9% of injuries related to athletes are associated with the hand and the wrist and younger athletes, such as children and adolescent athletes, tend to experience more wrist trauma than adult athletes. Untreated wrist injuries may lead to exacerbation of the injury and symptoms, which often lead to a decreased quality of performance at work or on the sport’s field (Parmalee-Peters and Eathorn, 2005).

2.2 Functional Anatomy of the Wrist

2.2.1 Osteology of the wrist

According to Moore, Dalley and Agur (2014), the wrist is formed by eight carpal bones, perfectly aligned in two chains of four carpal bones (Figure 2.1). The proximal chain, from lateral to medial, consists of the scaphoid, lunate, triquetrum and pisiform carpal bones. The most medial carpal bone, the scaphoid (G. skaphé, skiff, boat) is the largest of the proximal carpal bones. It is bow-shaped with a scaphoid tubercle. The scaphoid bone articulates proximally with the radius. The lunate (L. luna, moon), which has the same appearance as a half moon or sickle, is thicker
anteriorly compared to its posterior surface. It is positioned lateral to the scaphoid and medial to the triquetral carpal bones. The lunate’s superior or proximal surface articulates with the distal surface of the radius. The triquetrum (L. triquetus, triangular) is a pyramidal or three-cornered carpal bone articulates with the lunate on its lateral surface and the pisiform carpal bone on its medial surface. The articular disc of the distal radioulnar joint articulates distally with the triquetrum. Finally, the pisiform (L. pisum, pea) is a small knob-like bone, located on the medial border of the palmar surface of the wrist, closely related to the triquetrum bone.

![Figure 2.1: Bones of the Right Hand and Wrist (Moore, Dalley and Agur, 2014)](image)

The distal chain, from lateral to medial, contains the trapezium, trapezoid, capitate and hamate carpal bones. The trapezium (G. trapeze, table) is an asymmetrical, quadrangular carpal bone and is located distal to the scaphoid carpal bone on the lateral aspect of the wrist complex. The trapezium carpal bone articulates with the first and second metacarpal bones, scaphoid and trapezoid carpal bones. The Trapezoid (lesser multangular) is a keystone-shaped bone and resembles a trapezium shape. It is positioned medial to the trapezium and lateral to the capitate carpal bone and articulates with the second metacarpal bone and the trapezium, capitate and scaphoid carpal bones. The capitate (L. caput, head) is the largest bone in the wrist. It is a round, head-shaped bone and articulates with the third metacarpal bone distally and proximally with the
trapezoid, scaphoid, lunate and hamate carpal bones. Lastly, the hamate (L. *hamulus*, hook) is a wedge-shape bone with a hook process that extends anteriorly and is positioned medial to the capitate carpal bone on the medial aspect of the wrist. It articulates with both the fourth and fifth metacarpal bones and the capitate and triquetrum carpal bones (Moore, Dalley and Agur, 2014).

**2.2.2 Musculature surrounding the wrist joint**

Movement at the wrist complex is primarily generated by the tendons and muscles of the forearm. The tendons, of which extend along the four edges of the wrist, attaches to the bases of the metacarpal bones (Moore, Dalley and Agur, 2014). The primary function of the muscles of the wrist complex is to provide a stable base to allow for optimal range of motion for the hand. Wrist flexion is predominantly generated by the six muscles that have tendons crossing the volar or anterior aspect of the wrist. These are the flexor digitorum profundus (FDP), flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), palmaris longus (PL), flexor digitorum superficialis (FDS) and the flexor pollicis longus (FPL) muscles. Wrist extension is predominantly generated by the nine extensor tendons of the extensor muscles passing over the dorsal aspect of the wrist complex. These are the extensor indicis proprius (EIP), extensor digiti minimi (EDM), extensor digitorum communis (EDC), extensor pollicis brevis (EPB), extensor pollicis longus (EPL) and the abductor pollicis longus (APL) musculature. (Levangie and Norkin, 2011)

*Muscles of the volar aspect of the wrist*

The palmaris longus (PL), flexor carpi ulnaris (FCU) and flexor carpi radialis (FCR) are primary wrist muscles, while the flexor digitorum profundus (FDP), flexor pollicis longus (FPL) and the flexor digitorum superficialis (FDS), act as flexors of the digits and secondary wrist actions at the joint (Tables 2.1.1 and 2.1.2). All the volar muscles pass beneath the flexor retinaculum, except for the palmaris longus and flexor carpi ulnaris muscles (Figure 2.2).
Figure 2.2: Relationship of Tendons to the Flexor Retinaculum of the left wrist (Levangie and Norkin, 2011)

Table 2.1.1: Musculature of the Anterior/Volar Compartment of the Forearm, Superficial and Intermediate Layers (Moore, Dalley and Agur, 2014)

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Proximal Attachment</th>
<th>Distal Attachment</th>
<th>Innervation</th>
<th>Main Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Superficial Layer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pronator Teres</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ulnar head</td>
<td>Coronoid process</td>
<td>Middle of convexity of lateral surface of radius</td>
<td>Median nerve (C6,C7)</td>
<td>Pronates and flexes forearm at the elbow</td>
</tr>
<tr>
<td>Humeral head</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexor carpi radialis</td>
<td>Medial epicondyle of humerus from common flexor origin</td>
<td>Base of 2nd metacarpal</td>
<td></td>
<td>Flexes and abducts hand at the wrist</td>
</tr>
<tr>
<td>Palmaris longus</td>
<td></td>
<td>Distal half of flexor retinaclum and apex of palmar aponeurosis</td>
<td>Median nerve (C7,C8)</td>
<td>Flexes hand at the wrist and tenses palmar aponeurosis</td>
</tr>
<tr>
<td><strong>Intermediate Layer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexor carpi ulnaris</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ulnar head</td>
<td>Olecranion and posterior border of ulna via aponeurosis</td>
<td>Pisiform, hook of hamate and 5th metacarpal</td>
<td>Ulnar nerve (C7,C8)</td>
<td>Flexes and adducts the hand at the wrist</td>
</tr>
</tbody>
</table>
Table 2.1.2: Musculature of the Anterior/Volar Compartment of the Forearm, Deep Layers (Moore, Dalley and Agur, 2014)

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Proximal Attachment</th>
<th>Distal Attachment</th>
<th>Innervation</th>
<th>Main Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexor digitorum profundus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medial part</td>
<td>Proximal three quarters of medial and anterior surfaces of ulna and intersosseous membrane</td>
<td>Bases of distal phalanges of 4th and 5th digits</td>
<td>Ulnar nerve (C8,T1)</td>
<td>Flexes distal phalanges 4 and 5 at distal interphalangeal joints</td>
</tr>
<tr>
<td>Lateral part</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexor pollicis longus</td>
<td>Anterior surface of radios and adjacent intersosseous membrane</td>
<td>Base of distal phalanx of thumb</td>
<td>Anterior interosseous nerve derived from median nerve (C6,T1)</td>
<td>Flexes phalanges of 1st digit</td>
</tr>
<tr>
<td>Pronator quadratus</td>
<td>Distal quarter of anterior surface of ulna</td>
<td>Distal quarter of anterior surface of radius</td>
<td></td>
<td>Pronates forearm, the deep fibres bind radius and ulna together</td>
</tr>
</tbody>
</table>

Muscles of the dorsal aspect of the wrist

The extensor carpi ulnaris (ECU), extensor carpi radialis longus (ECRL) and the extensor carpi radialis brevis (ECRB) are primary wrist extensors, while the extensor pollicis longus (EPL), extensor pollicis brevis (EPB), extensor digitorum communis (EDC), extensor indicis proprius (EIP), extensor digiti minimi (EDM), and the abductor pollicis longus (APL) act as secondary extensors on the wrist complex and phalanges (Tables 2.2.1 and 2.2.2). All the dorsal wrist musculature pass under the extensor retinaculum (Figure 2.3). Each tendon is covered within its own tendon sheath to prevent friction between the surrounding structures (Levangie and Norkin, 2011).
Table 2.2.1: Musculature of the Posterior/Dorsal Compartment of the Forearm, Superficial Layer (Moore, Dalley and Agur, 2014)

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Proximal Attachment</th>
<th>Distal Attachment</th>
<th>Innervation</th>
<th>Main Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial layer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brachioradialis</td>
<td>Proximal two thirds of supra-epicondylar ridge of humerus</td>
<td>Lateral surface of distal end of radius proximal to styloid process</td>
<td>Radial nerve (C5-C7)</td>
<td>Weak flexion of forearm and maximal flexion of forearm in mid-pronated position</td>
</tr>
<tr>
<td>Extensor carpi radii</td>
<td>Lateral supra-epicondylar ridge of humerus</td>
<td>Dorsal aspect of base of 2nd metacarpal</td>
<td>Radial nerve (C6, C7)</td>
<td>Extend and abduct hand at wrist joint, ECRL active during fist clenching</td>
</tr>
<tr>
<td>Extensor carpi radialis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bravis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extensor digitorum</td>
<td>Lateral epicondyle of humerus via common extensor origin</td>
<td>Exensor expansions of metacarpal joints</td>
<td>Deep branch of radial nerve (C7, C8)</td>
<td>Extends 5th digit primarily at the metacarpophalangeal joint and secondarily at the interphalangeal joint</td>
</tr>
<tr>
<td>Extensor digiti</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>minimus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extensor carpi</td>
<td>Lateral epicondyle of humerus and posterior border</td>
<td>Dorsal aspect of base of 5th metacarpal</td>
<td></td>
<td>Extends and adducts hand at wrist joint</td>
</tr>
<tr>
<td>ulnaris</td>
<td>of ulna via a shared aponeurosis</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2.3: Relationship of Tendons of the Right Dorsal Wrist Musculature to the Extensor Retinaculum (Levangie and Norkin, 2011)
Table 2.2.2: Musculature of the Posterior Compartment/Dorsal of the Forearm, Deep Layer (Moore, Dalley and Agur, 2014)

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Proximal Attachment</th>
<th>Distal Attachment</th>
<th>Innervation</th>
<th>Main Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Deep layer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supinator</td>
<td>Lateral epicondyle of humerus, radial collateral and annular ligaments; supinator fossa and crest of ulna</td>
<td>Lateral, posterior and anterior surfaces of proximal third of radius</td>
<td>Deep branch of radial nerve (C7,C8)</td>
<td>Supinates forearm; rotates radius to turn palm anteriorly or superiorly when the elbow is fixed</td>
</tr>
<tr>
<td>Extensor indicis</td>
<td>Posterior surface of distal third of ulna and interosseous membrane</td>
<td>Extensor expansion of 2nd digit</td>
<td>Posterior interosseous nerve (C7,C8), continuation of deep branch of radial nerve</td>
<td>Extends 2nd digit and helps extend hand at the wrist</td>
</tr>
<tr>
<td><strong>Outcropping muscles of deep layer</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abductor pollicis longus</td>
<td>Posterior surface of proximal halves of ulna and interosseous membrane</td>
<td>Base of 1st metacarpal</td>
<td>Posterior interosseous nerve (C7,C8), continuation of deep branch of radial nerve</td>
<td>Abducts thumb and extends it at the carpometacarpal joint</td>
</tr>
<tr>
<td>Extensor pollicis longus</td>
<td>Posterior surface of middle third of ulna and interosseous membrane</td>
<td>Dorsal aspect of base of distal phalanx of thumb</td>
<td></td>
<td>Extends distal phalanx of thumb at interphalangeal joint, extends metacarpophalangeal and carpometacarpal joints</td>
</tr>
<tr>
<td>Extensor pollicis brevis</td>
<td>Posterior surface of distal third of radius and interosseous membrane</td>
<td>Dorsal aspect of base of proximal phalanx of thumb</td>
<td></td>
<td>Extends proximal phalanx of thumb at metacarpophalangeal joint and extends carpometacarpal joint</td>
</tr>
</tbody>
</table>

2.2.3 Joints of the wrist

*Distal radioulnar joint*

The spherical head of the ulna and the ulnar notch of the distal end of the radius articulate with one another to form the distal radioulnar joint. An articular disc, the triangular fibrocartilage articular disc of the distal radioulnar joint, is positioned between the extremities of the ulna and radius. This disc allows for better congruency between these two structures. The inferior surface of the articular disc connects to the medial boundary of the ulnar notch of the radius, and the superior boundary is attached to the lateral aspect of the inferior surface of the styloid process of the ulna. The distal surface of the head of the ulna and the proximal surface of the triangular fibrocartilage disc articulate with each other to increase congruency of the distal radioulnar joint. This triangular
The fibrous layer of the joint capsule of the distal radioulnar joint receives ligamentous support from the volar and dorsal radioulnar ligaments. Although rather frail, these transverse radioulnar ligaments extend
between the ulna and radius and inhabit the anterior and posterior surfaces of the distal radioulnar joint (Moore, Dalley and Agur, 2014).

The triangular fibrocartilage complex (TFCC) stabilise the DRUJ and ulnar aspect of the carpal bones. This ligament complex also transmits axial compressive loads among the carpal bones and the ulna. The TFCC consist of an ulnotriquetral ligament, ulnolunate ligament, volar and dorsal radioulnar ligaments, proximal ligamentous component and the ulnar collateral ligament, an articular disc and the meniscus homologue (Vezeridis, Yhosioka, Han and Blazar, 2009). Overall, the TFCC should be considered to function at the wrist as an extension of the distal radius, just as it does at the distal radioulnar joint (Levangie and Norkin, 2011).

The anterior and posterior interosseous arteries are responsible for the blood supply to the distal radioulnar joint. The anterior and posterior interosseous nerves supply innervation to the distal radioulnar joint (Moore, Dalley and Agur, 2014).

Radiocarpal joint structure
The radiocarpal joint (RCJ) is formed by the distal radius and the radioulnar disc as part of the TFCC proximally and by the scaphoid, lunate and triquetrum distally (Levangie and Norkin, 2011). The RCJ is characterised as a condyloid joint. The location of the condyloid joint is determined by a straight line between the styloid process of the radius and the distal aspect of the ulna. The fibrous layers of the joint capsule surrounding the wrist are attached to the proximal chain of carpal bones, the ulna and head of the radius. The synovial membrane of the RCJ lines the inner layer of the fibrous joint capsule (Moore, Dalley and Agur, 2014).

The wrist joint is stabilised and strengthened anteriorly and posteriorly by durable palmar and dorsal radiocarpal ligaments. These dorsal radiocarpal ligaments align with the direction of the hand so that during supination of
the forearm the hand shifts with the radius. The palmar radiocarpal ligaments pass from the radius to the two chains of carpal bones. They follow the direction of the hand so that during pronation of the forearm the hand shifts with the radius (Levangie and Norkin, 2011).

As discussed above, the scaphoid, lunate and triquetrum comprise the proximal carpal row (Figure 2.1). The proximal carpal row articulates with the distal radius and forms the radiocarpal joint. These bones are connected by two ligaments, namely, the scapholunate interosseous and lunotriquetral interosseous ligaments. The carpal bones together with the ligaments resemble the appearance of a single biconvex cartilage-covered joint surface that can alter its shape to adapt to the surface between the forearm and hand. The pisiform does not participate in radiocarpal movement and functions entirely as a sesamoid bone; presumably to increase range of movement of the flexor carpi ulnaris tendon that envelops it. The radiocarpal joint favours the range of flexion and ulnar deviation compared to the midcarpal joint (Levangie and Norkin, 2011).

The radiocarpal joint is essential for adduction from the neutral position while the midcarpal joint is responsible for abduction from the neutral position. The RCJ receives its blood supply from the branches of the dorsal and palmar carpal arches while the nervous innervation to the RCJ is supplied by the dorsal and deep branches derived from the ulnar nerve, the anterior interosseous branch derived from the median nerve and the posterior interosseous branch derived from the radial nerve (Moore, Dalley and Agur, 2014).

The midcarpal joint structure

The trapezium, trapezoid, capitate and hamate carpal bones collectively form the distal carpal chain or row (Figure 2.1). The midcarpal joint is formed between the proximal and distal carpal chains respectively, and has a fibrous capsule and synovial lining that is uninterrupted between
each intercarpal articulation. The midcarpal joint structure moves almost as a single functional unit and does not form a single uninterrupted articular surface. Owing to the union of these distal carpals, there is a nearly equal distribution of loads across the scaphoid-trapezium, scaphoid-capitate, lunate-capitate and triquetrum-hamate ligamentous articulations. The midcarpal joint favours the range of extension over flexion and radial deviation over ulnar deviation compared with the radiocarpal joint (Levangie and Norkin, 2011).

The blood supply to the midcarpal joint is derived from the dorsal and palmar carpal branches. The midcarpal joint receives its innervation from the dorsal and deep branches derived from the ulnar nerve and the anterior interosseous branch derived from the median nerve (Levangie and Norkin, 2011).

2.2.4 Carpal ligaments

The ligaments of the wrist complex are divided into intrinsic and extrinsic groups. The intrinsic ligaments connect the individual carpal bones to each other, and are labeled as intercarpal ligaments while the extrinsic ligaments link the carpal bones to the ulna and radius superiorly and to the metacarpal bones inferiorly (Levangie and Norkin, 2011).

Volar carpal ligaments

Volar extrinsic ligaments are divided into two groupings: radiocarpal ligaments and ulnocarpal ligaments. Volar radiocarpal ligaments contain three bands, namely: radioscapophocapitate, short and long radiolunate and radioscapopholunate. The ulnocarpal ligament complex consists of the TFCC, the ulnar collateral ligament and the ulnolunate ligament. The radial collateral ligament (Figure 2.5) may be considered an extension of the volar radial carpal ligament and capsule (Levangie and Norkin, 2011).
Two volar intrinsic ligaments are found in the wrist, the scapholunate and lunotriquetral ligaments. The scapholunate ligament plays a key role in stability between the scaphoid and lunate carpal bone and the wrist as a whole. The lunotriquetral ligament is credited with maintaining stability between the lunate and the triquetrum carpal bones. In general, the volar wrist ligaments are placed on stretch with wrist extension (Levangie and Norkin, 2011).

Two dorsal carpal ligaments contribute to stability of the dorsal aspect of the wrist. The first, the dorsal radiocarpal ligament, varies somewhat in description, owing to its oblique orientation. It passes over the triquetrum and lunate carpal bones and lunotriquetral ligament from the distal radius to provide stability to this region. The second, the dorsal intercarpal ligament, passes horizontally over the triquetrum, lunate, scaphoid and trapezium carpal bones. These two ligaments form a horizontal “V”-shaped ligament that contributes to radiocarpal stability and assists in the movement of the scaphoid and the wrist as a whole during flexion of the wrist (Levangie and Norkin, 2011).
2.2.5 Innervation of the hand

The median nerve in the hand

The median nerve arises from two spinal nerve roots, the lateral and the medial cords of the brachial plexus (C5-T1). The anterior interosseous nerve arises from the median nerve to supply the flexor pollicis longus, pronator quadratus, flexor digitorum profundus and second and third digits of the hand. The median nerve arises superficial to the proximal aspect of the wrist and passes to the flexor retinaculum through the carpal tunnel to the hand. The median nerve supplies the thenar muscles of the hand, except the adductor pollicis and the flexor pollicis brevis’ deep head and the lateral two lumbricals for the second and third digits. The median nerve provides sensation to the skin overlying the palmar and dorsal aspects of the lateral three and a half digits adjacent to the palm. The palmar cutaneous branch of the median nerve arises proximal to the carpal tunnel and flexor retinaculum, passes superficially over the carpal tunnel and supplies sensation to the central palm (Moore, Dalley and Agur, 2014).

The ulnar nerve in the hand

The ulnar nerve arises from the terminal branch of the medial cord of the brachial plexus (C8-T1). The ulnar nerve passes superficially in the distal forearm and travels to the flexor retinaculum to enter the hand medially to the pisiform and laterally to the ulnar artery within Guyon’s canal. The nerve innervates the flexor carpi ulnaris and the flexor digitorum profundus and the majority of the intrinsic muscles of the hand, such as the adductor pollicis, flexor pollicis brevis’ deep head, and medial lumbricals of the fourth and fifth digits, hypothenar and interosseous musculature. The palmar cutaneous branch of the ulnar nerve arises proximally to the wrist, passes superficially to the palmar aponeurosis and flexor retinaculum and provides sensation the medial side of the palm. The ulnar nerve provides cutaneous sensation to the skin overlying the palmar aspect and the distal part of the dorsal aspects of the medial half of the phalanges (Moore, Dalley and Agur, 2014).
The radial nerve in the hand

The radial nerve arises from the terminal branch of the posterior cord of the brachial plexus (C5-T1). It passes through cubital fossa, bounded by the brachioradialis and brachialis muscles, and passes anterior to the lateral epicondyle of the elbow to divide into the terminal deep and superficial branches. The ulnar nerve supplies sensory and motor functions to the forearm and arm, but only sensory function to the hand. It divides into a posterior cutaneous nerve of the forearm, which supplies sensation to the posterior aspect of the forearm and wrist, a superficial branch of the radial nerve, which supplies sensation to the skin on the dorsum of the hand, and a deep branch of the radial nerve, which divides to form the posterior interosseous nerve. The posterior interosseous nerve supplies motor function to all the posterior compartment muscles of the forearm (Moore, Dalley and Agur, 2014).

2.2.6 Proprioception of the wrist joint

When the mechanoreceptors in the intra-articular ligaments are stimulated by a stimulus (Figure 2.6, a), information is sent via the afferent fibres to the dorsal horn of the spinal cord (b) This information will be relayed via two pathways. A monosynaptic relay of immediate stimuli from the dorsal to the anterior horn (c) provides fast control of the musculature surrounding the wrist joint (e). A local, polysynaptic secondary interaction transmits afferent information via the spinocerebellar and dorsolateral tracts of the spinal cord to various areas in the brain (d). Some information is transmitted to primary somatic sensory areas for complex interpretation and integration of somatosensory stimuli and proprioception in the cerebellum. These areas control the unconscious neuromuscular behaviour of a joint. Areas which receive stimuli for the control of conscious neuromuscular control of the joint are located in the primary motor and sensory cortices (Hagert, 2010).
2.2.7 Movement at the wrist joint

The movement of the wrist joint is controlled by smaller, defined changes at the midcarpal and intercarpal joints. These changes or movements occurring at the wrist joint are flexion, extension, adduction, abduction and circumduction. Wrist joint movement are primarily produced by the muscles and tendons of the forearm, which pass over the wrist to attach to the metacarpals (Levangie and Norkin, 2011).

Flexion of the wrist joint is produced by the abductor pollicis longus, flexor carpi ulnaris, flexor carpi radialis, and palmaris longus. Extension of the wrist joint is produced by the extensor carpi radialis longus, extensor carpi ulnaris and extensor carpi radialis brevis. Abduction of the wrist joint is produced by the flexor carpi radialis, abductor pollicis longus, extensor carpi radialis brevis and extensor carpi radialis brevis. Adduction of the wrist joint is generated by concurrent stimulation of the flexor carpi ulnaris and extensor carpi ulnaris musculature (Moore, Dalley and Agur, 2014).
2.2.8 Prehension of the hand

Prehension animations of the hand involve the clasping or clinching of an object between any two contact areas in one hand. Prehension can be categorised into two groups: power grip, which utilises the full aspect of the hand during prehension, and precision handling, which uses specific finger and thumb prehension (Levangie and Norkin, 2011).

Power grip requires precise control and assists with maintaining flexor asymmetry of the hand. Greater static control and stability is mainly provided by the ulnar sided digits. Power grip will cause the Power®Ball to be maintained against the patient’s palm and held in position by the patient’s digits and tension in the extrinsic muscles of the forearm. The optimal position during the formation of the power grip is when the fingers are flexed and the wrist in slight ulnar deviation and extension while the combined joint position holds the hand in line with the forearm. Power grip can be categorised into four sub-groups, namely the hook, cylinder, fist and spherical grasp (Magee, 2008). Cylinder and spherical grips will be discussed in more detail, as these will be used to hold the Jamar Dynamometer in the optimum position during grip strength measurements (cylinder grip) and while holding the Power®Ball during the treatment periods (spherical grip).

Spherical grip

Spherical grip (Figure 2.7) utilises opposition of the digits to move the hand around a sphere or object. The metacarpophalangeal joint tends to abduct the digits, and more interosseous movement is used compared with other power gasps. The phalanges tend to deviate from each other to form the spherical grip. This grip is predominantly achieved by the tension in the flexor musculature, but the extensor also plays a role. Extensor muscles of the forearm provide a balancing force towards the tension of the flexor muscles and guide the flexor muscles in performing smooth
movement of the hand. This counter movement is achieved by activity of the lumbricals, extensor digitorum communis and the thumb extrinsic muscles (Levangie and Norkin, 2011).

Figure 2.7: Spherical grip of right hand (Magee, 2008)

Figure 2.8: Spherical grip while holding the Power®Ball in left hand (Photo by researcher)

*Cylinder grip*
Cylinder grip (Figure 2.9) utilises the contraction of the flexors to position the digits around an object. This grip is mainly maintained by activity of the flexor digitorum profundus muscle during the dynamic phase of closing the digits around a cylinder and by the flexor digitorum superficialis muscle,
during the static phase, when a greater intensity of force is required (Levangie and Norkin, 2011).

Figure 2.9 Cylinder grip of right hand (Magee, 2008)

Figure 2.10: Cylinder grip while holding the Jamar Dynamometer in left hand (Photo by researcher)
2.2.9 Biomechanics and Pathomechanics of the wrist

Injury to the wrist may either be due to a traumatic event, repetitive loading and overuse activities, which may be non-traumatic. The cause or history of the injury may often explain what structures are influenced and affected. Weight loading of the wrist may often lead to compression of osseous structures, such as the carpal, distal ulnar and radius bones. Stressing the wrist into flexion, extension and ulnar and radial deviation may place stress on the osseous structures, muscles, tendons and ligaments surrounding the wrist joint. Acute traumatic injuries such as falling on an outstretched hand may lead to distal radius and carpal fractures, while repetitive loading of the wrist joint into flexion, extension and ulnar and radial deviation risks injury or stress fractures at the wrist joint. Sports such as weightlifting, golf, tennis and gymnastics cause extensive repetitive crushing forces across the wrist joint, which may predispose the wrist to stress fractures (Parmalee-Peters and Eathorne, 2005).

Repetitive motions across the wrist joint may cause pain without incidence of trauma and, if left untreated, may cause the formation of tendonitis or tenosynovitis at the wrist (Wang et al., 2001).

Overuse injuries occurring in activities such as throwing and racquet sports may affect the soft tissue structures and ligaments surrounding the wrist joint. These injuries may cause injury to the flexor and extensor muscles and tendons crossing the wrist joint, tearing of the intercarpal ligaments and TFCC, midcarpal instability and carpal dislocation (Parmalee-Peters and Eathorne, 2005).

Injury to one or more of the intercarpal and midcarpal ligaments may lead to decreased stabilization and unified movement of the wrist joint. The deprivation of integrity of the ligament fibres between the scaphoid and lunate carpal bones causes the scaphoid to behave as an unconstrained segment. It tends to collapse into flexion on the distal surface of the
radius, and the base of the flexed scaphoid tends to sublux into a dorsal position in relationship with the distal radius. Loss of segmental stabilization between the scaphoid and lunate would cause the unconstrained lunate and triquetrum to slide into an extended position in relationship to the distal radius. The desynchronised position of the proximal carpal bones forces the distal carpals to flex on the extended lunate and triquetrum, thus further accentuating the extended lunate and triquetrum. This subluxed scaphoid and extended lunate and triquetrum presentation is known as dorsal intercalated segmental instability (DISI) (Levangie and Norkin, 2011).

Loss of integrity or damage to the ligamentous fibres between the lunate and triquetrum may also lead to carpal instability. This instability causes the scaphoid and lunate to progress into flexion while the triquetrum and the distal carpal row naturally tends to move into extension. This subluxed scaphoid and lunate together with extended triquetrum and distal carpal row is known as volar intercalated segmental instability (VISI). The conditions DISI and VISI illustrate the importance of unified segmental stabilisation to wrist function and the importance of the scaphoid carpal bone to maintain synchronised segmentation between the proximal and distal carpal bones (Levangie and Norkin, 2011).

The TFCC articulates with the distal ulnar on the ulnar aspect of the wrist joint complex. The TFCC, together with the volar radioulnar and dorsal radioulnar ligaments, plays a major role in stabilisation of the distal radioulnar joint and transmission of axial loads between the carpal and ulna bone. The distal radioulnar joint is described as a common site of wrist pain pathology. Hyperpronation with axial loading or injury to the wrist while it is locked in pronation may cause deterioration of the dorsal radioulnar ligament of the TFCC (Vezeridis et al, 2009).
This positioning of the wrist makes TFCC injuries common in sports such as gymnastics, hockey, racquet sports and boxing. The inadequate blood supply to the central ligamentous fibres of the TFCC may lead to a diminished ability to heal any trauma to this area. The TFCC is conveniently palpated between the flexor carpi ulnaris, ulnar styloid process and the pisiform bone. Pronating the wrist allows easier palpation of the TFCC. Injury to the TFCC structure is associated with discomfort, clicking and pain during pronation of the wrist (Parmalee-Peters and Eathorne, 2005).

Tendons crossing the wrist joint complex are designed to sustain great tensile loading. Shearing, compression and repetitive and forceful mechanical loading over the wrist joint often leads to the formation of tendinopathies. Injuries to the tendons are usually insidious in nature and are described as feeling a sharp or stabbing pain over the wrist during active range of movement but with rest would change to a constant dull and aching pain. An increase or change in normal activity often coincides with the onset of the pain, while loading the tendon would intensify the pain (Pfefer, Cooper and Uhl, 2009).

Inflammation of the tendon sheaths usually results in the formation of tenosynovitis. The repetitive pinching of the thumb and movement of the wrist and thumb abductors surrounding the radiostyloid process may lead to numbness, tingling or cramping over the dorsal compartment of the wrist. Accumulative prolonged microtrauma leads to stenosing tenosynovitis, or De Quervain’s tenosynovitis. Adults who use their hands and thumbs repetitively, such as when texting on a mobile phone, are prone to De Quervain’s tenosynovitis (Ali, Asim, Danish, Ahmad, Iqbal and Hasan, 2014).
2.2.10 Power®Ball

The Power®Ball is based upon the principles of a gyroscope. According to Webster and Eren (2014), a mechanical gyroscope is a device consisting of a spinning mass, generally a disk or wheel, anchored on a base so that its axis can turn freely in one or more directions and thereby maintain its orientation, regardless of any movement of the base. The Power®Ball is described in a study done by Balan and Garcia-Elias (2008) as a hollow sphere that contains in the interior a rotor of 200 grams of weight with an eccentric mass located two centimetres away from its axis. This internal cylinder rotates around an axis that is perpendicular to the main axis. The interior rotor is accelerated by a centrifugal force, causing the formation of a torsion force. The formation of this torsion force results in rotation of the interior motor. This generated rotational force may produce up to 10,000 revolutions per minute. The Power®Ball accelerates by means of rhythmical rotation of the wrist (Balan and Garcia-Elias, 2008). This centrifugal force causes the formation of an inertia torsion force within the ligaments of the wrist joint and muscles passing over the wrist joint complex.

![Power®Ball Components](https://example.com/poweredball-components.png)

**Figure 2.11: Power®Ball Components (RPM Sports, 2015)**

The Power®Ball has an on-board digital counter, which records the total revolutions produced by the user. Each one hundred revolutions are recorded as one unit on the digital counter display. The total revolutions
produced may be documented to indicate the total progression of the user through the study.

Recent studies done by Balan and Garcia-Elias (2008) indicate that the Power®Ball increases forearm endurance in a one month period. An increment of forearm muscle contractions after one month was also noted and the positive effects from using the Power®Ball remained for another month after the device was no longer used. A study done by Hagert (2010) that focused on the proprioception of the wrist joint and the rehabilitation thereof indicated that the Power®Ball may be used as a possible subconscious neuromuscular rehabilitation device to stimulate muscle activation in the forearm. These studies both focused on asymptomatic, healthy participants and suggest that the Power®Ball or gyroscope may play a role in future treatment protocol of forearm pathologies (Hagert, 2010).

2.2.11 Jamar dynamometer
The Jamar hand dynamometer is the most widely cited instrument in literature that focuses on hand dynamometers, and appears to be generally accepted as the benchmark by which all hand dynamometers are evaluated. It is accepted as having the most normative data (Roberts, Denison, Martin, Patel, Syddall, Cooper and Sayer, 2011).

Figure 2.12: Jamar Dynamometer Positioning in left hand (Photo by researcher)
According to Magee (2008), the grip of the Jamar dynamometer could be adjusted to fit five different hand and grip sizes via adjustable hand spacings to allow the patient to achieve maximum force output. The results, from an average of three trials recorded, form a bell curve graph. The greatest strength reading is measured at the middle or second reading while the first reading usually is the weakest. In the case of an injured hand or wrist, the bell curve should still be present but the force exerted would present less. A 5% to 10% difference between normal and injured hand indicates a weakness or abnormality. Optimal patient position for holding the Jamar dynamometer, Figure 3.2, is with the arm held at the patient’s side with the elbow flexed at 90 degrees when measuring the grip strength (Magee, 2008).
CHAPTER THREE:

METHODOLOGY
CHAPTER THREE - METHODOLOGY

3.1 Introduction
This discussion relates to participant selection, including sample size and selection/recruitment, inclusion and exclusion criteria and group allocation. The overall treatment approach, Power®Ball treatment protocol, the subjective and objective data, data analysis and ethical considerations of this study are also discussed to allow better for understanding of the study participants.

3.2 Participant Recruitment
Participants were recruited from the University of Johannesburg Campus, gymnasium and different University of Johannesburg sport associations such as golf, tennis, rugby and athletics clubs. Participants from businesses where the employee’s wrists are under constant stress were also invited to partake in the study. Recruitment was done via word of mouth and by means of advertisement leaflets (Appendix A) placed in the area surrounding the University of Johannesburg's Doornfontein Campus.

3.3 Sample Size and Selection
The research sample consisted of forty participants, selected via simple random sampling. The participants who wanted to participate in the study were between the ages of eighteen to thirty five. Twenty males and twenty females were recruited to ensure equal gender ratios. The participants were informed of the nature of the study and evaluated according to the inclusion and exclusion criteria. A hand and wrist examination was performed to assess the injury. Participants read and signed the participant information (Appendix B) and informed consent forms (Appendix C), which outlined the purpose of the study and the treatment process and protocol.
3.4 Inclusion Criteria

- Male or female participants.
- Participants between the ages of eighteen to thirty five years, because a study performed by Angst, Drerup, Werle, Herren, Simmen and Goldhahn (2010) showed grip strength remains constant between 18 to 35 years and starts declining thereafter.
- Participants who presented with non-specific pain over the wrist region.
- Participants who presented with decrease grip strength in the injured wrist compared with the average grip strength for the participant's age and gender (Massy-Westropp, Gill, Taylor, Bohannon and Hill, 2011).

3.5 Exclusion Criteria

- Participants who experienced a recent traumatic injury to the wrist, hand and/or forearm.
- Participants with recently diagnosed fractures, including acute Boxer's, Colle's and carpal bone fractures.
- Participants experiencing pain during the use of the Power®Ball.
- Participants who were being treated by another practitioner during the study period, including any form of physical therapy or medication, such as non-steroidal anti-inflammatory medication, that may have affected the wrist.

3.6 Treatment Approach

3.6.1 First visit

The participants were randomly selected, via simple random sampling to participate in the study. Each participant received a participant information (Appendix B) and consent form (Appendix C). These forms were discussed with the participant in detail and were signed by the participant after he or she fully understood the aim of the research. During the first
visit, a thorough case history and physical examination were performed. Thereafter, a hand regional examination (Appendix D) was performed and a Patient Rated Wrist Evaluation (PRWE) Questionnaire (Appendix E) was provided to each participant to complete in order to assess his or her wrist’s condition. The PRWE questionnaire formed part of the subjective data collected. An initial grip strength measurement was also taken, using the Jamar grip strength dynamometer (Appendix F), to assess the severity of the condition and the participant’s current grip strength. The grip strength data formed part of the objective data and was documented prior to the treatment session by the researcher. The participant was introduced to the Power®Ball gyroscope and received a demonstration on how to use the gyroscope: the Power®Ball was to be used with the participant’s arm at the side of the body with the elbow flexed to 90 degrees, in order to isolate the forearm musculature and prevent the use of shoulder muscles. Once the participant was accustomed to the device, the treatment session could begin.

The participants used the Power®Ball for five minutes in the affected hand. The number of revolutions produced during the five minute treatment session on the affected side was recorded with the Power®Ball on-board digital counter and documented by the researcher on the participant objective data collection form (Appendix F). Participants were not allowed to sit in a close proximity to each other during the treatment sessions to prevent any competition that might have arisen. The first treatment session took thirty minutes to complete.

3.6.2 Follow-up visits
Follow up visits occurred during the next four weeks, with three treatment sessions per week, each lasting ten minutes. Sessions two to six consisted of five minute Power®Ball treatments followed by the documentation of the number of revolutions done on the digital counter. On the seventh treatment, the grip strength of the concerned wrist was re-
measured with the Jamar dynamometer before the treatment session commenced, and the PRWE questionnaire was completed again by the participant. The participant continued with the five minute treatment session and the number of revolutions was documented. Sessions eight to eleven progressed in the same manner as sessions two to six. The twelfth treatment session was conducted in the same manner as session seven described above: the participant’s grip strength was measured before the treatment session with the Jamar dynamometer followed by completion of the PWER questionnaire. The participant’s wrist was re-assessed before each treatment to document the changes that had occurred since the last treatment.

3.7 Power®Ball
The Power®Ball (Figure 2.11 and 3.1) has an on-board digital counter that records the total revolutions produced by the user. Each one hundred revolutions are recorded as one unit on the digital counter display. The total revolutions produced may be documented to indicate the total progression of the user through the study.

Figure 3.1: Power®Ball (RPM Sports, 2015)

3.8 Subjective Data
The PRWE questionnaire score was used to evaluate wrist pain in the participants. The aim of this questionnaire (Appendix E) is to provide a valid and reliable tool for measuring patient rated wrist pain and disability.
Participants’ opinions on pain and on their ability to perform active daily tasks were assessed. The fifteen questions focus on brief and simple tasks and are scored from zero to ten, where zero indicates no pain and ten indicates the worst pain the patient has ever experienced. MacDermid, Turgeon, Richards, Beadle and Roth (1998) conducted a research study to measure the reliability and validity of the PRWE score on 101 patients with distal radius fractures. The outcome showed the test-retest value was excellent (intraclass correlation coefficients > 0.90). Validity assessment demonstrated that the instrument detected significant differences over time ($p < 0.01$) and was appropriately correlated with alternate forms of assessing parameters of pain and disability. Further studies done by Changulani, Okonkwo, Keswani and Kalairajah (2008) analysed the various outcome measures available for assessing wrist and hand function and found the PWRE score to be the most effective in measuring hand and wrist pain and disability.

3.9 Objective Data

3.9.1 Jamar dynamometer

Peolsson, Hedlund and Öberg (2001) conducted a research study measuring the intra- and inter-tester reliability of hand grip strength and index-grip strength using a Jamar dynamometer (Figure 3.2). The results from the reliability studies showed that hand grip and index grip strength measured with the Jamar dynamometer is a reliable method (ICC values 0.85-0.98) and can be recommended for use in clinical practice.

Figure 3.2: Jamar Dynamometer in left hand (Photo by researcher)
3.10 Data Analysis
Two measurements were collected on the participant data collection form (Appendix F): grip strength, measured in kilograms and taken by the grip strength dynamometer, and revolutions per five minute session, using the Power®Ball. Data from the forty participants collected on the participant data collection form was correlated by the researcher and analysed by a STATKON statistician at the University of Johannesburg. Descriptive analysis tests were performed by the statistician to analyse the biographical details regarding the age, gender, injured hand and PRWE score (Appendix E). Wilcoxon Signed Ranks Test and One-way Repeated Measures ANOVA, using Statistical Package for the Social Science (SPSS), were used to analyse the change in grip strength, using data from the dynamometer and change in revolutions per five minute session with the Power®Ball respectively.

3.11 Ethical Considerations
All participants that wished to partake in this particular study were requested to read and sign the information and consent form specific to this study. The information and consent outlined the name of the researcher, purpose of the study and benefits of partaking in the study and participant assessment and treatment procedure. Any potential risks, benefits and discomforts pertaining to the treatments involved were explained, as well as the fact that the participant’s safety was ensured (prevention of harm). The information and consent form also explained that the participant’s privacy was protected, as only the researcher and participant were in the treatment room, and that anonymity was ensured, as the participant’s information was converted into data and therefore could not be traced back to the individual. The form also stated standard doctor/patient confidentiality was adhered to at all times while compiling the research dissertation. The participants were informed that their participation was on a voluntary basis and that they were free to withdraw from the study at any stage. If the participant had any further questions,
those were explained by the researcher, whose contact details were made available. The participants were required to sign the information and consent forms, signifying that they understood all that were required of them for this particular study. Results of the study were made available on request.

With regards to this particular study, the benefits were to eliminate or decrease the presence of non-specific wrist pain, possibly increase grip strength and help strengthen the wrist to prevent future injury. The following risks might have occurred: slight discomfort or tenderness after using the Power®Ball due to muscle, tendon or ligament fatigue of the surrounding wrist structures after three five minute treatment sessions per week.

Participants were to be referred when necessary. This study and its protocol were submitted to the University of Johannesburg Higher Degrees Committee (Appendix G) and the University of Johannesburg Research Ethics Committee (Appendix H) and written approval was granted by the committees aforementioned. This study was also submitted to Turnitin (Appendix I) to prevent plagiarism and an overall similarity percentage of 18% was obtained (Appendix J).
CHAPTER FOUR:

RESULTS
CHAPTER FOUR - RESULTS

4.1 Introduction

In this chapter, the results that were collected throughout the clinical trial will be discussed in detail. Grip strength, number of revolutions produced per session with the Power®Ball and non-specific wrist pain changes within the two groups were noted and compared. Note for brevity and clarity from this chapter onwards, numerals instead of words will be used.

The subjective data was collected via the PRWE score. The objective data was collected by the researcher, utilising the Jamar dynamometer, as described by Magee (2008). The total number of revolutions produced on the Power®Ball per session was collected by the researcher after each session. The PRWE scores and Jamar dynamometer readings were recorded on the first, seventh and twelfth sessions. The biographical details of the participants were captured while completing a thorough case history and physical and wrist examination. The sample group consisted of forty participants, all of whom had met the inclusion criteria.

4.2 Demographic Data

4.2.1 Age distribution

Participants were required to be between the ages of 18 to 35 years in order to ensure that optimum grip strength remained constant (Angst et al. 2010). As described within Figure 4.1, the age of the participants in this study ranged from 21 to 28, thus there was a range of 7 years between the youngest and oldest participant. The mean age of the 40 participants was 25.58 years of age, with a median age of 26. A variance of 3.02 and a standard deviation of 1.74 was noted. A negative skewness of -0.595 was noted, indicating a slight clustering towards the high end of the spectrum of ages of participants. A negative kurtosis of -0.05 was noted, indicating that the distribution of participants was rather peaked or slightly towards
the extreme. The age distribution within the study is illustrated in the following figure:

![Age distribution graph](image)

**Figure 4.1**: Line graph of age distribution within study population

### 4.2.2 Gender distribution

The study population consisted of 20 males and 20 females, thus forming an equal ratio of 50% males and 50% females within the overall study population of 40 participants. The gender group displayed no variation regarding the test for normality and displayed no statistical significance regarding the gender distribution.

### 4.3 Subjective Data

#### 4.3.1 Analysis of the normality of data

The Shapiro-Wilk Test was used to test for normality, as the groups contained fewer than 50 participants. Several researchers suggest that the Shapiro-Wilk Test is the best test for analysing the normality of data (Gashemi and Zahediasl, 2012). A \( p \)-value of less than or equal to 0.05 \( (p \leq 0.05) \) was set to indicate if the data was regarded as statistically significant. Table 4.1 indicates that the test statistic was \( t = 0.94 \) and the \( p\)-
value was $p = 0.03$, implying normal distribution within the study population and that the results were significant.

**Table 4.1: Tests of Normality using Shapiro-Wilk Test**

<table>
<thead>
<tr>
<th></th>
<th>Shapiro-Wilk Statistic</th>
<th>Df (degree of freedom)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.94</td>
<td>40</td>
<td>0.03</td>
</tr>
<tr>
<td>GS Visit 1</td>
<td>0.91</td>
<td>40</td>
<td>0.01</td>
</tr>
<tr>
<td>GS Visit 7</td>
<td>0.93</td>
<td>40</td>
<td>0.02</td>
</tr>
<tr>
<td>GS Visit 12</td>
<td>0.93</td>
<td>40</td>
<td>0.01</td>
</tr>
<tr>
<td>PRWE Visit 1</td>
<td>0.99</td>
<td>40</td>
<td>0.85</td>
</tr>
<tr>
<td>PRWE Visit 7</td>
<td>0.96</td>
<td>40</td>
<td>0.19</td>
</tr>
<tr>
<td>PRWE Visit 12</td>
<td>0.89</td>
<td>40</td>
<td>0.00</td>
</tr>
</tbody>
</table>

GS = Grip Strength
PRWE = Patient Rated Wrist Evaluation

Within the study population, the following $p$-values were found to be significant and normally distributed. Grip strength at the first treatment session had a $p$-value of 0.01, $p$-value of 0.02 at treatment session 7 and a $p$-value of 0.01 at treatment session 12. The PRWE score indicated an insignificant and abnormal distributed $p$-value of 0.85 on treatment session 1 and treatment session 7 ($p = 0.19$), but significant and normal distributed $p$-value on treatment session 12 ($p = 0.00$). Table 4.2 illustrates that the revolutions per second recorded on the Power®Ball only recorded 1 significant and normally distributed recording, on the 4$^{th}$ treatment session ($p = 0.04$). The other 11 out of 12 treatment sessions recorded were all insignificant and abnormally distributed, with $p$-values over 0.05, but may be statistically significant from a normal distribution in any larger samples.
Table 4.2: Tests of Normality using Shapiro-Wilk Test. Power®Ball Recordings

<table>
<thead>
<tr>
<th>Visit</th>
<th>Statistic</th>
<th>Df (degree of freedom)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.97</td>
<td>40</td>
<td>0.42</td>
</tr>
<tr>
<td>2</td>
<td>0.98</td>
<td>40</td>
<td>0.56</td>
</tr>
<tr>
<td>3</td>
<td>0.97</td>
<td>40</td>
<td>0.44</td>
</tr>
<tr>
<td>4</td>
<td>0.94</td>
<td>40</td>
<td>0.04</td>
</tr>
<tr>
<td>5</td>
<td>0.97</td>
<td>40</td>
<td>0.34</td>
</tr>
<tr>
<td>6</td>
<td>0.96</td>
<td>40</td>
<td>0.18</td>
</tr>
<tr>
<td>7</td>
<td>0.96</td>
<td>40</td>
<td>0.13</td>
</tr>
<tr>
<td>8</td>
<td>0.98</td>
<td>40</td>
<td>0.53</td>
</tr>
<tr>
<td>9</td>
<td>0.96</td>
<td>40</td>
<td>0.24</td>
</tr>
<tr>
<td>10</td>
<td>0.96</td>
<td>40</td>
<td>0.17</td>
</tr>
<tr>
<td>11</td>
<td>0.98</td>
<td>40</td>
<td>0.67</td>
</tr>
<tr>
<td>12</td>
<td>0.95</td>
<td>40</td>
<td>0.09</td>
</tr>
</tbody>
</table>

P = Power®Ball Recordings
4.3.2 Patient rated wrist evaluation score

One-way Repeated Measures ANOVA analysis was used to measure the same participant’s PRWE score at different points in time: the 1st, 7th and 12th sessions.

Table 4.3: Descriptive Statistic Patient Rated Wrist Evaluation Score

<table>
<thead>
<tr>
<th>Visit</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visit 1</td>
<td>31.96</td>
<td>12.82</td>
<td>40</td>
</tr>
<tr>
<td>Visit 7</td>
<td>25.83</td>
<td>13.12</td>
<td>40</td>
</tr>
<tr>
<td>Visit 12</td>
<td>13.9</td>
<td>10.48</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 4.3 illustrates a decrease in the average pain experienced by the 40 participants from the 1st session to the 12th session. A mean value of 31.96 out of a possible 100 was noted on the 1st treatment session, which decreased to 25.83 on the 7th treatment session and ended on the 12th treatment session with a pain value of 13.9. Thus, a mean decrease percentage of 19.18% was noted between the 1st and 7th treatment sessions and a further decrease of 46.19% between the 7th and 12th treatments. An overall decrease of 56.51% of pain perceived from the first treatment to the last treatment session was recorded.

Table 4.4: Pairwise Comparisons for Patient Rated Wrist Evaluation Score

<table>
<thead>
<tr>
<th>PRWE(a)</th>
<th>PRWE(b)</th>
<th>Mean difference (a-b)</th>
<th>Std. Error</th>
<th>P Value</th>
<th>95% Confidence Interval for difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower Bound</td>
<td>Upper Bound</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 2</td>
<td>3</td>
<td>6.14</td>
<td>18.06</td>
<td>0.74</td>
<td>0.00</td>
</tr>
<tr>
<td>2 1</td>
<td>3</td>
<td>-6.14</td>
<td>11.93</td>
<td>0.74</td>
<td>0.00</td>
</tr>
<tr>
<td>3 1</td>
<td>2</td>
<td>-18.06</td>
<td>-11.93</td>
<td>1.19</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Table 4.4 compares each of the 3 readings recorded and reveals that the differences between these recordings are significant at all 3 treatment sessions ($p \leq 0.05$). A mean difference of 6.14 was noted between the first PRWE score and the second recorded PRWE score. A mean difference of 18.06 was noted between the PRWE score of the first treatment session and the last recorded PRWE score.

Table 4.5: Multivariate Test for Patient Rated Wrist Evaluation Score

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>F</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>P Value</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wilks' lambda</td>
<td>0.14</td>
<td>144.67</td>
<td>2.00</td>
<td>38.00</td>
<td>0.00</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Table 4.5 illustrates a Wilks’ lambda value of 0.14 with a probability value of 0.00 ($p \leq 0.05$), which indicates that there was a statistically significant effect present over the period of the 12 treatments. The Partial Eta Squared value of 0.86 suggested a large effect size occurred. In conclusion, there was a significant effect on the PRWE score 1 on the 1st treatment session and PRWE score 3 on the 12th treatment session, and can be summarised as Wilks’ Lambda = 0.14, F (2, 38) = 144.87, $p \leq 0.00$, multivariate partial eta squared = 0.86.
4.4 Objective Data

4.4.1 Grip strength

A Wilcoxon Signed Rank Test was used to analyse the change in grip strength by means of measurement with the Jamar dynamometer. The Wilcoxon Signed Rank Test is a non-parametric alternative to the repeated measures t-test, but instead of comparing means, the Wilcoxon converts scores to ranks and compares them to different time periods (Pallant, 2014).

Table 4.6: Descriptive Statistics for Grip Strength

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visit 1</td>
<td>40</td>
<td>37.13</td>
<td>12.43</td>
<td>20.33</td>
<td>62.00</td>
</tr>
<tr>
<td>Visit 7</td>
<td>40</td>
<td>41.00</td>
<td>12.76</td>
<td>19.00</td>
<td>67.00</td>
</tr>
<tr>
<td>Visit 12</td>
<td>40</td>
<td>42.41</td>
<td>13.09</td>
<td>24.00</td>
<td>74.33</td>
</tr>
</tbody>
</table>

Figure 4.2: Descriptive Statistics for Grip Strength
Table 4.6 and Figure 4.2 illustrates the 3 grip strength data (GSD) recordings, the number of participants treated (N), the mean grip strength recorded during that treatment session and the standard deviation, minimum and maximum values reached during each treatment session.

According to the results, there was an increase in mean percentage of 9.44% between GSD1 and GSD7, and an increase in mean percentage of 3.34% between GSD7 and GSD12. Overall an increase in mean percentage of 12.45% between the beginning of the study (GSD1) and the final treatment session (GSD12) was recorded.

<table>
<thead>
<tr>
<th>Table 4.7: Test Statistics for Grip Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>Z</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
</tr>
</tbody>
</table>

Table 4.7 illustrates that the difference between the three grip strength scores is less than 0.00 ($p \leq 0.00$) and is statistically significant. It may be concluded that the Wilcoxon Signed Rank Test revealed a statistically significant increase in grip strength following the 12 Power®Ball treatment sessions, summarised as $z = -5.07$, $p < 0.00$ with a large effect size ($r = 0.8$). The mean score increased from GSD1 ($m = 37.13$) to GSD12 ($m = 42.4$).

4.4.2 Power®Ball on-board digital counter readings
One-way Repeated Measures ANOVA analysis was used to measure the each participant’s total number of revolutions using the Power®Ball during each treatment session.
Figure 4.3 and Table 4.8 illustrate a slight increase in mean recorded revolutions over the period of 12 treatments by the 40 participants. A mean value of 183.90 was recorded on the 1st session, which increased to 218.60 on the 7th session and 228.33 on the 12th session. Thus, an
increase mean percentage of 15.87% was noted from the beginning of the study to the 7th treatment, and an increased mean percentage of 19.46% was noted from the 1st treatment to the last treatment session.

**Table 4.9: Pairwise Comparisons for Power®Ball Readings**

<table>
<thead>
<tr>
<th>Visit A</th>
<th>Visit B</th>
<th>Mean Difference (A-B)</th>
<th>Std. Error</th>
<th>P-Value</th>
<th>95% Confidence Interval for Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>-34.70</td>
<td>5.63</td>
<td>0.00</td>
<td>(-55.27, -14.13)</td>
</tr>
<tr>
<td>12</td>
<td>7</td>
<td>-44.43</td>
<td>5.31</td>
<td>0.00</td>
<td>(-63.82, -25.03)</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>34.70</td>
<td>5.63</td>
<td>0.00</td>
<td>(14.13, 55.27)</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>-9.73</td>
<td>3.64</td>
<td>0.73</td>
<td>(-23.04, 3.59)</td>
</tr>
<tr>
<td>12</td>
<td>7</td>
<td>44.43</td>
<td>5.31</td>
<td>0.00</td>
<td>(25.03, 63.82)</td>
</tr>
<tr>
<td>12</td>
<td>7</td>
<td>9.73</td>
<td>3.64</td>
<td>0.73</td>
<td>(-3.59, 23.04)</td>
</tr>
</tbody>
</table>

Pairwise Comparisons for Power®Ball readings was found to be significant between certain recordings of Power®Ball readings taken on visits 1, 7 and 12. Table 4.9 compares each of the 3 day’s readings and illustrates that the recorded number of revolutions on the Power®Ball was statistically significant between the 1st and 7th and 1st and 12th readings. Recorded data between the 7th and 12th treatment sessions was statistically insignificant. A mean difference of 34.70 was noted between the 1st and 7th readings and a mean difference of 44.43 was noted between the 1st and 12th readings.
Table 4.10: Multivariate Test for Power®Ball Readings

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>F</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>P-Value</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wilks’ Lambda</td>
<td>0.27</td>
<td>7.08</td>
<td>11.00</td>
<td>29.00</td>
<td>0.00</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Table 4.10 illustrated a Wilks’ lambda value of 0.27 with a probability value of 0.00 ($p \leq 0.05$), which indicates there was a statistically significant effect present over the period of 12 treatments. The Partial Eta Squared value of 0.73 suggests a large effect size occurred. In conclusion, there was a significant effect from the number of revolutions produced with the Power®Ball over 12 treatments and can be summarised as Wilks’ Lambda = 0.27, F (11, 29) = 7.08, $p \leq 0.00$, multivariate partial eta squared = 0.73.
CHAPTER FIVE: DISCUSSION
CHAPTER FIVE - DISCUSSION

5.1 Introduction
In this chapter, the results that were analysed and referenced in Chapter Four will be discussed, with reference to the aim of the study proposed in Chapter One. The aim of this study was to determine the effect of using the Power®Ball gyroscope as a treatment device with regards to pain reduction and change in endurance in the wrist for participants with a non-specific wrist injury. The data collected with the Jamar dynamometer as an objective measurement device and the PRWE (PRWE) questionnaire as a subjective measurement was scrutinised to evaluate if this aim was achieved.

5.2 Demographic Data
The study population consisted of 40 participants, with an equal ratio of 20 males and 20 females. The gender group displayed no variation regarding the test for normality and displayed no statistical significance involving the gender distribution. The age range for the study population consisted of participants between 21 and 28 years of age, with a mean age of 25.58 years.

5.3 Subjective Data
5.3.1 PRWE score
Each participant was required to complete a PRWE questionnaire on the 1st, 7th and 12th treatment sessions. This data provided a numerical score out of 100 to describe what the participants were experiencing throughout the study. While analysing this score (Table 4.3), it was noted that a constant decrease in non-specific wrist pain was noted. A small decrease in mean percentage of 19.8% was noted during the first 7 treatment sessions, with a more constant decrease in mean percentage of 46.19% from treatment session 7 to the final treatment (session 12). The
participants began with a mean PWRE score of 31.96 and ended with a mean score of 13.9.

The One-way Repeated Measures ANOVA Test was used to analyse the data collected, and indicated that an improvement of pain was present over the period of 12 treatment sessions. According to Table 4.4, a greater mean difference was noted between the 2\textsuperscript{nd} and 3\textsuperscript{rd} PRWE scores than the 1\textsuperscript{st} and 2\textsuperscript{nd} scores. This result implies that a constant decrease of pain was noted from using the Power®Ball gyroscope and that most of the benefits occurred after treating a participant for 7 treatments or more. A significant $p$ value of 0.00 was present throughout all three recordings. Table 4.4 also illustrated that a significant effect from PRWE score 1 on the 1\textsuperscript{st} treatment session and score 3 on the 12\textsuperscript{th} treatment session was noted. The One-way Repeated Measures ANOVA Multivariate Test summarised that Wilks’ lambda = 0.14, $F (2, 38) = 144.87$, $p \leq 0.00$, multivariate partial eta squared = 0.86.

5.3.2 Pain and disability

Bleeding and subsequent inflammation plays an important role in the acute response to many soft tissue trauma or injuries but differs from the pathophysiological process of a long term, chronic injury. Overuse or repetitive stress injuries occurs in tissues with poor blood supply, such as the ligaments and tendons surrounding the wrist joint. Chronic injuries classically present with collagen separation and degeneration in this area, compared with the typical three-phase inflammatory, repair and remodelling response to an acute injury (Childress and Beutler, 2013).

Scott, Docking, Vicenzino, Alfredson \textit{et al}, (2013) stated that in tendinopathies, tenocytes produce nociceptive as well as inflammatory substances, which are induced through repetitive stress loading. Nerve fascicles containing sensory afferents present within the peritendinous tissue express receptors for the nociceptive substances. Continuous
activation of these substances causes the nerves to be chronically sensitised and leads to constant pain signalling. In most chronic cases, inflammatory cells would be absent, or minimal, leading to further degeneration of the tendon structure and progression into tendinosis. It is further stated that the analgesic effect of exercise on the central pain mechanism contributing to tendon pathology may play an important role in rehabilitation of chronic pain.

A study done by Zepppetzauer, Drexel, Vonbank, Rein, Aczel and Saely (2013) found that eccentric endurance exercise economically improves metabolic and inflammatory risk factors, with a decrease in serum levels of C-reactive protein and creatine kinase activity noted within 45 healthy, sedentary individuals. There is also evidence suggesting it is appropriate to perform specific eccentric exercises into pain for maximal efficiency in the rehabilitation of certain tendinopathies (Scott et al. 2013).

Pull and Ranson (2007) stated that eccentric training demonstrated a positive effect in the prevention of ligamentous or tendinous damage and injury. The authors further state that there was also considerable evidence that eccentric contractions might induce a protective effect, called a repeated bout effect, to reduce the likelihood of further exercise-induced muscle damage. Neural adaptation produced by eccentric muscle exercise could also contribute to the repeated bout effect. This neural adaptation seems to be related to a more efficient motor unit recruitment patterns produced by eccentric training.

LaStayo, Marcus, Dibble, Frajacom and Lindstedt (2014) claimed that when a muscle is stretched while contracting, the energy released by the muscle is reduced. It was further established that the energy used for force production is increased if the work is done by the isolated muscle and reduced if the work is done on the muscle, thus eccentrically induced negative work. The results from this research imply that the energy cost to
produce identical magnitude and duration of force is at its least during eccentric contractions.

In addition, a research study conducted by Tyler, Thomas, Nicholas and McHugh (2010) was done to test the addition of isolated wrist extensor eccentric exercise to standard treatment for chronic lateral epicondylitis. The prospective randomised trial assessed the efficiency of a novel eccentric exercise added to standard treatment for chronic lateral epicondylitis. A Disability of Arm, Shoulder and Hand Questionnaire (DASH) was used to determine the degree of disability and a Visual Analog Scale (VAS) was used to grade the intensity of pain. Wrist extension and middle finger extension strength was measured by utilising a hand-held dynamometer. Eleven participants used a rubber bar (Thera-Band FlexBar®) in conjunction with ultrasound, cross-friction, cryo- or thermo-therapy, while 10 participants used only the standard treatment without eccentric exercise until resolution of symptoms occurred. Improvement in the DASH, VAS and the grip strength measurements was better for the eccentric group compared with the standard group, indicating that the inclusion of an eccentric exercise tool to a treatment protocol may deliver excellent results in decreasing pain and increasing grip strength and mobility.

Hagert (2010) stated that eccentric exercises, such as using the Power®Ball, are designed to create an opposing load to the muscles involved in the exercise, thus lengthening these muscles and ultimately increasing the muscle’s strength. Eccentric exercise is mostly used in the rehabilitation of tendinopathies and chronic ligamentous injuries, where it was shown to significantly decrease pain while building tendon strength. The increase in grip strength, which will be discussed in the following section, in conjunction with the decrease in energy consumption of using an eccentric exercise tool and the decrease in perceived pain after
treatment with the Power®Ball in this study, resonates with this statement by Hagert (2010).

5.4 Objective Data

5.4.1 Grip strength

Each participant was required to provide a grip strength measurement before the 1\textsuperscript{st}, 7\textsuperscript{th} and 12\textsuperscript{th} treatment sessions. The grip strength measurement, measured in kilograms, was collected by utilising the Jamar Dynamometer and provided an indication if a change in grip strength occurred throughout the study.

In Table 4.6 and Figure 4.2, a mean increase from 37.13 kg to 41.00 kg was noted from grip strength measurement 1 to measurement 2. A mean increase was then noted from the 41.00 kg grip strength measurement 2 to 42.41 kg grip strength measurement 3. This result indicated a mean percentage increase in grip strength of 9.44% between grip strength measurement 1 and 2, a mean percentage increase of 3.34% between grip strength measurement 3 and 3 was noted and an overall increase in mean percentage of 12.45% was recorded.

The Wilcoxon Signed Rank Test was used to analyse the change in grip strength by means of measurement with the Jamar dynamometer. Table 4.7 illustrated that the difference between grip strength measurements 1 and 7 and the difference between grip strength measurements 1 and 12 was less than 0.00 (p ≤ 0.00) and statistically significant. The difference between grip strength measurements 7 and 12 was recorded as 0.01 and statistically significant. It may be concluded that the Wilcoxon Signed Rank Test revealed a statistically significant increase in grip strength following the 12 Power®Ball treatment sessions and could be summarised as $z = -5.07$, $p < 0.00$ with a large effect size ($r = 0.8$). The mean score increases from GSD1 ($m = 37.13$) to GSD12 ($m = 42.4$). From the recorded data, it
could be noted that a larger increase in grip strength was noted within the first 7 treatments compared with a relatively small increase from treatments 7 to 12.

A study done by Balan and Garcia-Elias (2008) also concluded that there was a tendency for participants to increase their maximum grip strength while using the Power®Ball. The study was done to ascertain the utility of the Power®Ball in the invigoration of the forearm musculature and to determine if the increase in maximum grip force and muscular endurance was possible. Ten asymptomatic adults used the Power®Ball gyroscope twice a day for 4 weeks and were measured by using the Jamar dynamometer. The participants were measured again after a 4 week resting period. An increase in maximum grip strength was noted, with a highly statistically significant increase in muscle endurance. The 15% increase in grip strength in Balan and Garcia-Elias’ study correlates with the change in grip strength found in this clinical trial (12.45%). The muscle endurance remained slightly unchanged after the 4 week resting period without using the Power®Ball gyroscope. The authors further state that the multidirectional force generating properties of the Power®Ball may be useful in the treatment of patients with acquired or congenital hyperlaxity, having developed wrist dysfunction secondary to weak proprioceptive neuromuscular control, which was included in this study of the effect of Power®Ball on non-specific wrist pain.

5.4.2 Power®Ball on-board digital counter readings
The Power®Ball has an on-board digital counter that records the total revolutions produced by the user. Each one hundred revolutions are recorded as one unit on the digital counter display. The total revolutions produced by each participant over 5 minutes were recorded after each treatment session.
One-way Repeated Measures ANOVA analysis was used to measure each participant’s total number of revolutions achieved while using the Power®Ball during each treatment session. Figure 4.3 indicated a mean increase in recorded revolutions from treatment session 1 to treatment session 12. A mean value of 183.90 was recorded on the 1st session, which increased to 218.60 on the 7th session and 228.33 on the 12th session. Thus, an increase mean percentage of 15.87% was noted from the beginning of the study to the 7th treatment and an increased mean percentage of 19.46% was noted from the 1st treatment to the 12th treatment session.

Pairwise Comparisons (Table 4.9) was found to be significant between the 1st and 7th and 1st and 12th readings ($p \leq 0.00$). Recorded data between the 7th and 12th treatment sessions was statistically insignificant ($p \leq 0.73$). A Multivariate Test (Table 4.10) indicated that a large effect size occurred over the period of 12 treatments and may be summarised as Wilks’ lambda = 0.27, $F (11, 29) = 7.08$, $p \leq 0.00$, multivariate partial eta squared = 0.73.

The steadily increase in Power®Ball readings may be attributed to the participants’ increase in endurance and co-ordination. Co-ordination is an important aspect of our everyday activities and is achieved by various combinations and degrees of complex movement (Serrien, 2007). Synchronisation between the sensory and motor system is important in producing stable coordination patterns. By performing a repetitive specific motion in a coordinated manner, a smooth and controlled coordinated movement is produced (Torre and Delingnieres, 2008). As previously stated by Balan and Garcia-Elias (2008), Power®Ball exercise creates a significant increase in forearm musculature’s endurance, which would remain relatively constant for a period of 4 weeks after no activity. In Balan and Garcia-Elias’s study, the endurance was established by asking the volunteers to alternate between periods of maximal contraction and
periods of relaxation. In this study of the effect of Power®Ball on non-specific wrist pain, the endurance was measured by the number of revolutions the participants could produce while maintaining a slow and comfortable pace without causing pain or any discomfort. Close attention was paid to ensure that these parameters were maintained. Balan and Garcia-Elias stated that although no participants experienced any discomfort or pain during the trial, eccentric exercise in weak or improperly trained musculature has a potential for higher pain index and damage of the muscular ultrastructure (Balan and Garcia-Elias, 2008). However, later studies done by LaStayo et al. (2014) stated that evidence exists that eccentric exercise training could be used safely and effectively in rehabilitation. The increase in the number of revolutions acquired with the Power®Ball throughout this study showed that an increase in endurance and grip strength was achieved with the presence of a decline in pain perception.
CHAPTER 6 – CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The aim of this study was to determine the effect of using the Power®Ball gyroscope as a treatment device for pain and change in endurance in the wrist for participants with a non-specific wrist injury. Whether or not the aim was achieved was determined by using the Jamar dynamometer as an objective measurement device and the PRWE questionnaire as a subjective measurement.

The changes in this study could have been brought on by the positive effects of the use of an eccentric exercise device causing stretching of a muscle, tendon or ligament without causing an increase in the reduction of energy and thus increasing the endurance of the muscle. The presence of the repeated bout effect increases the neural adaptation surrounding the wrist joint and prevents further structural damage or injury. It is also stated by Zepppetzauer et al. (2013) that eccentric endurance exercise has an effect on metabolic and inflammatory risk factors thus decreasing the level of pain perception.

Hagert (2010) believes that eccentric exercises, such as using the Power®Ball, are designed to create an opposing load to the muscles involved in the exercise, thus lengthening these muscles and ultimately increasing the muscle’s strength which leads to an increased endurance of the structure.

Pull and Ranson (2007) stated that eccentric training demonstrated a positive, beneficial effect in the prevention of ligamentous or tendinous damage and injury. The authors’ further state that the eccentric contractions induce a protective effect, called a repeated bout effect, to
reduce the possibility of further exercise induced muscle trauma. Neural adaptation generated by eccentric muscle exercise could also contribute to the formation of the repeated bout effect. This neural adaptation seems to be associated with a more dynamic motor unit recruitment pattern produced by eccentric training. In addition, LaStayo et al. (2013) found when a muscle is stretched while contracting; the energy released by the muscle is reduced.

A study done by Zeppetzauser et al. (2013) found that eccentric endurance exercise economically improves metabolic and inflammatory risk factors with a decrease in serum levels of C-reactive protein and creatine kinase activity noted within 45 healthy, sedentary individuals. In addition, a study done by Tyler et al. (2010) found that using an eccentric exercise device combined with a standard treatment for chronic lateral epicondylitis found that a considerable decrease in pain and increase in grip strength was noted.

The results of this study suggest that the Power®Ball gyroscope has a positive effect on the treatment and rehabilitation of non-specific wrist pain. Statistically significant differences were found in the reduction of pain over the course of 12 treatment sessions and an increase in grip strength during the first 7 treatment sessions, with a small increase of grip strength over the last 5 treatments. A statistically significant increase of Power®Ball revolutions was recorded for the first 7 treatments, thus indicating an increase in endurance during these treatment sessions.

The possible effect/outcome for the chiropractic profession is that the Power®Ball may be used as an alternative, conservative treatment modality or in conjunction with an existing treatment protocol for treating sub-acute or chronic non-specific wrist pain. Additionally, the results indicated that the Power®Ball may serve as a grip strengthening or endurance device to prevent future injury to the wrist.
6.2 Recommendations

The following recommendations were made for dealing with a similar treatment protocol in future studies:

- The number of participants could be increased. An increase of 50 or more participants would be able to represent a greater statistical significance. A larger population would be more effective in scrutinising the changes occurring during the last 5 treatment sessions.

- Studies isolating either male or female participants should be considered, to improve and isolate statistical relevance and demographic data.

- A one month follow-up could be included to re-evaluate the long term benefits, as was included in the study by Hagert (2010).

- The study could be repeated involving different upper limb components, such as the effect on elbow and shoulder pathologies.

- A future study could compare the use of the Power®Ball on other eccentric exercise or rehabilitation devices.

- Further studies may be done to test the effects of including the Power®Ball with primary Chiropractic spinal manipulation therapy of upper limb pathologies.

- It may be beneficial to compare the outcome of including the Power®Ball as an eccentric rehabilitation device in a treatment protocol to a standard treatment protocol without the use of an eccentric rehabilitation device.
• This study may be used to compare the difference between symptomatic and asymptomatic groups.

• An extra, objective questionnaire may be included to improve the standard of clinical findings and to decrease the chance of human error during these data recordings.


ARE YOU SUFFERING FROM NON-SPECIFIC WRIST PAIN?
ARE YOU UNABLE TO PERFORM YOUR DAILY TASKS DUE TO AN
AGGRAVATED OR PAINFUL WRIST?

You may qualify to participate in a free research study testing the
effect of using the Power®ball on non-specific wrist pain.

Researcher seeks participants between the ages of 18 and 35 years to
take part in a research trial for the duration of 4 weeks with 3 sessions of
treatment per week.

For more information and how to take part in this study please
contact:
Jacques Maree on 0782737303
Appendix B: Information Form.

DEPARTMENT OF CHIROPRACTIC
FACULTY OF HEALTH SCIENCES
Telephone: (011) 559 6218

Date: ____________________________

INFORMATION FORM

Dear Participant,

I, Jacques Herman Maree, am currently a Chiropractic student, completing my Masters’ Degree at the University of Johannesburg. I would like to invite you to participate in my research study, entitled:

THE EFFECT OF POWER®BALL ON NON-SPECIFIC WRIST PAIN

Before agreeing to participate, it is important that you read and understand the following explanation of the purpose of the study, the study procedures, benefits, risks, discomforts, and precautions as well as the alternative procedure that is available to you. You have the right to withdraw from the study at any time without any consequence.

This information leaflet is to help you to decide if you would like to participate. You need to understand what is involved before you agree to take part in this study. You may find that this form may contain words that you may not understand. If you have any questions, do not hesitate to ask me. You may also take home a copy of this form before signing the
consent form to think about or discuss with family or friends before making your decision.

The aim of this study is to determine the effect of using the Power®ball gyroscope as a treatment device for participants with non-specific wrist pain. A secondary aim of this study will be to measure the change in grip strength after using a Power®ball gyroscope. Should you decide to partake in this study you will first be screened to determine if you are suitable for this research trial or not. The Inclusion criteria are: any gender, between the ages of 18-35 years old, participants must have a non-specific painful wrist due to a non-traumatic injury. Participants must show signs of decreased grip strength in the injured wrist compared to the average grip strength for the participant’s age and gender. The exclusion criteria are: a recent traumatic injury to the wrist, hand and forearm. Participants with recently diagnosed fractures: Acute Boxer's, Colle’s and carpal bone fractures. Participants experiencing pain while use of the Power®ball gyroscope.

After screening and examination of your injured wrist you will be informed if you are eligible to participate in the study. I would especially like you to note that you may not participate in another research study, nor take any medication that may influence the outcome of this study. Not all medication could interfere, so please be open with me regarding any medication or supplementation you are using. Also, please be open with me regarding your health history, since you may otherwise harm yourself by participating in this study. If it is deemed to be in your interest, I retain the right to withdraw you from this study. If you are diagnosed by another medical practitioner during this trial for any medical condition that was not stated in your original history, please notify me immediately.

Forty participants will participate in this study and will be chosen randomly if more than forty participants apply. Participants need to be between the
age of 18 and 35 years of age. The total amount of time required for your participation in this study will be a maximum of 12 treatments. You will be asked to visit me at the University of Johannesburg Chiropractic Clinic 3 times per week over a four week period during this study. The initial visit will be approximately 30 minutes and every treatment visit thereafter 10 minutes.

With regards to this particular study, the adverse effects may include possible post muscular tightness due to activation of musculature surrounding the wrist joint. As this study is investigational there may be other risks or side effects which are unforeseen or unknown. You should immediately contact me if any side effects occur throughout your participation in this study. Every precaution and safety measure will be adhered to ensure minimal side effects.

As your participation in this study is entirely voluntary you may decline to participate, or stop the treatment process at any time without stating any reason. Your withdrawal will not affect your access to other medical care. Furthermore it is deemed in your best interest, I retain the right to withdraw you from this study.

Your anonymity will be ensured as the recorded data being statistically analysed and data that may be recorded in scientific journals, will not include any information that could possibly identify you as a participant in this study. Confidentiality will be adhered to at all times when compiling the research dissertation. Results of this study will be made available to you on request.

This study and its protocol have been submitted to the University of Johannesburg Academic Ethics Committee and written approval has been granted by the committee aforementioned.
Should you have any concerns or queries regarding the current study, the following persons may be contacted.

Researcher: Jacques Maree | 011 559 6493
Supervisor: Dr. Irmarie Landman | 011 559 6820
Faculty of Health Sciences REC Chairperson: Prof. M. Poggenpoel | 011 559 6686
NHREC Registration no: REC-241112-035
Appendix C: Consent Form.

DEPARTMENT OF CHIROPRACTIC

CONSENT FORM

I have fully explained the procedures and their purpose. I have asked whether or not any questions have arisen regarding the procedures and have answered them to the best of my ability.

Date: ______________________  Researcher: Jacques Maree

I have been fully informed as to the procedures to be followed and have been given a description of the discomfort risks and benefits expected from the treatment. In signing this consent form I agree to this form of treatment and understand my rights and that I am free to withdraw my consent and participation in this study at any time. I understand that if I have any questions at any time, they will be answered.

Date: ______________________  Participant: ______________________
Appendix D: Wrist and Hand Regional examination.

HAND AND WRIST REGIONAL EXAMINATION
Patient: ______________________ File No.: __________ Date: ______________
Student: _____________________ Signature: _________
Clinician: ____________________ Signature: __________

OBSERVATION
- Bony and soft tissue contours _______________________________________
- Hand posture ______________________________________________________
- Vasomotor changes ________________________________________________
- Scars, skin creases, and muscle wasting ______________________________
- Fingernails _______________________________________________________
- Dominant hand __________________ right ____________________________ left

PALPATION

Posterior surface
1. Anatomical snuff box __________ 5. Pulses and capillary refill ___________
2. Carpal bones _________________ 6. Radial styloid ______________________
3. Metacarpal bones ____________ 7. Radial (lister's) tubercle ______________
4. Phalanges ____________________ 8. Ulnar styloid ________________________
9. 6 extensor tendon tunnels
   i. Abd poll long ___________ iv. Ext digit __________________
      Ext poll brev ___________ Ext digit __________________
      Ext index ______________
   ii. ECRB _________________ v. Ext digiti mini _________________
      ECRL __________________ vi. ECU _________________________
   iii. Ext poll long __________

Anterior surface
1. Tendons (Lateral to medial)
   a) Flexor carpi radialis ________________________________
   b) Flexor poll longus _________________________________
   c) Flexor digit super ________________________________
   d) Flexor digit profound ______________________________
   e) Palmaris long _________________________________
   f) Flexor carpi ulnaris ______________________________
2. Palmar fascia and intrinsic muscles ____________________________
## ACTIVE MOVEMENTS

<table>
<thead>
<tr>
<th>Movement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pronation (85-90°)</td>
<td>Tissue stretch</td>
</tr>
<tr>
<td>Supination (85-90°)</td>
<td>Tissue stretch</td>
</tr>
<tr>
<td>Ulnar deviation (15°)</td>
<td>Bone-bone</td>
</tr>
<tr>
<td>Radial deviation (30-45°)</td>
<td>Bone-bone</td>
</tr>
<tr>
<td>Wrist flexion (80-90°)</td>
<td>Tissue stretch</td>
</tr>
<tr>
<td>Wrist extension (70-90°)</td>
<td>Tissue stretch</td>
</tr>
<tr>
<td>Finger movements</td>
<td></td>
</tr>
<tr>
<td>Thumb movements</td>
<td></td>
</tr>
</tbody>
</table>

## PASSIVE MOVEMENTS

<table>
<thead>
<tr>
<th>Movement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tissue stretch</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Resisted isometric movements:

<table>
<thead>
<tr>
<th>Movement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Functional movements

### GROSS GRIP STRENGTH

- **Fist grip:**
- **Cylinder grip:**
- **Hook grip:**
- **Sphere grip:**

### PRECISION GRIP STRENGTH

- **Pinch:**
- **Chuck:**
- **Key:**

## Special tests:

1. Finkelstein's test:
2. Tinel's:
3. Phalan's test:
4. Reverse phalan's test:
5. Allen's test:
6. Froment's sign:
7. Watson's test:
8. Scaphoid compression test:
9. Lunatotriguetral ballotment test:
10. Bunnel littler test:
11. Tight retinacular test:
12. Ligament stability:

## Joint play movements

I. Hand and fingers

A. MCP and PIP + DIP
   1. Long axis extension
   2. AP, PA glide
   3. Rotation
   4. Side glide

B. Distal inter-metacarpals

II. Wrist

A. Long axis extension
B. AP glide
C. Carpal extension
D. Carpal extension
E. Ulnar deviation
F. Radial deviation
1. AP, PA glide ______________________  G. Ul-men-triq AP + AP glide ______
2. Rotation _________________________  H. Inf rad ulnar rotation __________

Radiographic examination_____________________________________________

Diagnosis________________________________________________________________

Treatment________________________________________________________________
Appendix E: Patient Rated Wrist Evaluation Form.

Number: _______________________________ Date: ______________________

PATIENT RATED WRIST EVALUATION

The questions below will help us understand how much difficulty you have had with your wrist in the past week. You will be describing your average wrist symptoms over the past week on a scale of 0-10. Please provide an answer for ALL questions. If you did not perform an activity, please ESTIMATE the pain or difficulty you would expect. If you have never performed the activity, you may leave it blank.

1. PAIN

Rate the average amount of pain in your wrist over the past week by circling the number that best describes your pain on a scale from 0-10. A zero (0) means that you did not have any pain and a ten (10) means that you had the worst pain you have ever experienced or that you could not do the activity because of pain.

<table>
<thead>
<tr>
<th>RATE YOUR PAIN: Sample Scale</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>At rest</td>
<td></td>
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<td></td>
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<tr>
<td>When doing a task with a repeated wrist movement</td>
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<tr>
<td>When lifting a heavy object</td>
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<tr>
<td>When it is at its worst</td>
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<tr>
<td>How often do you have pain?</td>
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</tr>
</tbody>
</table>

2. Function

A. SPECIFIC ACTIVITIES

Rate the amount of difficulty you experienced performing each of the items listed below - over the past week, by circling the number that describes your difficulty on a scale of 0-10. A zero (0) means you did not experience any difficulty and a ten (10) means it was so difficult you were unable to do it at all.

<table>
<thead>
<tr>
<th>Sample Scale</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turn a door knob using my affected hand</td>
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<tr>
<td>Cut meat using a knife in my affected hand</td>
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<td></td>
</tr>
<tr>
<td>Fasten buttons on my shirt</td>
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</tr>
<tr>
<td>Use my affected hand to push up from a chair</td>
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</tr>
<tr>
<td>Carry a 4.5kg object in my affected hand</td>
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<tr>
<td>Use bathroom tissue with my affected hand</td>
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</tbody>
</table>
2. Function

B. USUAL ACTIVITIES

Rate the amount of difficulty you experienced performing your usual activities in each of the areas listed below, over the past week, by circling the number that best describes your difficulty on a scale of 0-10. By “usual activities”, we mean the activities you performed before you started having a problem with your wrist. A zero (0) means that you did not experience any difficulty and a ten (10) means it was so difficult you were unable to do any of your usual activities.

<table>
<thead>
<tr>
<th>Activity</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal care activities (dressing, washing)</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Household work (cleaning, maintenance)</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Work (your job or usual everyday work)</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recreational activities</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

© JC MacDermid
Appendix F: Participant Data Collection Form.

Participant Data Collection Form

File number: ______________________ Injured hand: ______________________
Age: __________________________ Gender: ____________________________

Grip strength measurement in Kilograms taken by the Grip strength Dynamometer:

<table>
<thead>
<tr>
<th>Grip Strength Reading</th>
<th>Initial Reading</th>
<th>Before treatment no. 7</th>
<th>Before treatment no. 12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.</td>
<td>2.</td>
<td>3.</td>
</tr>
<tr>
<td></td>
<td>1.</td>
<td>2.</td>
<td>3.</td>
</tr>
<tr>
<td>Injured Hand</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Revolutions per 5 minute session using the Power®ball (x100):

<table>
<thead>
<tr>
<th>Week 1</th>
<th>Session</th>
<th>Revolutions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Week 2</th>
<th>Session</th>
<th>Revolutions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Week 3</th>
<th>Session</th>
<th>Revolutions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td></td>
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<tr>
<td></td>
<td>3.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
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Appendix G: Higher Degrees Committee Approval

TO WHOM IT MAY CONCERN:

STUDENT: MAREE, JH
STUDENT NUMBER: 200700891

TITLE OF RESEARCH PROJECT: “The Effect of Powerball on Non-Specific Wrist Pain”

DEPARTMENT OR PROGRAMME: CHIROPRACTIC

SUPERVISOR: Dr DM Landman
CO-SUPERVISOR:

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 Y Coopoo

Chair: Faculty of Health Sciences HDC
Tel: 011 559 6944
Email: yogac@uj.ac.za
Appendix H: Research Ethics Committee Approval:

UNTHERNSITY
JOHANNESBURG

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

REC-01-161-2015
29 April- 2015

TO WHOM IT MAY CONCERN:

STUDENT: MAREE, JH
STUDENT NUMBER: 200700891

TITLE OF RESEARCH PROJECT: "The Effect of Powerball on Non-Specific Wrist Pain"

DEPARTMENT OR PROGRAMME: CHIROPRACTIC

SUPERVISOR: Dr DM Landman
CO-SUPERVISOR:

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

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

Yours sincerely,

[Signature]

Prof M Poggenpoel
Chair: Faculty of Health Sciences REC
Tel: 011 559 6686
Email: marlemp@uj.ac.za
Appendix I: Turnitin digital receipt

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: JH MAREE
Assignment title: 2015 Proposals, theses, dissertations
Submission title: THE EFFECT OF POWERBALL O...
File name: Jacques_Herman_Maree_All_Chap...
File size: 1.4M
Page count: 55
Word count: 12,127
Character count: 66,400
Submission date: 04-Nov-2015 06:21PM
Submission ID: 593300194

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Appendix J: Turnitin submission info and overall similarity score

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OF JOHANNESBURG