AN INVESTIGATION INTO THE ROLE OF MUSCLE IMBALANCES WITHIN THE WRIST FLEXOR AND EXTENSOR MUSCLE GROUPS AS AN ASSOCIATED FACTOR IN THE PRESENTATION OF LATERAL EPICONDYLITIS.

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AN INVESTIGATION INTO THE ROLE OF MUSCLE IMBALANCES WITHIN THE WRIST FLEXOR AND EXTENSOR MUSCLE GROUPS AS AN ASSOCIATED FACTOR IN THE PRESENTATION OF LATERAL EPICONDYLITIS.

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I, Nicolette Bourgault du Coudray, do hereby declare that this dissertation represents my own work.

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DEDICATION

This work is dedicated to my loving mother and father who almost shed more “blood, sweat and tears” than me throughout this course. It is your unconditional support, love and encouragement that has motivated me and your involvement in my life and never-ending faith in me that has kept me sane and inspired me to be the best I can be. Thank you for the sacrifices you have made to give me the opportunity to achieve my dream.

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ABSTRACT

Many studies have been done investigating the role that muscle imbalances play in causing injury to the body, for example the knee and the shoulder. It has been found that keeping muscle balances around a joint play an important role in protecting the soft tissue structures. There is a need to further investigate the effect of muscle imbalances in the upper limb. Additionally, according to the literature, as yet no effective treatment protocol or a specific cause has been found for lateral epicondylitis making it a troubling condition for practitioners to treat and a disabling condition for patients to live with. Therefore, this research aimed at investigating whether muscle imbalances are associated with the aetiology of lateral epicondylitis. If an association was found, people involved in predisposing activities could improve the imbalance to avoid the condition, thereby minimizing time spent away from work and sport. Also, a more effective and efficient management protocol for the painful condition could be attained.

The objectives of this study included: 1) assessing the peak torque (using the Cybex Orthotron II) and muscle activity (using surface electromyography) of the wrist flexor and extensor muscle groups of asymptomatic subjects; 2) assessing the peak torque (using the Cybex Orthotron II) and muscle activity (using surface electromyography) of the wrist flexor and extensor muscle groups of symptomatic subjects and 3) to integrate this information, compare the two groups and subgroups and statistically analyse the difference between them.

Thirty-two subjects between the ages of 25-50 years were selected following a screening examination for inclusion and exclusion criteria. Once selected, the individuals were divided into two groups of 16 subjects. These groups were defined as asymptomatic and symptomatic. These groups were further divided into subgroups of eight males and eight females in each. Each individual underwent muscle activity and peak torque testing for the movements of wrist flexion and extension. An average of three readings was obtained from the surface EMG (amplitude of the spike) for muscle activity and an average of six readings was taken using the Cybex orthotron II for torque assessment. These measurements formed the objective data for the study.

Data were captured in MS Excel and exported in SPSS (Statistical Package for Social Sciences) version 11.5 for data analysis (SPSS Inc, Chicago, Ill, USA). An outline of the demographics of the sample in terms of age, ethnicity, height, weight, occupations and level of activity was followed by the descriptives of the symptomatic sample according to history and clinical features. This was then followed by both intragroup and intergroup analysis.

The results showed that there were no significant relationships between age and any of the isokinetic or EMG measurements or ratios. There were no significant differences in means of any of the measurements between the race groups. There was however, a vast overrepresentation of whites in the study (n=27, 84%), therefore no generalization in terms of race should be made for the other races due to the small sample size and the results with regards to race should be interpreted with caution. Weight was positively related to the results with EMG and isokinetic readings increasing as weight increased. As expected, the males, symptomatic and asymptomatic, had higher isokinetic and EMG readings than the females, with the wrist flexors being consistently stronger than the wrist extensors. It was found in these descriptives that the strength differences lay between the genders and not between the symptomatic and asymptomatic groups. The descriptives for isokinetic and EMG ratios showed variable results. These ratios when tested isokinetically were not significantly different between the asymptomatic and symptomatic groups but the asymptomatic group had slightly better ratios than the symptomatic group with the males having slightly higher ratios when compared to the females. These trends need to be further investigated. They are not congruent with the findings in the EMG ratios. These were found to be much higher in the symptomatic group with the females being especially high. Asymptomatic ratios were found to be lower, with male and female results being similar.

These results are inconsistent with each other, which could be due to the small sample size, therefore a larger study should be done to fully explore the statistical significance of the above findings.

In conclusion, no significant imbalances were found when comparing the ratios between the asymptomatic groups and the lateral epicondylitis groups with regards to peak torque and muscle activity therefore hypothesis 1 and hypothesis 2 are both rejected.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

DEFINITIONS

Absolute peak torque is the highest single value obtained during a series of repetitions. It is an appropriate indicator of an individual's maximum capability to generate torque (Albert 1991:101).

Electromyography (EMG) is an electrical recording of muscle activity that aids in the diagnosis of neuromuscular disease (Robinson 2004).

Isokinetic refers to a muscle group contracting against a controlled accommodating resistance, which in turn causes a limb to move at a constant angular or linear velocity within a prescribed sector of its range of motion (Dvir 2004).

Little league elbow syndrome Avulsion of the medial epicondylar apophysis. A common companion to this is osteochondritis dessicans of the capitellum (Nirschl and Kraushaar 1996).

Motor neurons are nerve cells that transmit signals from the brain or spinal cord to the muscles (Robinson 2004).

Motor unit action potentials Spikes of electrical activity recorded during an EMG that reflect the number of motor units (motor neurons and the muscle fibres they transmit signals to) activated when the patient voluntarily contracts a muscle (Robinson 2004).

Muscle balance is a term used to describe the relationship between agonist-antagonist muscle groups, one limb to another agonist groups, or eccentric to concentric muscle actions. In terms of agonist/ antagonist muscle groups the imbalance is referred to as a reduced ratio (Hunter 2004).

Power is the rate of doing work or the amount of work to be performed over time (Albert 1991:102). It is the product of force (torque) and velocity (Madan 2004).

Strength is defined by Anderson et al. (2000) as the ability of a muscle or group of muscles to produce a resulting force in one maximal resistance effort, either statically or dynamically. Isokinetic testing, using the Cybex Orthotron II, may be performed as a screening technique to determine any weakness or imbalance of the torque (force (N) x radius (m) of any of the major peripheral joints (Chan and Maffuli 1996 and Siqueira et al. 2002). The common understanding of strength is the point in the range of motion where strength reaches its maximum, hence the term peak moment or peak torque is used in the literature to describe strength (Dvir 2004).

Tendonitis is defined as inflammation of the tendon (Nirschl orthopeadic Centre 2004)

Torque is the force multiplied by the perpendicular distance from the axis for rotation—measured in Newton meters (Albert 1991:101)

Work is calculated as the area under the torque curve during a single isokinetic contraction or multiple contractions (Albert 1991:101-102)

CHAPTER ONE

1.0 INTRODUCTION

1.1 THE PROBLEM AND ITS SETTING

Lateral epicondylitis is a disabling, common, overuse condition of the elbow with an incidence of 1%-3% of all adults (Sharat and Maffulli 1997, Viola 1998). In a study of world class tennis players, 13% had current symptoms of lateral epicondylitis (Reid 1992:1016) and more than 50% had suffered from this condition at one time or other (Noteboom et al. 1994, Reid 1992:1016).

Lateral epicondylitis may affect a vast spectrum of the population including golfers, carpenters, bricklayers, squash players, housewives, dentists, surgeons, computer operators and students (Viola 1998, Shaik 2000, Roodt 2001).

Although lateral epicondylitis occurs in the population aged between 20 and 80 years (Viola 1998), it occurs most commonly between the ages of 30 and 55 years (Jackson 1997). The prevalence of this condition is equal in males and females (Sharat and Maffulli 1997), and according to Noteboom et al. (1994), Sharat and Maffulli (1997) and Viola (1998) it usually affects the dominant side.

Lateral epicondylitis is caused by multiple factors and presents in a variety of ways in different patients (Shaik 2000). It is a frequent occupational hazard in individuals carrying out forceful pronation and supination motions (Reid 1992:1014) or repetitive wrist flexion and extension movements (Chumbley et al. 2000, Viola 1998). This impairment of function most often manifests itself as pain in the elbow and lateral proximal forearm associated with forceful gripping or wrist extension (Noteboom et al. 1994).

The word epicondylosis should be substituted for epicondylitis because degeneration rather than inflammation is thought to exist (Nirschl and Kraushaar 1996).

In reviewing the literature it is evident that there is still debate as to the specific cause of the condition and as yet there is no agreement on the most effective treatment for this condition (Viola 1998).

1.2 THE STATEMENT OF THE PROBLEM

The purpose of this investigation is to determine whether imbalances in the wrist flexor and extensor muscle groups are an associated factor in the presentation of lateral epicondylitis, by measuring the peak torque (using the Cybex Orthotron II) and muscle activity (using surface EMG) of these specific muscle groups.

1.3 OBJECTIVES OF THE STUDY

OBJECTIVE 1: To assess the peak torque and muscle activity of the wrist flexor and wrist extensor muscle groups of 16 right-hand dominant, asymptomatic subjects, eight males and eight females.

OBJECTIVE 2: To assess the peak torque and muscle activity of the wrist flexor and wrist extensor muscle groups of 16 right-hand dominant, lateral epicondylitis patients, eight males and eight females.

OBJECTIVE 3: To integrate this information, compare the two groups and sub-groups and statistically analyse the difference between them.

1.4 Hypothesis

<u>Hypothesis 1:</u> It was hypothesised that there will be greater imbalances when assessing peak torque of the wrist flexor and wrist extensor muscle groups of 16 right-hand dominant, lateral epicondylitis patients, when compared to 16 right-hand dominant, asymptomatic subjects.

<u>Hypothesis 2:</u> It was hypothesised that there will be greater imbalances when assessing the muscle activity of the wrist flexor and wrist extensor muscle groups of 16 right-hand dominant, lateral epicondylitis patients, when compared to 16 right-hand dominant, asymptomatic subjects.

1.5 Benefits of the study

The aim of this study was to investigate whether muscle imbalances in the wrist flexor and extensor muscle groups were an associated factor in the presentation of lateral epicondylitis.

The literature on lateral epicondylitis does not give a convincing explanation for the symptoms, which suggests that a major cause may have been overlooked (Travell et al. 1999:734). Lateral epicondylitis is a very persistent disorder that does not easily resolve itself (Nirschl Orthopaedic Centre 2004), therefore, having an understanding of the etiologic features, according to Reid (1992:1016), will lead to a logical approach to therapy.

Normal wrist extensors should be about 45-50% of the flexor strength (Reid 1992:1017, Magee 2002:376). No studies could be found stating that an imbalance in this ratio is a possible cause for lateral epicondylitis. The degeneration occurring in the extensor tendon, which is due to an overuse injury (Nischl Orthopaedic Centre 2004), could possibly be linked to or exacerbated by a muscular imbalance between the wrist flexors and extensors.

Should this study indicate that a torque ratio or muscle activity imbalance is present in the wrist flexor and extensor groups in patients with lateral epicondylitis, it could then be regarded as an associated factor. Appropriate treatment could then follow, and patients involved in predisposing activities will be able to take preventative measures by correcting the imbalance, to decrease the chance of injury and minimise time spent away from work and sport.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION TO LATERAL EPICONDYLITIS

Lateral epicondylitis is the most common overuse syndrome of the elbow (Chumbley et al. 2000 and Disabella 2004) and has traditionally been known as “tennis elbow” (Jobe and Ciccotti 1994 and Nirschl Orthopaedic Centre 2004). However, this is an unsatisfactory term as it gives very little indication of the pathological processes involved (Brukner and Khan 2002:274), and only 5% of cases actually occur in tennis players (Cyriax and Cyriax 1993:58 and Ernst 1992).

This condition is caused by multiple factors and presents in a variety of ways in different patients (Shaik 2000), although, it is most commonly characterised by pain and acute tenderness on the lateral side of the elbow, which is usually related to the extensor tendon (Thomson et al. 1991:60).

2.2 EPIDEMIOLOGY

This disabling condition has an incidence of 1%-3% of all adults (Sharat and Maffulli 1997 and Viola 1998) and about three times that in manual workers (Ernst 1992).

Although lateral epicondylitis occurs in the population aged between 20 and 80 years (Viola 1998), it occurs most commonly between the ages of 30 and 55 years (Jackson 1997). According to Cyriax and Cyriax (1993:58), the patient is nearly always over 25 years. In studies done at the Durban Institute of Technology; 66% of Shaik’s (2000) sample were between the ages of 20-50 years, 70% of Oehley’s

(2002) sample were between the ages of 31-50 and Haswell (2002) had an average representation of 36 years.

The prevalence of lateral epicondylitis is equal in males and females (Jobe and Ciccotti 1994, Sharat and Maffulli 1997 and Viola 1998), and previous studies at Durban Institute of Technology have shown a good representation of both sexes with Shaik (2000) having a representation of 57% female and 43% male, Roodt (2001) having 55% male and 45% female, Haswell (2002) having 58% female and 42% male and Marquis (2002) having 57% male and 43% female. The average of the percentages represented above is males at 49.25% and females at 50.75%.

Jobe and Ciccotti (1994), Noteboom et al. (1994), Sharat and Maffulli (1997) and Viola (1998) state that lateral epicondylitis usually affects the dominant side, but the development of the condition bilaterally may be due to increased stress placed on the unaffected arm (Viola 1998). According to Viola (1998), right-sided epicondylitis is found to be twice as common as left-sided epicondylitis.

The incidence of lateral epicondylitis has been found to vary with different population groups (Noteboom et al. 1994). No reliable statistics could be found concerning the incidence of this condition in South Africa. In a literature review by Viola (1998), it was shown that Blacks are affected less frequently than Whites and according to Ernst (1992) Coloured people are affected less frequently than Whites. This supports current research trends in South Africa as studies done by Shaik (2000), Roodt (2001), Haswell (2002), Marquis (2002) and Oehley (2002) showed that lateral epicondylitis is far more prevalent in White South Africans. However, one cannot conclude from these studies that lateral epicondylitis does not affect other races in South Africa. As stated by Shaik (2000), racial demographics may have been biased by the method of advertising, the location of the Chiropractic Day Clinic and the relative lack of awareness of the role of chiropractic in the management of the condition in the previously disadvantaged communities of South Africa.

2.3 AETIOLOGY

The precise aetiology of lateral epicondylitis is unknown, but the syndrome is often ascribed to a combination of degenerative changes and chronic overuse (Ernst 1992).

Lateral epicondylitis is a frequent occupational hazard in individuals carrying out forceful pronation and supination motions (Reid 1992:1014), repetitive wrist flexion and extension movements (Chumbley et al. 2000, Viola 1998) or radial deviation motions (Sharat and Maffulli 1997). This impairment of function most often manifests itself as pain in the elbow and lateral proximal forearm associated with forceful gripping or wrist extension (Noteboom et al. 1994).

As suggested by Travell et al. (1999:734), a major cause may have been overlooked, because the literature on lateral epicondylitis does not give a convincing explanation for the symptoms. However having an understanding of the etiologic features, according to Reid (1992:1016), is necessary as it leads to a logical approach to therapy. Although the aetiology of lateral epicondylitis is unclear, the primary factor is most likely to be a mechanical predisposition of the elbow associated with a force overload (Viola 1998).

Lateral epicondylitis may affect a vast spectrum of the population including golfers, carpenters, bricklayers, squash players, housewives, dentists, surgeons, computer operators (Viola 1998) and students (Roodt 2001 and Shaik 2000). Other common causes of lateral epicondylitis include all activities requiring repetitive gripping and lifting, for example carrying large heavy briefcases (Jackson 1997), other parcels (Haswell 2002), and sports like gymnastics and swimming (Sharat and Maffulli 1997). In a study of world class tennis players, 13% had current symptoms of lateral epicondylitis (Reid 1992:1016) and more than 50% had suffered from the condition at one time or other (Viola 1998, Noteboom et al. 1994 and Reid 1992:1016). However, tennis players represent less than 5% of all reported cases

(Nirschl Orthopaedic Centre 2004). Viola (1998) states that most cases of this condition are actually caused by occupational stress rather than racket sports.

2.3.1 RESEARCH ON MUSCLE IMBALANCES

In a literature review by Noteboom et al. (1994), it was found that the chronic symptoms are commonly associated with inadequate muscle power and endurance. Jackson (1997) states that when evaluating lateral epicondylitis patients, it is found that many have poorly conditioned muscles surrounding the lateral epicondyle. Repetitive strain injury cases are prevalent in today's society because most tasks involve unidirectional resistive force eg. typing and gripping a steering wheel, therefore leading to a muscle imbalance between overused and underused muscle groups (Balance Systems Inc. 2003).

The synergic actions of the wrist flexor and extensor groups in functional activities have been well documented (Reid 1992:1054). As the agonist contracts, the antagonist progressively relaxes; this co-ordination produces a smooth movement. The antagonists are also called into action at the end of the greatest movement to protect against injury (Moore 1992:22). The limitation of both flexion and extension is mainly due to tension in the antagonistic muscle group (Reid 1992:1054).

In dysfunction between agonist and antagonist muscle pairs, there may be an imbalance in the muscles that take part in specific movements. These imbalances may be due to inefficient length-tension relationships and are measured with surface electromyography (EMG) (Cram 2003). Muscle imbalances, in general, may lead to pain and chronic injury by interfering with the natural movement of the joint (Holt 2005). Loss of muscular protection when there is disruption of normal agonist to antagonist force ratios can produce abnormal shear and compression loads to the tendon tissue (Albert 1991:5).

According to Lee and McMahon (2002) muscle imbalances in the shoulder area may lead to instability, impingement disease, rotator cuff tears and degenerative joint disease. With regards to the glenohumeral joint, instability or excessive laxity has been said to derive, in part, from muscle strength imbalances. Significant differences in the internal rotator/external rotator ratios have been found in patients with instability and impingement of the shoulder (Dvir 2004:228). Muscle balance is therefore a vital component to injury prevention (Delzeit 2003).

Recent research has begun to look at muscle strength imbalance between the hamstrings and the quadriceps (Anderson et al. 2000:446). The hamstring/quadriceps ratio has been used as an indicator of normal balance between the extensor and flexor function in the knee (Dvir 2004:150). If the muscles are unable to meet the demand of stabilization, inert internal tissues such as ligaments, cartilage and bone are at risk for injury. Therefore a deficit in eccentric hamstrings strength relative to eccentric quadriceps strength could predispose an athlete to an ACL injury (Anderson et al. 2000:446).

In a literature review by Hunter (2004), a number of studies were found assessing whether a particular strength profile was present in subjects who have suffered initial or recurrent hamstring strains. Statistical analysis of data in a study by Crosier et al. (2000) showed a reduced hamstring/quadriceps ratio when compared to the non-injured limb and with the control group. The aim of another study by Crosier et al. (2002) was to determine whether complete recuperation of isokinetic muscle strength levels and agonist/antagonist ratio correction could significantly reduce the incidence of injury when athletes return to sport after an initial hamstring muscle injury. Isokinetically corrected subjects were observed for 12 months after return to sport, none of which sustained a clinically diagnosed reinjury. This study was necessary because there is only sparse clinical documentation of the relationship between muscle imbalances and extremity injuries (Crosier et al. 2002). They conclude that correction of agonist/antagonist imbalances should represent a primary goal in rehabilitation.

Forthomme et al. (2003) conducted a study on the dominant arm of ten asymptomatic men and women. The test was performed twice, ten days apart. The wrist flexion/extension strength ratios from isokinetic tests done at various speeds are shown in the table below. This ratio of approximately two indicates that the wrist flexors are about twice as strong as the wrist extensors.

Table 2.3.1 Wrist flexion/extension strength ratios adapted from Dvir (2004:241).

Gender	Type of contraction and speed ˚/s	Dominant arm ratio
Men	Concentric 30	2.38 +- 0.43
	Concentric 90	2.55 +- 0.29
	Eccentric 60	2.02 +- 0.53
Women	Concentric 30	2.25 +- 0.77
	Concentric 90	2.16 +- 0.63
	Eccentric 60	1.23 +- 0.28

(No normal results could be found testing concentric contraction at a speed of 60˚/s.—which was utilised in this study.)

The greatest torque around the elbow is produced by the wrist flexors, then the wrist extensors (Magee 2002:376). Normal wrist extensors should be about 45-50% of the flexor strength (Magee 2002:376, Reid 1992:1017). No research could be found stating that an imbalance in the above ratio was an associated factor in the presentation of lateral epicondylitis or regarding the impact of muscle imbalances at the elbow.

2.4 ANATOMY OF THE ELBOW JOINT

Having knowledge of the anatomy of the elbow joint aids in constructing a differential diagnosis (Chumbley et al. 2000).

The elbow is made up of a complex set of closely related, compound synovial joints including the ulnohumeral, radiohumeral and superior radioulnar joints (Magee 2002:321). Osseous stability of the elbow is reinforced by the medial and collateral ligament complexes (Chumbley et al. 2000).

The musculotendinous structures at the lateral epicondyle of the elbow are those of the common extensor origin and include the Extensor Carpi Radialis Longus, Extensor Carpi Radialis Brevis, Extensor Carpi Ulnaris and Extensor Digitorum Communis (Jobe and Ciccotti 1994). These muscles elicit wrist extension (Moore and Dalley 2006:808). The muscles that elicit wrist flexion include the Flexor Carpi Radialis, Palmaris Longus, Flexor Digitorum Superficialis and Flexor Carpi Ulnaris (Jobe and Ciccotti 1994). These muscles attach at the medial epicondyle of the elbow (Moore 2006:804). These muscles are referred to collectively as the wrist extensors and wrist flexors. These muscles and their nerve supply are listed in the table below (adapted from Moore and Dalley 2006:804-805, 808-809).

Table 2.4 Individual Muscles and Innervations of the Wrist Flexor and Extensor Muscle Groups

Action	Muscles	Nerve Supply	Nerve Root Deviation
Wrist Flexion	1. Flexor Carpi Radialis	Median	C6-C7
	2. Flexor Carpi Ulnaris	Ulnar	C7-C8
	3. Palmaris Longus	Median	C7-C8
	4. Flexor Digitorum Superficialis	Median	C7-C8-T1
Wrist Extension	1. Extensor Carpi Radialis Longus	Radial	C6-C7
	2. Extensor Carpi Radialis Brevis	Radial	C7-C8
	3. Extensor Carpi Ulnaris	Radial	C7-C8
	4. Extensor Digitorum Communis	Radial	C7-C8

(For the purposes of this study the muscle groups were utilised and not the individual muscles.)

2.5 PATHOLOGY

There is still much confusion as to the site of the pathology (Reid 1992:1021) and the exact pathophysiology (Disabella 2004). However, according to Thomson et al. (1991:61) a tear or injury can occur at one or more of the following sites:

[a] the tendon
[b] the teno-muscular junction
[c] the teno-periosteal junction

Lateral epicondylitis is traditionally viewed as inflammation of the tendons that insert at the epicondyle (Schneider 1994:120). This is known as tendinitis (Nirschl Orthopaedic Centre 2004). The resulting inflammation produces exudate in which fibrin is formed to heal the torn tissue. However, excessive fibrin may be produced which could lead to adhesions between the tendon and the surrounding tissues. This can cause pain on stretching and impairment of function (Thomson et al. 1991:61). These inflammatory conditions of the tendons, according to Reid (1992:78), may be acute or chronic. Chronic inflammation may cause degenerative changes in the tendon, which is then called tendinosis rather than tendinitis as in the acute scenario (Nirschl and Kraushaar 1996, Reid 1992:78). Tendinosis is defined by the Nirschl Orthopaedic Centre (2004) as a *distinctly non-inflammatory, degenerative, avascular process occurring in a tendon due to an overuse injury, which results from accumulated micro-traumatic events*. Brukner and Kahn (2002:274) state that the primary pathology in this condition is degeneration of the extensor carpi radialis brevis tendon usually within 1-2cm of its attachment to the common extensor origin at the lateral epicondyle and therefore the term epicondylitis is inappropriate. At biopsy of the tendon, no evidence has been found of an immune cell response but rather angiofibroblastic degeneration, which leads to the term tendinosis being used (Nirschl Orthopaedic Centre 2004). However the criticism of this is that these biopsies are only being performed in chronic cases after 6-12 months of conservative care has failed (Disabella 2004).

Travell et al. (1999:734) agree that the symptoms may be caused by repetitive microtrauma at the common extensor origin resulting in inflammation, but may also be as a result of chronic tension from the taut bands of myofascial trigger points. Travell et al. (1999:734) state that recognition of the contribution of these trigger points would help in explaining a possible cause of lateral epicondylitis. Schneider (1994:120) is also of the opinion that any tendinitis may be secondary to chronic muscle hypertonicity, which repeatedly overloads its tendinous attachments.

2.6 DIAGNOSIS OF LATERAL EPICONDYLITIS

A good case history and physical examination is necessary to correctly identify the condition (Chumbley et al. 2000). Making the correct diagnosis avoids harsh and incorrect treatment, to which the elbow responds poorly (Magee 2002:321).

2.6.1 CLINICAL FEATURES

A) PAIN

The onset of the pain may be sudden or gradual (Sharat and Maffulli 1997), but often begins 24-72 hours after the provocative activity (Jackson 1997). The persistent pain is intensified by grasping or twisting and often radiates into the forearm (Sharat and Maffulli 1997). This referred pain, which may be either aching or sharp, begins over the wrist extensors at the elbow and extends distally along the forearm to the wrist (Thomson et al. 1991). There may also be a dull ache at rest (Nischl Orthopaedic Centre 2004).

B) MOVEMENTS

All elbow, wrist and hand joints have full active range of motion, however resisted wrist extension may be painful, but passive movements are pain free (Thomson et al. 1991).

C) PALPATION

There is palpatory tenderness at the site of the lesion and over the tendon (Thomson et al. 1991). This is commonly just distal to the lateral epicondyle over the Extensor Carpi Radialis Brevis tendon (Disabella 2004).

2.6.2 ORTHOPAEDIC TESTS

A) MILL'S TEST

A positive test is indicated by pain over the lateral epicondyle on forearm pronation with wrist flexion and active extension of the elbow (Magee 2002:336).

B) PALPATION OF THE LATERAL EPICONDYLE

Pain can be induced by palpation of the lateral epicondyle, which induces point tenderness (Sharat and Maffulli 1997).

C) LATERAL EPICONDYLITIS TEST

A positive test is indicated by pain over the lateral epicondyle on resisted extension of the third digit of the hand distal to the proximal interphalangeal joint (Magee 2002:336).

D) COZEN'S TEST

A positive test is indicated by pain over the lateral epicondyle on resisted
wrist extension and radial deviation with forearm pronation (Magee 2002:336).

2.7 DIFFERENTIAL DIAGNOSIS

Disabella (2004) suggests a number of other conditions that may be the source of lateral elbow pain. These include:

- Cervical radiculopathy
- Little league elbow syndrome
- Radial neuropathy
- Radial tunnel syndrome
- Lateral elbow instability
- Humeral fracture
- Radial head fracture
- Rotary instability of the elbow
- Posterior pinch syndrome/plica of the elbow
- Degenerative joint disease of the elbow
- Loose bodies
- Osteochondritis dessicans of the capitellum

Ernst (1992) suggests other causes including lipoma and ganglion.

Lateral epicondylitis is not usually associated with visible signs of swelling. A presence of this may indicate arthritis, synovitis, infection, trauma or tumour (Viola 1998).

It is beyond the scope of this research to investigate each of the above conditions and the reader is thus referred to the appropriate texts.

2.8 TREATMENT

In reviewing the literature it is evident that there is still debate as to the specific cause of the condition and as yet there is no agreement on the most effective treatment for this condition (Viola 1998).

Recovery of this condition can be prolonged, therefore it is important to be dedicated to correcting the underlying problems (Jackson 1997).

In 1999, over 40 different treatment methods for lateral epicondylitis had been reported in the literature (Sevier and Wilson 1999). Treatment is aimed at relief of inflammation, promotion of healing, reducing the overload forces, and increasing the strength, endurance, co-ordination and flexibility of the patient's whole upper limb (Reid 1992: 1018, 1022 and Nirschl and Kraushaar 1996). Although local fitness is emphasised in the treatment of this condition, most rehabilitation has been directed at just the wrist extensor mechanism (Noteboom et al.1994). Noteboom et al. (1994) found that the recommended strengthening goal for competitive athletes in their playing arm wrist extensor strength should be 10% greater than their nondominant arm, while a 5% difference is recommended for the recreational athlete. As yet, there is no scientific evidence to document the efficacy of these efforts (Noteboom et al. 1994). No mention in this literature review by Noteboom et al. (1994) was made of the relevance of wrist flexor strengthening or maintenance of the balance between the two muscle groups.

The outcome of conservative treatment is still variable. In controlled clinical trials by Oehley (2002) and Roodt (2001) on different treatment methods for lateral epicondylitis which included manipulation of the elbow joint and applying local flurbiprofen patches, no statistically significant improvement was noted. In a study by Shaik (2000), Mill's manipulation and cross friction was compared to cross friction alone and neither was found to be any more effective than the other. Although Haswell's study (2002) showed that dry needling may be an effective method in treating lateral epicondylitis, no single treatment has proven to be totally effective in the management of this conditon (Brukner and Khan 2002:279). In a study by Marquis (2002), it was shown that combining two treatments, dry needling and cross friction, was more effective than just one on its own.

Ernst (1992) states that because of the considerable prevalence and relapse rate, a prophylaxis for this condition is needed, however, nothing as yet can be offered. It has been shown that by correcting muscle imbalances throughout the body it is possible to eliminate a wide variety of disorders, returning the individuals back to their previous professions and recreational activities pain free (Balance Systems Inc. 2003).

2.9 Measurement tools

Two measurement tools were utilised in this study; surface EMG, to test the amount of muscle activity and the Cybex Orthotron II device, for isokinetic muscle testing. In a study by Snyder-Mackler and Epler (1989) on testing the effect of standard and aircast tennis elbow bands on the forearm extensor muscles, the two measurement tools used were EMG and the Cybex II, which they found to be adequate.

2.9.1 Surface EMG

Surface EMG was chosen as an effective measurement tool as a number of investigators have used surface EMG as an objective measuring tool of muscle function (Mould 2003).

Surface electromyography is a technique that measures muscle (motor unit) activity non-invasively, using surface electrodes placed on the skin overlying the muscle (Pullman et al. 2000). The magnitude of the electromyographic activity in an active muscle is determined by the number of muscle fibres that are recruited and the frequency of excitation—the same factors that determine muscle force (Lewis and Fulco 1998). The amplitude of the integrated EMG activity provides immediate feedback on the magnitude of muscle forces (Van Den Bogert 1994). The number of motor units being activated, therefore, relates positively to the strength of that muscle (Hamilton et al. 2004).

A neuronal action potential activates all of the muscles innervated by the motor neuron. This activation process involves a motor unit action potential and a contraction of the muscle fibres. During a contraction there is synchronous activity in a number of fibres in the same muscle (Physiology Experiments Manual Pp 69). Surface EMG monitors these muscle action potentials (Cram 2003). Using this technique it is possible to analyse the activity of an individual muscle during different movements. The differences in electrical action potentials of the muscles are amplified and recorded. Surface EMG identifies incorrect muscle substitution patterns (Cram 2003) and is often used in diagnosing different conditions that cause weakness (Robinson 2004).

The technique is completely non-invasive and there are no known contraindications to utilising surface EMG (Gentempo and Kent 1991). Abou-Chadi et al. (2001) agree that surface EMG is a reliable measurement tool when used correctly and provides an integrated system of analysis, to assist the physician with making a diagnosis.

2.9.2 ISOKINETIC DYNOMOMETRY

Isokinetics is defined as the unilateral ratio comparison between the agonist and antagonist muscle groups based on peak torque measurements (Davies 1992:61-62). Comparing the relationship between the agonist and antagonist muscles may identify particular weaknesses in certain muscle groups (Davies 1992:63). Isokinetic exercise has also been defined as a dynamic muscular contraction when the velocity of the movement is controlled and held constant by a specific isokinetic device, usually an electromechanical appliance (Chan and Maffulli 1996:7).

Isokinetic assessment is mostly recommended for strength testing as a maximal force is applied during all phases of movement of the joint at a constant velocity (Albert 1991:99, De Ste Croix et al. 2003).

Isokinetic testing of muscle performance is a newer method that is used more commonly in sports and rehabilitation clinics to test function and is a safe tool even in painful conditions (Pienimäki et al. 1996). Flexion and extension movements on the Cybex have been tolerated clinically by most patients with lateral epicondylitis before pronation and supination (Davies 1992:484). Therefore, only flexion and extension movements were measured so as to avoid any further injury or discomfort to the patient.

Isokinetic exercise is able to quantify muscle function by evaluating peak torque, average torque, work and power of the muscle that is contracting (De Ste Croix et al. 2003). The peak torque of concentric muscle contractions gives a good indication into the power output and work of the muscle being tested. Peak torque is measured in Newton's (force) per second [N/s] by the Cybex Orthotron II device (Jackson 2005).

2.9.2.1 Reliability and validity of isokinetic testing

Several studies have shown that the Cybex is a valid and reliable method of quantifying objective information (Davies 1992:35).

A) Reliability

The reliability of isokinetic dynamometers is extremely high. The studies, which have examined the accuracy of peak torque, work, and power, have shown correlation coefficients between 0.93 and 0.99 (www.isokinetics.net).

Callaghan et al. (2000) conducted a study to test the reliability of isokinetic testing. They concluded, from their study, that the isokinetic values for peak torque, average power and total work were highly reliable and should be confidently used by clinicians.

B) VALIDITY

Certain factors have been recognised as establishing convergent validity due to the relationship they have with isokinetic testing. These factors include:

- **Gender differences**

Many isokinetic studies have shown that men are significantly and consistently stronger than women (www.isokinetics.net).

- **Age**

Strength normally reaches its peak in the third decade and thereafter declines moderately with age until the seventh decade where there is a steeper decline (www.isokinetics.net).

- **Body weight**

Muscle mass rises proportionately with body weight. Heavier subjects therefore, produce higher isokinetic moments. However, this relationship is not linear and is one of the reasons for normalizing strength to body weight using Newton meter per kilogram body weight (www.isokinetics.net).

- **Muscle characteristics**

The slope of moment angular velocity curve changes with age in that children cannot utilize stretch shortening cycles as adults can, possibly because of softer muscles (i.e. they are more flexible). This is seen in isokinetics especially in adolescents who generate more moment at slower speeds (www.isokinetics.net).

2.10 SUMMARY

According to Noteboom et al. (1994), lateral epicondylitis may present as a multifactorial syndrome. Crosier et al. (2002) state that persistence of muscle strength abnormalities may effectively give rise to recurrent injuries in the thigh. No studies could be found assessing the correlation of muscle imbalances to the incidence of lateral epicondylitis. According to Magee (2002:321), the elbow joint responds poorly to incorrect treatment and although many clinical trials have been done there is no agreement as to the most effective treatment for the management of lateral epicondylitis (Viola 1998). However, it has been shown that correcting muscle imbalances elsewhere in the body, eliminates many disorders, returning the individuals back to their previous professions and recreational activities pain free (Balance Systems Inc. 2003).

Furthermore, isokinetic dynamometers and surface electromyography can effectively and accurately measure the maximal capacity of muscles [Dvir (2004) and Abou-Chadi et al. (2001)].

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 INTRODUCTION

This chapter outlines the procedure used to carry out this study. It includes the study design, sample selection, exclusion and inclusion criteria, ethical considerations and the materials and methods of intervention. It describes the primary and secondary data and the methods of statistical analysis and data evaluation.

3.2 STUDY DESIGN

This was an investigative, prospective, controlled clinical trial.

3.3 THE STUDY SAMPLE

A large sample size would have been preferable for this study, however, as previous research on lateral epicondylitis at the Durban Institute of Technology has had a poor patient response (Marquis 2002, Oehley 2002 and Roodt 2001), and due to financial constraints, a smaller sample size of 32 patients was used.

Although lateral epicondylosis occurs in the population aged between 20 and 80 years (Viola 1998), it occurs most commonly between the ages of 30 and 55 years (Jackson 1997). In studies done at the Durban Institute of Technology; 66% of Shaik's (2000) sample were between the ages of 20-50 years, 70% of Oehley's (2002) sample were between the ages of 31-50 and Haswell (2002) had an average had representation of 36 years. Therefore the age group of 25-50 years was acceptable and utilised in this study.

The prevalence of lateral epicondylitis is equal in males and females (Sharat and Maffulli 1997), and previous studies at Durban Institute of Technology have shown a good representation of both sexes (Haswell 2002, Marquis 2002, Roodt 2001 and Shaik 2000). Therefore both males and females were considered for this study. There were eight females and eight males in each of the two groups.

Noteboom (1994), Sharat and Maffulli (1997) and Viola (1998) state that lateral epicondylitis usually affects the dominant side, therefore only patients that had the symptoms present in that arm were considered for this study. To minimise variables only right arm dominant patients were included. There were no other restrictions in terms of occupation, race or area of residence.

Advertisements requesting participation in this investigative study of lateral epicondylitis were placed on notice boards at the Durban Institute of Technology, library notice boards, local sports clubs, local gyms, local universities, local newspapers as well as pamphlet distribution to specific residential areas (Appendix G). Patients presenting to the Chiropractic Day Clinic at Durban Institute of Technology with lateral epicondylitis were also considered for the study. Sixteen asymptomatic people aged between 25-50 years with no history of lateral epicondylitis were required to volunteer for the study for the control group.

3.3.1 THE INCLUSION CRITERIA

Applicants were screened for inclusion to the study by conducting a

- case history (Appendix C),
- physical examination (Appendix D) and a
- regional elbow examination (Appendix F).

Because of the potential referral of symptoms from the cervical spine and the necessity of differentiating nerve root symptoms from peripheral lesions, the inclusion of a cervical assessment (Appendix E) was essential.

The following criteria were used to determine which patients should be included into the study:

Symptomatic group

- Local tenderness on the outside of the elbow at the common extensor origin (Reid 1992:1014).

- Tenderness on palpation over the lateral epicondyle (Sharat and Maffulli 1997).

- A positive finding of at least one of the following tests performed according to the procedure set out by Magee (2002:336).

1. **COZEN'S TEST:** A positive test is indicated by pain over the lateral epicondyle on resisted wrist extension and radial deviation with forearm pronation (Magee 2002:336).

2. **MILL'S TEST:** A positive test is indicated by pain over the lateral epicondyle on forearm pronation with wrist flexion and active extension of the elbow (Magee 2002:336).

- Active myofascial trigger points in the Brachoradialis; Extensor Carpi Radialis Longus and Brevis; 4^{th} and 5^{th} Finger Extensors, Extensor carpi ulnaris, or the Supinator muscle because these muscles refer primarily to the lateral epicondyle (Travell et al. 1999:691).

Control group

Subjects in the control group did not:

- have any of the above mentioned criteria
- have any subjective or objective symptoms of lateral epicondylitis
- have ever previously been diagnosed with lateral epicondylitis.

For sample homogeneity, subjects had to be right hand dominant.

3.3.2 THE EXCLUSION CRITERIA

Applicants were excluded from the study if they presented with any of the following.

- Complaints of pain in several joints as they may have a systemic arthritic disorder e.g. Rheumatoid Arthritis or localised Osteoarthritis (Magee 2002:324).

- Any dysfunction at the C5-C6 segment, as a C6 radiculopathy may cause weakness of the radial wrist extensors (Reid 1992:1014).

- Any tumours of the involved extremity.

- Any absolute contra-indications for Cybex testing (Davies 1992:37):

-Extremely limited ROM (for isokinetic testing 70-80º flexion/extension is necessary) (Davies 1992:487)
-Severe effusion
-Unstable joint/bone (noted whilst doing the ligamentous tests of the elbow regional)
-Acute sprain

and if:

- radiographs were necessary to confirm a diagnosis;

- the symptoms were present in the patient's non-dominant arm;

- they were professional sports people, playing at a provincial or international level.

- According to Disabella (2004), in professional tennis players there are many other external factors which may affect the elbow e.g. grip size, racquet weight, string tension and heavy or wet balls. This criterion was selected for the purposes of sample homogeneity study because of the possibility of interference of these factors on the subjects and research results.

- they were receiving any form of treatment for their lateral epicondylitis.

  - Those patients taking any painkillers or oral NSAIDs for their condition would have needed a three-day wash out period before the commencement of the study (Oehley 2002).

All dropouts were replaced until 32 participants were recruited.

The patients were informed that during the course of the study they could not receive treatment in any form for the lateral epicondylitis

3.3.3 ALLOCATION OF SUBJECTS

The symptomatic group consisted of eight males and eight females with lateral epicondylitis and the control group consisted of eight males and eight females without lateral epicondylitis.

3.4 ETHICAL CONSIDERATIONS

Once the subjects were accepted to participate in the study, a letter of information (Appendix A) was given, explaining what was expected of them and an informed consent form (Appendix B) was completed by all those participants. They were given an opportunity to ask questions to eliminate any misunderstandings. Their details were then recorded for future reference.

At this stage the patients were informed that they were free to withdraw from the study at any stage without giving a reason.

Surface EMG and the Cybex Orthotron II are established and widely used instruments. Isokinetic testing may cause some muscle stiffness, but is otherwise harmless to the patient. There are no known contraindications to performing surface EMG on a patient.

All participation was voluntary and no financial benefit was provided to the patient.

The rights and welfare of the patient were protected at all times.

All information gathered during the research process was regarded as strictly confidential. All patients were assigned file numbers on entry into the clinic. The data obtained were coded per patient file and was handled in such a manner that the participant remained unidentifiable in the data analysis and presentation

3.5 Intervention

A case history (Appendix C), abbreviated physical examination (Appendix D), elbow (Appendix F) and cervical (Appendix E) examination were conducted on all participants at the Chiropractic Day Clinic on the Durban Institute of Technology campus.

Electromyography:

All participants had the muscle activity of their wrist flexors and wrist extensors measured, in the Physiology laboratory at Durban Institute of Technology by using surface EMG. All participants had their dominant arm measured. The instrument used was the PowerLab/410 (137) unit (AD Instruments Pty Ltd, unit 6, Gladstone Rd, Castle Hill, NSW 2154, Australia).

The raw EMG signal during voluntary contractions may be processed in various ways to indicate the intensity of EMG activity. In the method utilised in this study, the negative-going portions of the EMG were inverted and the whole signal was integrated in such a way as to smooth out individual spikes. The height of the integrated trace reflected the overall activity of the raw EMG signal and gave a simpler view of the muscle's electrical activity. The height of the trace correlated with the force produced by the muscle and was recorded in millivolts (Physiology Experiments Manual Pp 69-73).

The interpretation of EMG results requires the analysis of the characteristics of the spikes. A decrease in the amplitude of the spike is associated with muscle disease or long-standing muscle disorders where muscle tissue is replaced by fibrous tissue or fat (Robinson 2004). A resting normal muscle shows only a baseline activity (Moore and Dalley 2006:38). For the purposes of this study only the amplitude of the spike was analyzed.

PROCEDURE:

The patient removed all jewellery and watches on the testing arm and was seated comfortably in a relaxed position with the elbow at 90º and forearm supinated. Two small crosses were lightly marked 3cm apart, on the surface of the skin overlying the wrist flexor and extensor muscle group. These were aligned with the long axis of the ulna and radius, respectively. The skin was lightly abraded over these marks to reduce its electrical resistance.

The electrodes were placed on these marked points and fastened with adhesive tape.

Two to three seconds of resting EMG signal was recorded for each patient. The patient performed three voluntary contractions of the wrist flexors by flexing the wrist maximally against resistance holding each contraction for three seconds before relaxing for two seconds. Thereafter the patient did the same for the wrist extensor group by extending the wrist with maximal strength. An average was taken of the three readings.

Isokinetic Cybex Testing:

All participants then had the average torque of their wrist flexors and extensors measured by using the Cybex orthotron II device.

Flexion and extension movements on the Cybex have been tolerated clinically by most patients with lateral epicondylitis before pronation and supination (Davies 1992:484). Therefore, only flexion and extension movements were measured so as to avoid any further injury to the patient. Torque is measured in Newton meters by the Cybex Orthotron II device.

PROCEDURE:

The patient underwent a standardised 2-minute warm-up session. This consisted of peddling an ergometric bicycle with their upper limbs. Then the patient performed active stretches of their wrist flexors and extensors holding each stretch for 15 seconds and repeating it three times for each muscle group (Jackson 2005). Thereafter the patient was instructed on the procedure for isokinetic testing.

The elbow was placed in 90º flexion to prevent the muscle-tendon unit from contracting in a fully lengthened position (Davies 1992:484).

All patients were lying prone to standardise positions, as testing in different positions could have affected the collection of raw data, and could change the balance of unilateral agonist/antagonist strength ratios (Davies 1992:488).

In orthopaedic examinations resisted movements are tested in neutral positions to minimise the stress placed on inert tissues (Magee 2002:12). Therefore, forearm supination was the recommended position for testing on the Cybex extremity systems (Davies 1992:484).

The protocol included concentric exertions of both the wrist flexors and extensors at an angular speed of 60 deg/sec. The average torque was recorded for each muscle group after six repetitions (Jackson 2005).

3.6 THE DATA COLLECTION

This study made use of both primary and secondary data.

3.6.1 THE PRIMARY DATA

The primary data consisted of the muscle activity readings that were recorded using the surface EMG method [PowerLab/410 (137) unit (AD Instruments Pty Ltd, unit 6, Gladstone Rd, Castle Hill, NSW 2154, Australia)] and the isokinetc readings that were recorded using the Cybex Orthotron II device.

3.6.2 THE SECONDARY DATA

The secondary data consisted of relevant published books, journal articles and information from the Internet.

3.7 STATISTICAL METHODS AND ANALYSIS

Data were captured in MS Excel and exported into SPSS (Statistical Package for Social Sciences) version 11.5 for data analysis (SPSS Inc, Chicago, Ill, USA).

Ratios were generated by dividing the flexion by the extension measurement, multiplying by 100 and subtracting 100 to give the percentage increase in strength of the flexor muscle groups over the extensor muscle groups.

Ratios and measurements were described and compared between subgroups using parametric statistics. One-way ANOVA with Bonferroni post hoc tests were used to compare mean values between subgroups.

A p value of <0.05 was considered as statistically significant.

3.8 SUMMARY

Thirty-two patients were selected to participate in this study. The symptomatic group consisted of 16 patients (eight males and eight females) with lateral epicondylitis and the control group consisted of 16 patients (eight males and eight females) without lateral epicondylitis. Each participant was assessed objectively by testing their peak torque and muscle activity of their wrist flexors and extensors and all the necessary data was obtained for statistical analysis.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter includes the statistical analysis of the four groups allocated to this study. A brief outline of the demographics of the sample in terms of age, race, occupation and level of activity is followed by the descriptives of the symptomatic group and then both intragroup and intergroup analysis.

Key for Abbreviations in Tables and Graphs:

P : Probability
Sd : Standard deviation
Sig : Significance
N : Number
Df : Degrees of Freedom

4.2 Demographic Data

4.2.1 Age

The sample consisted of 32 participants, 16 in each group (eight males and eight females). They ranged in age from 25 to 50 years, with a mean age of 35.75 years, and a standard deviation of 9.9 years was noted. This falls into the age interval of between 30-55 years that was described by Jackson (1997) as the period of peak incidence. This age is slightly higher than Haswell's (2002) study at the Durban Institute of Technology, which had an average representation of 36 years.

There was however, a statistically significant difference in mean age between the symptomatic group and the asymptomatic group (p=0.001). The mean age of the asymptomatic group including males and females was 30.44 years while that of the symptomatic group, males and females, was slightly older at 41.06 years. This age difference between the groups did not affect the results as discussed later in the chapter.

There was no difference in mean age between the genders (p=0.649). These tests are shown in Tables 4.2.1.1 and 4.2.1.2. Figure 1 shows the mean ages between the groups and genders.

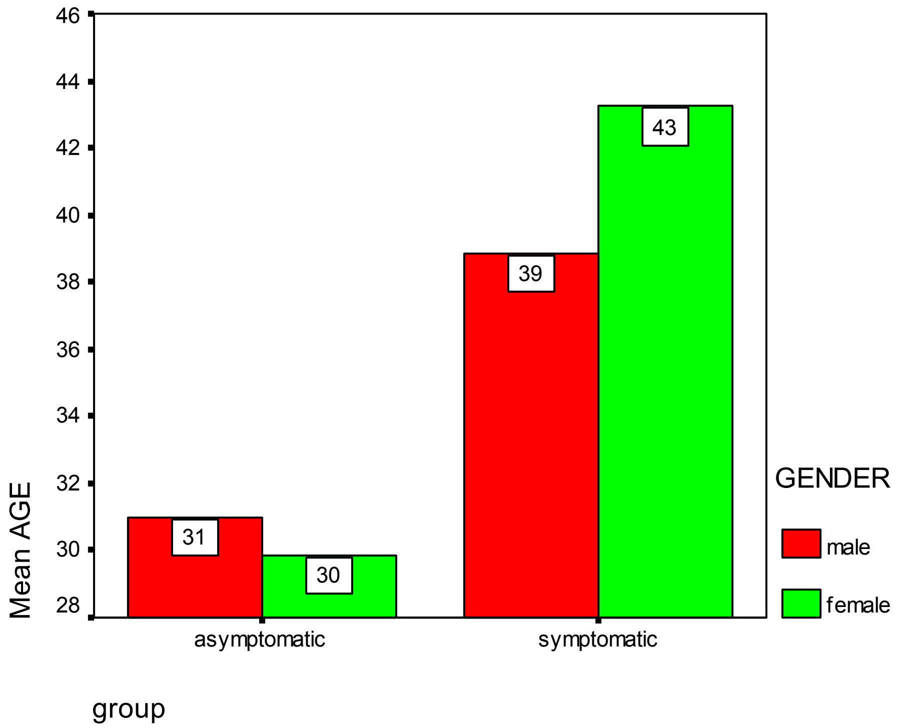
Table 4.2.1.1: T-test for comparison of mean age between groups (n=32)

	Group	N	Mean	Std. Deviation	Std. Error Mean	P value
AGE	Asymptomatic	16	30.44	8.099	2.025	0.001
	Symptomatic	16	41.06	8.668	2.167	

Table 4.2.1.2: T-test for comparison of mean age between genders (n=32)

	GENDER	N	Mean	Std. Deviation	Std. Error Mean	P value
AGE	Male	16	34.94	9.705	2.426	0.649
	Female	16	36.56	10.263	2.566	

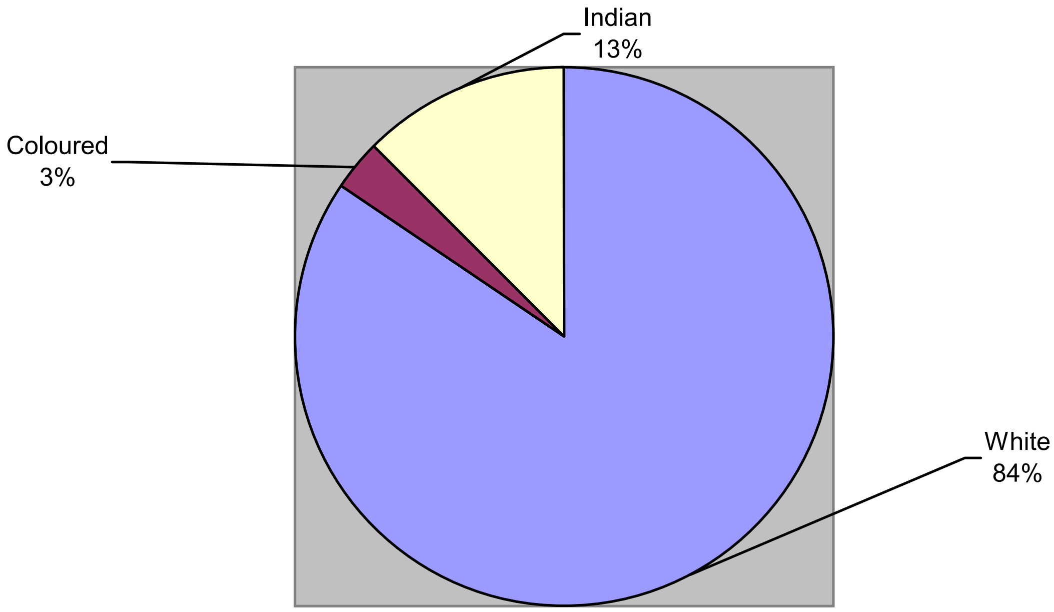
Figure 1: Mean age by group and gender (n=32)



4.2.2 ETHNICITY

Three race groups were represented in this study, Coloured, White and Indian. The breakdown of race representation is shown in Figure 2.

Figure 2: Race Groups represented in the study recorded as a percentage (n=32)



There was a significant association between race and group (p=0.043), due to lack of stratification in the sampling method. All the participants in the asymptomatic group were White, while Coloured and Indian race groups were represented in the symptomatic group. There were no Black participants in this study. This is shown in Table 4.2.2.

The predominance of White participants in this study is in keeping with a study of 1000 patients in the USA in which lateral epicondylitis was found to be rare in Blacks and occur more frequently in Caucasions (Delee and Drez 1994:860). Viola (1998) also states that black people are affected less frequently than white people. However, one cannot conclude from this study that lateral epicondylitis does not affect other races in South Africa, because as argued by Shaik (2000), Haswell (2002) and Marquis (2002) the racial demographics may have been biased by the methods of advertising employed, the location of the Chiropractic Day Clinic as well as the relative lack of awareness of the role of chiropractic in the management of the condition in the previously disadvantaged communities of South Africa. This is consistent with the findings of Van Der Meulen (1997) whose study showed that over 90% of people with low back pain, living in a formal Black South African township, relied heavily on drug-therapy for treatment, having had little or no exposure to physicians in private practice. This is supported by the fact that only the White racial group was represented in the asymptomatic group. The sample in this study is probably unrealistic therefore, no deductions should be made about the prevalence of lateral epicondylitis in Black, Coloured and Indian people from this study.

There was no association between race and gender (p=1.00).

Table 4.2.2: Cross-tabulation of race by group

Race		Group		Total
		Asymptomatic	Symptomatic	
White	Count	16	11	27
	% Within race	59.3%	40.7%	100.0%
Other	Count	0	5	5
	% Within race	.0%	100.0%	100.0%
Total	Count	16	16	32
	% Within race	50.0%	50.0%	100.0%

P=0.043

4.2.3 HEIGHT

Height was not different between the symptomatic and asymptomatic groups (p=0.345, Table 4.2.3.1) while there was a significant difference in height between the genders (p=0.027, Table 4.2.3.2) with males being taller than females. This is shown in Figure 3. There were no expectations that height would have an effect on the muscle activity or isokinetic results in this study therefore no deductions will be made. This test was done to check homogeneity of the sample group, and for the sake of further isokinetic or muscle activity research.

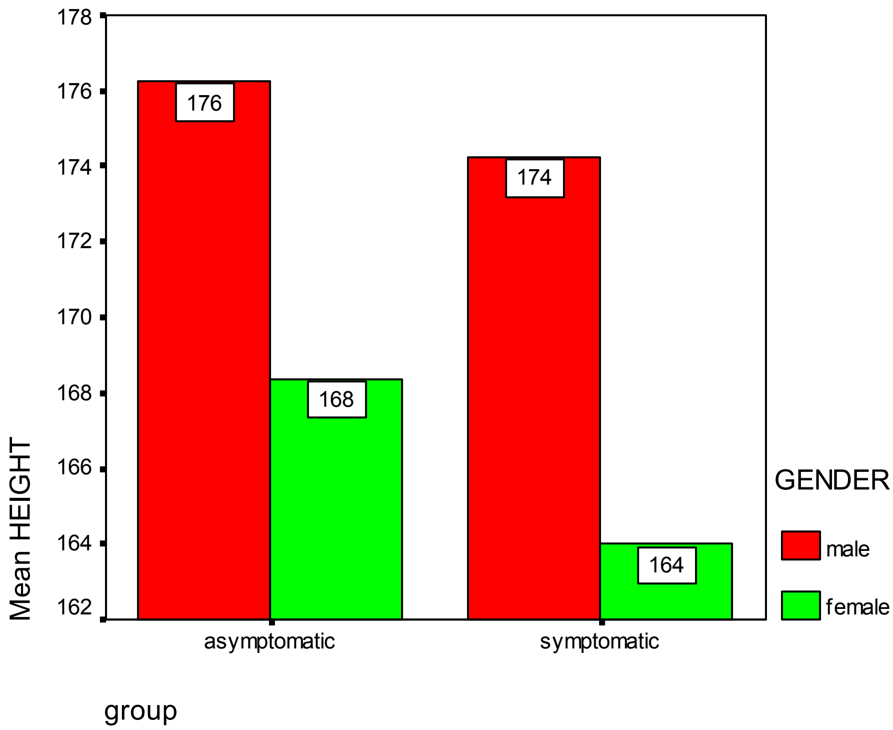
Table 4.2.3.1: T-test for comparison of mean height between groups (n=32)

	Group	N	Mean	Std. Deviation	Std. Error Mean	P value
HEIGHT	Asymptomatic	16	172.31	8.048	2.012	0.345
	Symptomatic	16	169.13	10.576	2.644	

Table 4.2.3.2: T-test for comparison of mean height between genders (n=32)

	GENDER	N	Mean	Std. Deviation	Std. Error Mean	P value
HEIGHT	Male	16	175.25	8.851	2.213	0.027
	Female	16	166.19	7.739	1.935	

Figure 3: Mean height by group and gender (n=32)



4.2.4 WEIGHT

There was no significant difference between the symptomatic and asymptomatic groups in terms of weight (p=0.397, Table 4.2.4.1), keeping homogeneity between the sample groups, but there was a significant difference between the genders (p=0.001, Table 4.2.4.2). This is shown in Figure 4. This could be an explanation for the strength ratio being higher in men than in women as heavier subjects produce higher isokinetic moments, but also many isokinetic studies have shown that men are significantly and consistently stronger than women and this is normally documented as an obvious observation (www.isokinetics.net).

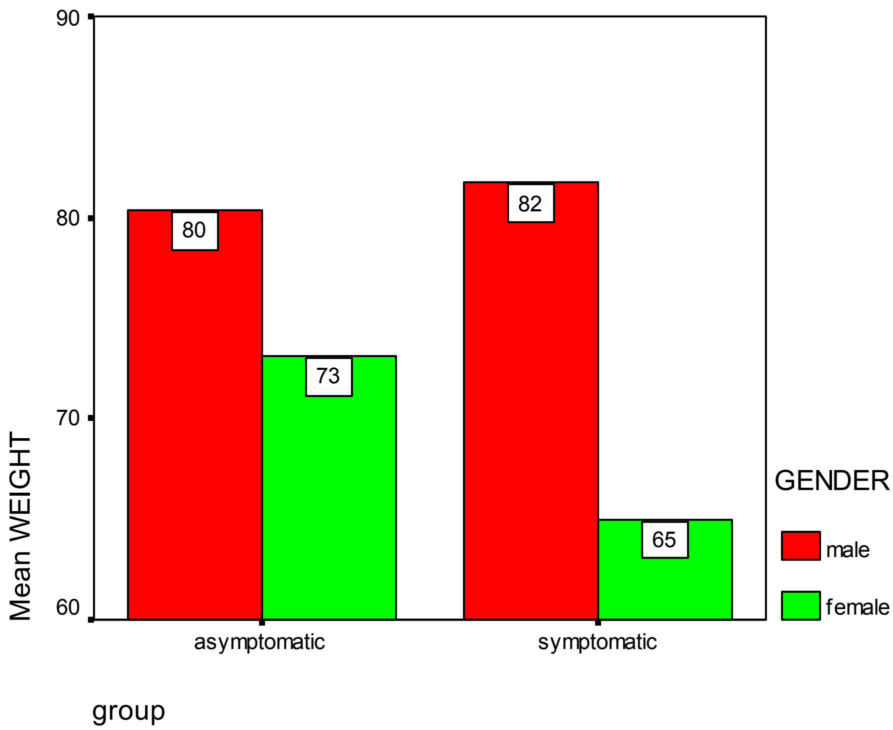
Table 4.2.4.1: T-test for comparison of mean weight between groups (n=32)

	Group	N	Mean	Std. Deviation	Std. Error Mean	P value
WEIGHT	Asymptomatic	16	76.750	10.7285	2.6821	0.397
	Symptomatic	16	73.375	11.4826	2.8706	

Table 4.2.4.2: T-test for comparison of mean weight between genders (n=32)

	Gender	N	Mean	Std. Deviation	Std. Error Mean	P value
WEIGHT	Male	16	81.063	8.6908	2.1727	0.001
	Female	16	69.063	10.0347	2.5087	

Figure 4: Mean weight by group and gender (n=32)



4.2.5 OCCUPATIONS REPRESENTED IN THE STUDY

Table 4.2.5 Occupations represented in this study

Occupation	Quantity in the symptomatic group	Quantity in the asymptomatic group
Adventure Guide		2
Business Owner	1	
Caterer	1	
Chiropractor		1
Construction	1	
Director		1
Engineer	1	3
Homeopath		2
Housewife	3	
HR Officer		1
IT Specialist	1	
Paralegal	1	
Personal Trainer	1	
Sales Rep	1	
Secretary	1	1
Self Employed		1
Student	1	1
Student co-ordinator		1
Stylist		1
Teacher/Lecturer	1	1
Technician	2	

As can be seen in table 4.2.5, many different occupations were represented in this study however, only few patients attributed their pain to work-related activities unless their job involved heavy lifting or gripping as in the case of the caterer, personal trainer and engineer. However, three engineers were represented in the asymptomatic group that have never suffered from the condition. The highest occupation represented in the symptomatic group of this study was housewives, which is in keeping with the findings of Viola (1998). Two of the three housewives related their pain to their daily housework. The only other occupation that appeared to uniquely predispose an individual to lateral epicondylitis was a construction worker who reported symptomatic aggravation when using a screwdriver, which involves repetitive supination and pronation of the forearm. Reid (1992:1014) agrees that lateral epicondylitis is a frequent occupational hazard in individuals carrying out forceful pronation and supination motions. This is in keeping with a study done by Marquis (2002), who found the highest incidence of lateral epicondylitis to be in housewives and builders. Both of these occupations involve a high degree of physical activity and may result in the development of an overuse syndrome. Shaik (2000) and Oehley (2002) however, found a high incidence of lateral epicondylitis amongst managers.

4.2.6 DAILY ACTIVITY LEVEL

Activity level is important, as differences have been found in isokinetic ankle strength between trained versus sedentary subjects (www.isokinetics.net).

The participants in this study were categorised into two groups according to whether their daily activities were physically active or inactive. There was no association between activity level and symptomatic and asymptomatic groups of this study (p=0.704). This is shown in Table 4.2.6. There was a slightly higher percentage of inactive participants in the asymptomatic group than in the symptomatic group, but this was not statistically significant.

In future studies, this category should be divided up further according to what sports/activities the participants take part in daily and how many hours per day they are active or inactive. There was possibly no statistical difference as the category could have been too broad.

Table 4.2.6: Cross-tabulation of activity level by group

			Group		Total
			Asymptomatic	**Symptomatic**	
Activity Level	**Active**	Count	4	6	10
		% Within activity level	40.0%	60.0%	100.0%
	Inactive	Count	12	10	22
		% Within activity level	54.5%	45.5%	100.0%
Total		Count	16	16	32
		% Within activity level	50.0%	50.0%	100.0%

P=0.704

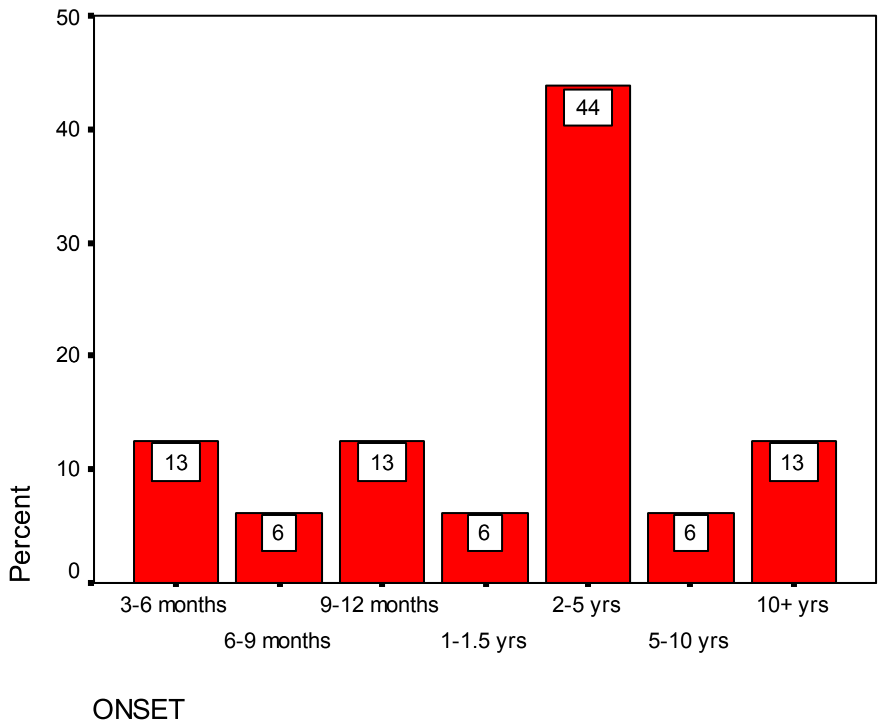
4.2.7 Symptomatic Group Descriptives

4.2.7.1 History

- **Onset**

The vast majority of the symptomatic patients had had their condition for two to five years (n=7, 44%, Figure 5). This could possibly be accounted for by the chronicity of the syndrome. Thirty two percent of the patients had the symptoms between three months and a year. With 13% of the participants having suffered with the condition for more than ten years. These results reinforce Jackson's (1997) statement that recovery of this condition can be prolonged. None of the participants in this study were in the acute phase of the condition as none had had the symptoms for less than three months.

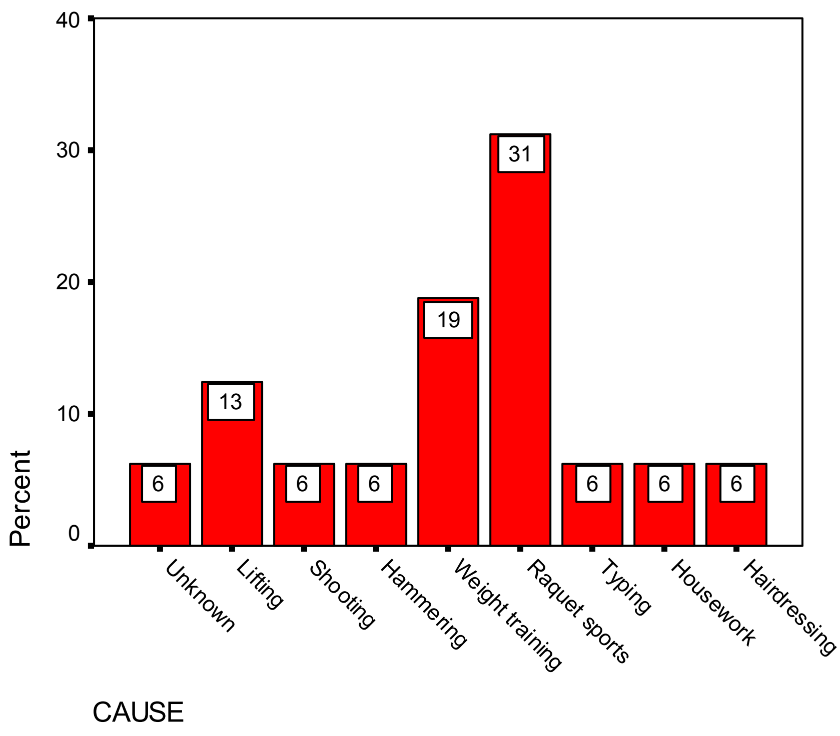
Figure 5: Percentage of symptomatic participants by onset of condition (n=16)



- **Cause**

The majority of symptomatic participants felt that the cause of their condition was racket sports (n=5, 31%) which included squash and tennis. This is in keeping with Viola (1998) and Reid (1992:1016) who stated that more than 50% of world class tennis players had suffered from the condition at one time or other. Jackson (1997) stated that a common cause included all activities requiring repetitive lifting and gripping. That is evident in this study as, second to racket sports was weight training (n=3, 19%) and lifting heavy objects (n=2, 13%). A variety of other causes were also implicated, with only one patient (6%) presenting with a cause of unknown origin. This is shown in Figure 6.

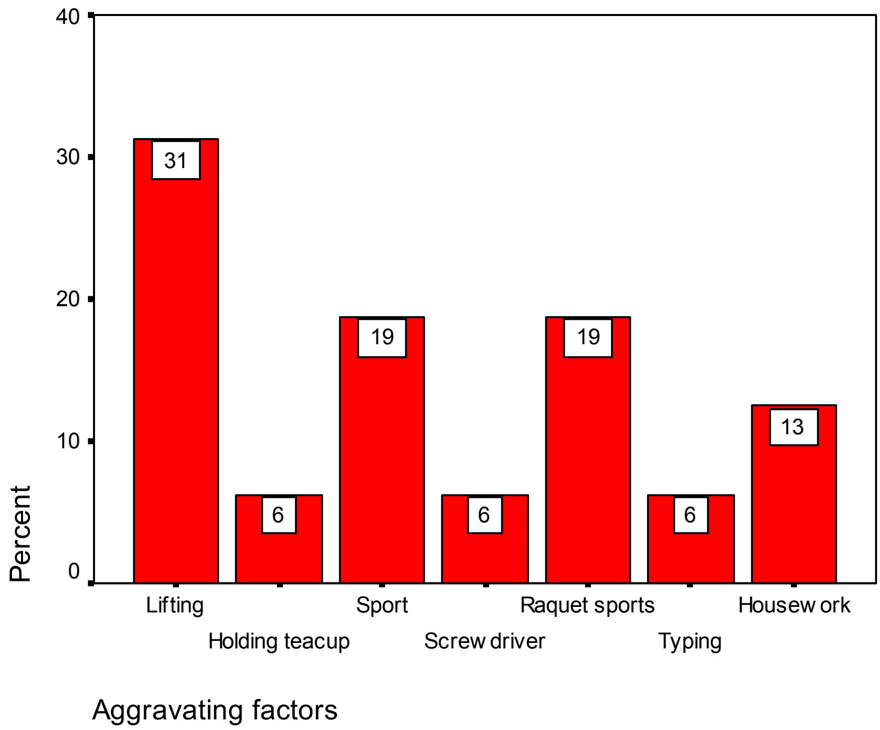
Figure 6: Percentage of symptomatic participants by suspected cause of condition (n=16)



- **Aggravating factor**

Figure 7 shows a wide range of activities that were reported as the prime aggravating activity. The most frequent aggravating factor was lifting (n=5, 31%). This is in keeping with the findings of Jackson (1997), Roodt (2001) and Marquis (2002). Racket sports (n=3, 19%), other sports (n=3, 19%) and housework (n=2, 13%) also contributed to the aggravation of the condition in many of the cases. Viola (1998) found that it occurred commonly in housewives and Reid (1992:1016), Roodt (2001) and Marquis (2002) found a high prevalence in racket sports. Disabella (2004) states that a frequent complaint is the “coffee cup sign” which he explains is an exacerbation of the pain when a patient grips a coffee cup. One patient (6%) in this study presented with this as their main aggravating factor.

Figure 7: Percentage of symptomatic participants by aggravating factor of condition (n=16)



4.2.7.2 SUBJECTIVE OUTCOMES

- **The 11-point box scale**

The patients were asked to rate their pain on a scale from 0 to 10 with 0 being no pain and 10 being maximum pain. Table 4.2.7.2 shows the descriptives for this scale in the 16 symptomatic subjects. The mean score was 7.6 (SD 1.5). The range of scores was from 5 to 10. Sharat and Maffulli (1997) state that this is a disabling condition and the results obtained in this study from the above scale substantiate the severity of the condition and the effect that it has on the patient.

Table 4.2.7.2: Descriptive statistics for the 11-point box scale in the symptomatic subjects (n=16)

N	16
Mean	7.56
Std. Deviation	1.459
Minimum	5
Maximum	10

4.2.7.3 CLINICAL FEATURES

- **Active trigger points**

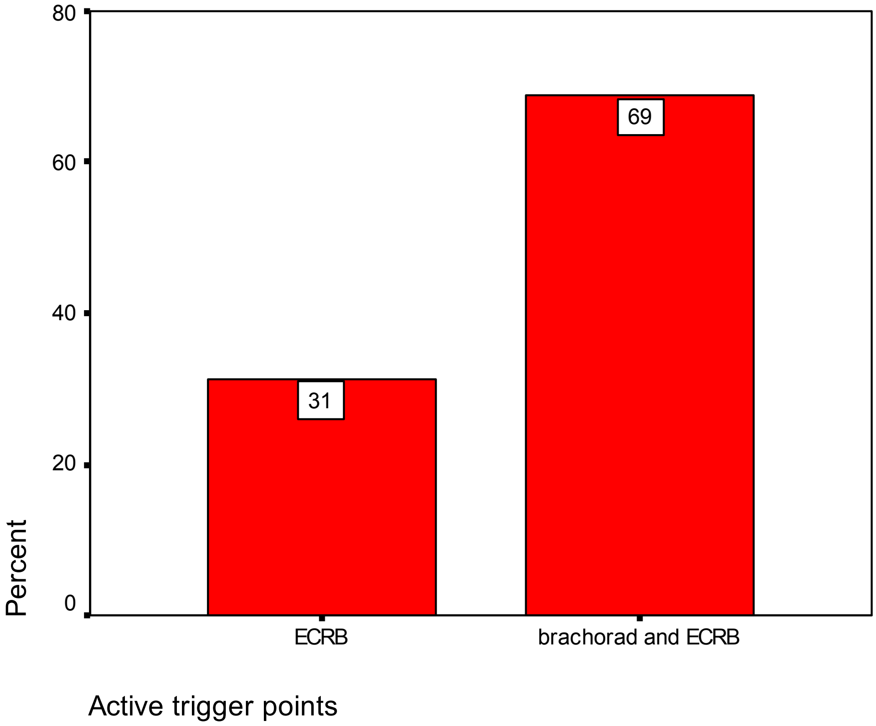
Figure 8 shows the percentages of symptomatic patients with each type of active trigger point. The majority of the patients had both Brachoradialis and Extensor Carpi Radialis Brevis (ECRB) active trigger points (n=11, 69%), while the remaining 31% (n=5) of the patients had just active ECRB trigger points. This means that every patient had an active trigger point in the wrist extensor compartment. This supports Brukner and Kahn (2002) who state that the primary pathological process occurs in the ECRB tendon. It is interesting to note that there was such a high percentage of patients with Brachoradialis trigger points. This muscle acts as an elbow flexor, but does refer pain to the lateral epicondyle (Travell et al. 1999:691).

The high incidence of trigger points in the forearm extensor muscles suggests that the role that trigger points play in lateral epicondylitis is important and should not be ignored. This supports Travell et al.'s (1999) belief that lateral epicondylitis is frequently of myofascial origin.

Taut bands caused by the trigger points in the ECRB muscle places a chronic strain on the tendinous attachment to the lateral epicondyle, thereby further exacerbating the symptoms of the condition. This may explain why the ECRB tendon has been implicated as the most commonly affected tendon of the extensor muscle group (Sharat and Maffulli 1997). Cyriax and Cyriax (1993) explain that the ECRB is more frequently the site of the lesion as a result of increased tensile loads placed on its tendon by the radial head when the tendon is stretched for example during extension of the elbow.

Haswell (2002) found active ECRB trigger points in 22% of the participants while 35% of Marquis' (2002) patients had active ECRB trigger points.

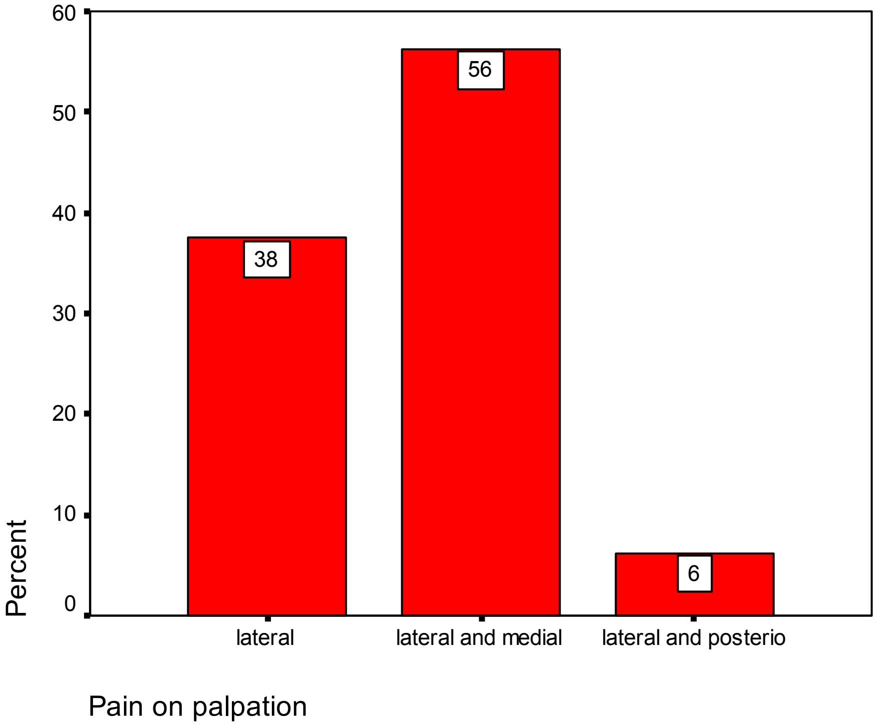
Figure 8: Percentage of symptomatic participants by type of active trigger point (n=16)



- **Pain on palpation**

Figure 9 shows that most symptomatic participants had lateral and medial pain on palpation (n=9, 56%). The other participants had only lateral pain (n=6, 38%) and some had lateral and posterior pain on palpation (n=1, 6%). These figures support Disabella (2004) who states that there is palpatory tenderness just distal to the lateral epicondyle over the ECRB tendon.

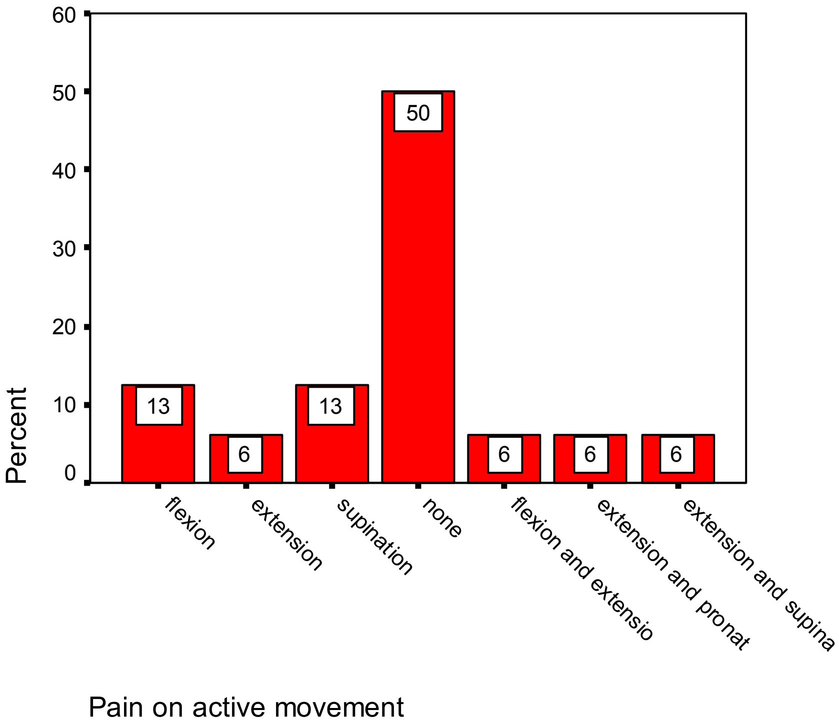
<u>Figure 9: Percentage of symptomatic participants by pain on palpation (n=16)</u>



- **Pain on active movements**

Fifty percent of the symptomatic patients had no pain on active movement while the others had pain in one or more directions, including flexion, extension, supination, or a combination of these. This is shown in Figure 10.

Figure 10: Percentage of symptomatic participants by pain on active movement (n=16)



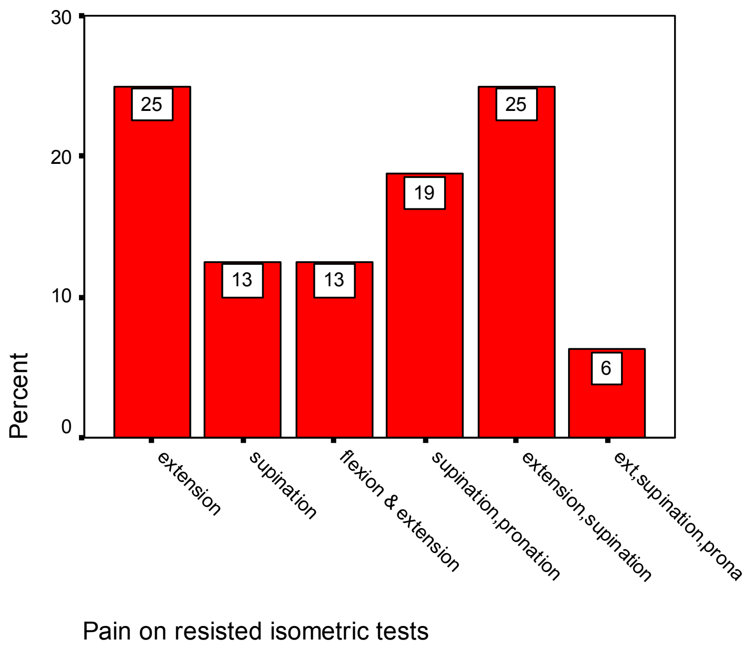
- **Pain on passive movements**

None of the participants had any pain on passive movements (not shown). This finding is in keeping with Thomson et al. (1991) and Noteboom et al. (1994) who state that lateral epicondylitis presents with painless passive movements.

- **Pain on resisted isometric movements**

On resisted isometric movements, 25% (n=4) of the participants had pain on extension and 25% (n=4) had pain on both supination and extension. The remainder experienced pain on supination (n=2, 13%), a combination of supination and pronation (n=3, 19%), and flexion and extension (n=2, 13%). One patient (6%) experienced pain on extension, supination and pronation. This is shown in Figure 11. Thomson et al. (1991) state that resisted wrist extension is normally painful, which supports the fact that 50% of the participants in this study experienced pain on resisted wrist extension.

Figure 11: Percentage of symptomatic participants by pain on resisted isometric movements (n=16)

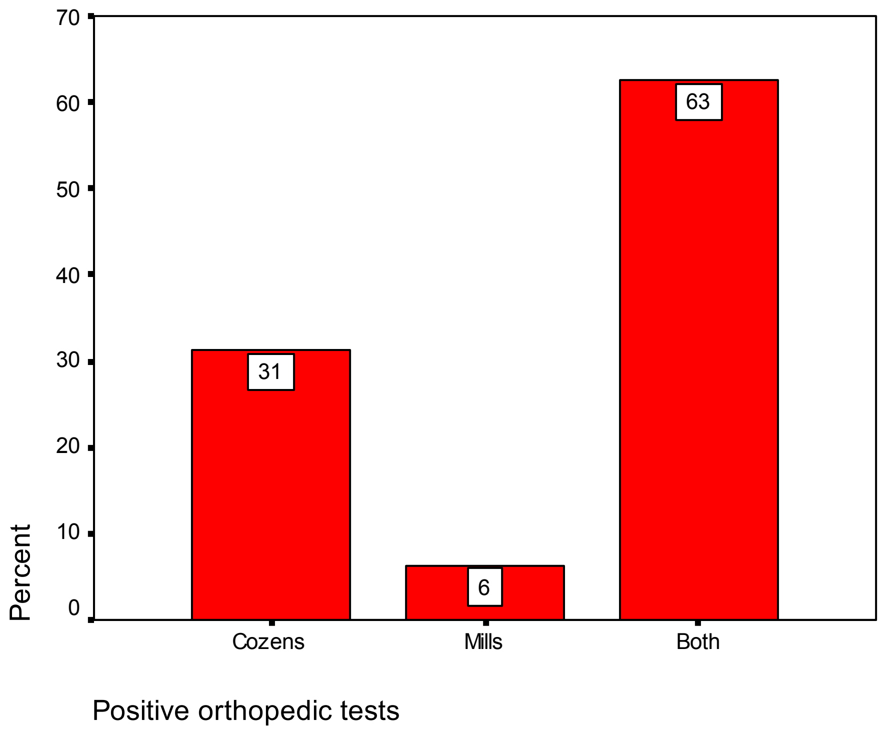


- **Positive orthopaedic tests**

Most (n=10, 63%) of the symptomatic subjects were positive on both of the orthopaedic tests necessary to be accepted into the study. The rest were positive on one or the other (Cozen's n=5, 31% and Mill's n=1, 6%). This is shown in Figure 12.

Cozen's test was positive in 94% (n=15) of the symptomatic group indicating that wrist extension against resistance is the primary indicator of lateral epicondylitis. Marquis (2002) also found Cozen's to be the primary orthopaedic test (83%), while in contrast, Haswell (2002) and Oehley (2002) found Mill's test to be the primary orthopaedic test.

<u>Figure 12: Percentage of symptomatic participants by positive orthopedic tests (n=16)</u>



4.2.8 COMPARISON OF CYBEX AND SURFACE EMG READINGS WITH RESPECT TO THE AGE, WEIGHT AND ETHNIC GROUPS

To assess whether age, race and weight influenced the Cybex and surface EMG readings, the readings were compared between these groups.

4.2.8.1 AGE AND WEIGHT VS CYBEX AND SURFACE EMG READINGS

Strength normally reaches its peak in the third decade and thereafter declines moderately with age until the seventh decade where there is a steeper decline (www.isokinetics.net). The mean age for the sample (n=32) was 35.75 years, therefore it can be deducted that the sample strength was close to its peak. No significant relationships between age and any of the isokinetic or EMG measurements or ratios was noted. This is possibly due to the relatively small, appropriate age group selected for the sample (25-50 years). This is shown in table 4.2.8.1.

In normal individuals, muscle mass rises with body weight. Therefore heavier subjects produce higher isokinetic moments. This relationship is not normally linear though (www.isokinetics.net). In this study, weight was positively related to isokinetic flexion (r=0.491, p=0.004) and isokinetic extension (r=0.578, p=0.001). Thus, as weight increased so did isokinetic flexion and extension. The same is true of EMG extension (r=0.417, p=0.018). Thus as weight increased so did EMG extension. The correlation coefficients were not very strong, although they were statistically significant. This is shown in table 4.2.8.1.

Table 4.2.8.1 Pearson's correlation between age, weight and isokinetic and EMG measurements

		AGE	WEIGHT
AGE	Pearson Correlation	1	-.057
	Sig. (2-tailed)	.	.757
	N	32	32
WEIGHT	Pearson Correlation	-.057	1
	Sig. (2-tailed)	.757	.
	N	32	32
Isokinetic flexion	Pearson Correlation	-.096	.491(**)
	Sig. (2-tailed)	.602	.004
	N	32	32
Isokinetic extension	Pearson Correlation	-.237	.578(**)
	Sig. (2-tailed)	.192	.001
	N	32	32
Isokinetic ratio	Pearson Correlation	.055	-.018
	Sig. (2-tailed)	.767	.922
	N	32	32
EMG flexion	Pearson Correlation	-.250	.289
	Sig. (2-tailed)	.168	.109
	N	32	32
EMG extension	Pearson Correlation	-.186	.417(*)
	Sig. (2-tailed)	.309	.018
	N	32	32
EMG ratio	Pearson Correlation	.001	-.155
	Sig. (2-tailed)	.995	.397
	N	32	32

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

4.2.8.2 Ethnicity vs Cybex and EMG readings

There were no significant differences in means of any of the flexion, extension or ratio measurements between the race groups (White vs. other races). Therefore nothing can be extrapolated about the effect of race on the results. This is shown in table 4.2.8.2. Due to the vast overrepresentation of Whites (n=27, 84%), no generalization in terms of race should be made and results with regards to race should be interpreted with caution.

Table 4.2.8.2 Independent t-tests for comparison of mean measurement by racial group

	Race	N	Mean	Std. Deviation	Std. Error Mean	P value
Isokinetic flexion	White	27	24.63	10.092	1.942	0.964
	Other	5	24.40	11.845	5.297	
Isokinetic extension	White	27	16.81	4.608	.887	0.873
	Other	5	16.40	8.503	3.803	
Isokinetic ratio	White	27	44.4137	32.46364	6.24763	0.399
	Other	5	60.7172	68.04976	30.43278	
EMG flexion	White	27	64.296	25.9556	4.9952	0.255
	Other	5	79.558	32.9719	14.7455	
EMG extension	White	27	47.130	24.2518	4.6673	0.439
	Other	5	56.386	24.3447	10.8873	
EMG ratio	White	27	61.4914	107.47980	20.68450	0.899
	Other	5	68.1473	100.98572	45.16219	

4.3 Descriptive statistics and comparisons for peak torque and muscle activity by subgroup

Descriptive statistics by subgroup are shown for the wrist flexion and extension measurements in Tables 4.3.1 and 4.3.2.

Table 4.3.1: Descriptive statistics for isokinetic flexion and extension by subgroup (n=32)

SUBGROUP		Isokinetic Flexion at 60˚/s	Isokinetic Extension at 60˚/s
Asymptomatic Males	Mean	32.63	20.50
	N	8	8
	Std. Deviation	7.945	2.928
Asymptomatic Females	Mean	17.13	14.00
	N	8	8
	Std. Deviation	3.603	3.423
Symptomatic Males	Mean	31.63	20.25
	N	8	8
	Std. Deviation	10.609	5.148
Symptomatic Females	Mean	17.00	12.25
	N	8	8
	Std. Deviation	3.162	3.412
Total	Mean	24.59	16.75
	N	32	32
	Std. Deviation	10.175	5.212

Table 4.3.1 shows that the peak torque for isokinetic flexion in the asymptomatic males is 32.63 Nm and for isokinetic extension it is 20.50 Nm, with the torque for asymptomatic females being considerably less at 17.13 Nm for isokinetic flexion and 14.00 Nm for isokinetic extension.

The peak torque for isokinetic flexion in the symptomatic males is 31.63 Nm and for isokinetic extension it is 20.25 Nm, with the symptomatic females again being considerably less at 17.00 Nm for isokinetic flexion and 12.25 Nm for isokinetic extension.

The average peak torque for male wrist flexion is 32.13Nm and for wrist extension it is 20.38Nm, while the average peak torque for female wrist flexion is 17.06Nm and wrist extension is 13.13Nm. No normal reference values could be found in the literature regarding a concentric strength test on the wrist flexors and extensors at 60˚/s. However, these findings are in keeping with the other isokinetic studies that have shown that men are consistently and significantly stronger than women (www.isokinetics.net).

The combined values (males, females, symptomatic and asymptomatic) for isokinetic flexion shows a mean of 24.59 Nm and the isokinetic extension shows a mean of 16.75 Nm. This supports Magee's (2002:376) statement that the greatest torque around the elbow is produced by the wrist flexors.

Table 4.3.2: Descriptive statistics for EMG flexion and extension by subgroup (n=32)

SUBGROUP		Integrated EMG Flexion in ųV.s	Integrated EMG Extension in ųV.s
Asymptomatic Males	Mean	78.964	65.670
	N	8	8
	Std. Deviation	12.7772	26.7784
Asymptomatic Females	Mean	45.023	36.140
	N	8	8
	Std. Deviation	18.2323	13.9582
Symptomatic Males	Mean	89.276	55.551
	N	8	8
	Std. Deviation	29.9308	24.7907
Symptomatic Females	Mean	53.460	36.944
	N	8	8
	Std. Deviation	19.5089	18.0948
Total	Mean	66.681	48.576
	N	32	32
	Std. Deviation	27.1479	24.1126

Table 4.3.2 shows that the peak muscle activity measured for EMG flexion in the asymptomatic males is 78.964ųV.s and for EMG extension it is 65.67ųV.s, with the asymptomatic females being slightly less at 45.023ųV.s for EMG flexion and 36.140ųV.s for isokinetic extension.

The peak muscle activity measured for EMG flexion in the symptomatic males is 89.276ųV.s and for EMG extension it is 55.551ųV.s, with the symptomatic females again being slightly less at 53.46ų.V.s for EMG flexion and 36.944ųV.s for EMG extension.

The average peak muscle activity for male wrist flexion is 84.12ųV.s and for wrist extension it is 60.61ųV.s, while the average peak muscle activity for female wrist flexion is 49.242ųV.s and for wrist extension it is 36.542ųV.s. Because the number of muscle fibres that are recruited determines the magnitude of the electromyographic activity in an active muscle (Lewis and Fulco 1998), the amplitude of the integrated EMG activity provides immediate feedback on the magnitude of muscle forces (Van Den Bogert 1994). Therefore the number of motor units being activated, relates positively to the strength of that muscle (Hamilton et al. 2004). No normal reference values could be found in the literature regarding muscle activity of the wrist flexors and extensors. However, these findings are in keeping with the other isokinetic studies that have shown that men are consistently and significantly stronger than women (www.isokinetics.net).

The combined values for EMG flexion (males, females, symptomatic and asymptomatic) show a mean of 66.681ųV.s and the EMG extension shows a mean of 48.576ųV.s. This is consistent with the wrist flexors being stronger than the wrist extensors.

Figure 13: Mean isokinetic and EMG flexion and extension by subgroup

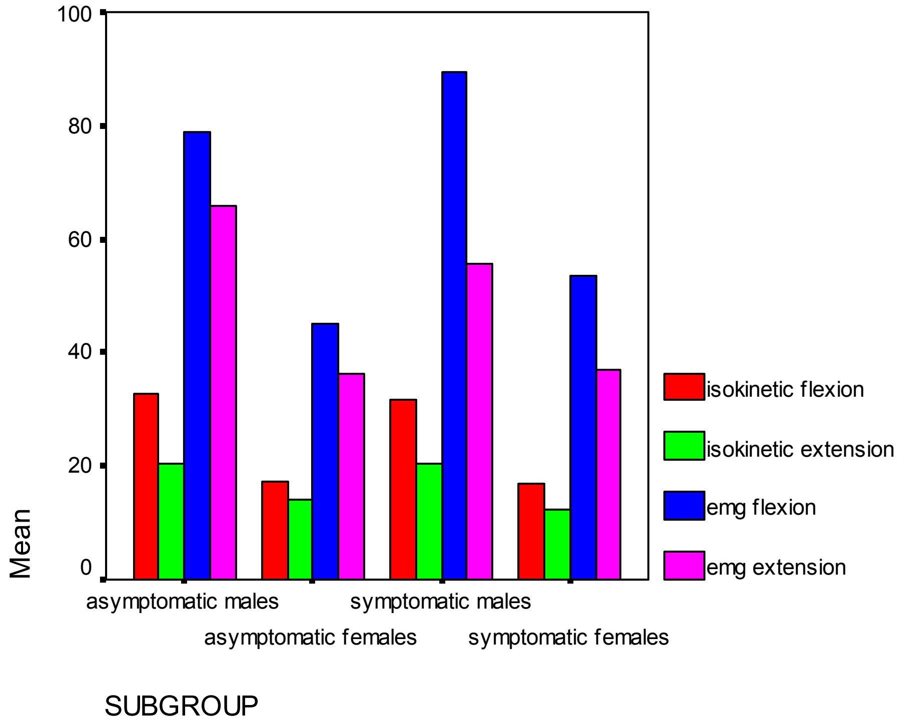


Figure 13 is a diagrammatic representation of Table 4.3.1 and 4.3.2 showing that the mean values for isokinetic flexion and EMG flexion were higher than for isokinetic extension and EMG extension, respectively. This is true for each subgroup and the ratios. This supports Magee (2002:376) stating that the wrist flexors produce the greatest torque around the elbow, followed by the wrist extensors. The EMG flexion could have been higher in the symptomatic subjects because over time, the flexors could have been compensating for the weak or painful extensors in normal daily movements thereby gaining strength.

An ANOVA statistical test comparing the mean isokinetic and EMG flexion and extension values between the subgroups showed that the differences between the subgroups were statistically significant for isokinetic flexion and extension ($p<0.001$), and for EMG flexion ($p=0.001$) and EMG extension ($p=0.025$). This is shown in table 4.3.3.

A Bonferroni multiple comparison test was then carried out for pairwise comparisons between the subgroups, which showed that the statistical differences found in the ANOVA test lay between the genders and not between the symptomatic and asymptomatic groups (Table 4.3.4 and Figure 13).

Table 4.3.3: ANOVA test for the comparison of mean isokinetic and EMG flexion and extension between the subgroups

		Sum of Squares	df	Mean Square	F	P value
Isokinetic flexion	Between Groups	1819.094	3	606.365	12.209	<0.001
	Within Groups	1390.625	28	49.665		
	Total	3209.719	31			
Isokinetic extension	Between Groups	433.000	3	144.333	9.881	<0.001
	Within Groups	409.000	28	14.607		
	Total	842.000	31			
EMG flexion	Between Groups	10442.374	3	3480.791	7.857	0.001
	Within Groups	12404.876	28	443.031		
	Total	22847.250	31			
EMG extension	Between Groups	5046.578	3	1682.193	3.629	0.025
	Within Groups	12977.408	28	463.479		
	Total	18023.987	31			

Table 4.3.4: Bonferroni multiple comparison tests for pairwise comparisons between the subgroups

Dependent Variable	(I) SUBGROUP	(J) SUBGROUP	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval	
						Lower Bound	Upper Bound
Isokinetic flexion	Asymptomatic males	Asymptomatic females	15.50(*)	3.524	0.001	5.50	25.50
		Symptomatic males	1.00	3.524	1.000	-9.00	11.00
		symptomatic females	15.63(*)	3.524	0.001	5.62	25.63
	Asymptomatic females	Asymptomatic males	-15.50(*)	3.524	0.001	-25.50	-5.50
		Symptomatic males	-14.50(*)	3.524	0.002	-24.50	-4.50
		Symptomatic females	.13	3.524	1.000	-9.88	10.13
	Symptomatic males	Asymptomatic males	-1.00	3.524	1.000	-11.00	9.00
		Asymptomatic females	14.50(*)	3.524	0.002	4.50	24.50
		Symptomatic females	14.63(*)	3.524	0.002	4.62	24.63
	Symptomatic females	Asymptomatic males	-15.63(*)	3.524	0.001	-25.63	-5.62
		Asymptomatic females	-.13	3.524	1.000	-10.13	9.88
		Symptomatic males	-14.63(*)	3.524	0.002	-24.63	-4.62
Isokinetic extension	Asymptomatic males	Asymptomatic females	6.50(*)	1.911	0.012	1.07	11.93
		Symptomatic males	.25	1.911	1.000	-5.18	5.68
		Symptomatic females	8.25(*)	1.911	0.001	2.82	13.68
	Asymptomatic females	Asymptomatic males	-6.50(*)	1.911	0.012	-11.93	-1.07
		Symptomatic males	-6.25(*)	1.911	0.017	-11.68	-.82
		Symptomatic females	1.75	1.911	1.000	-3.68	7.18
	Symptomatic males	Asymptomatic males	-.25	1.911	1.000	-5.68	5.18
		Asymptomatic females	6.25(*)	1.911	0.017	.82	11.68
		Symptomatic females	8.00(*)	1.911	0.002	2.57	13.43
	Symptomatic females	Asymptomatic males	-8.25(*)	1.911	0.001	-13.68	-2.82
		Asymptomatic females	-1.75	1.911	1.000	-7.18	3.68
		Symptomatic males	-8.00(*)	1.911	0.002	-13.43	-2.57

Dependent Variable	(I) SUBGROUP	(J) SUBGROUP	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval	
						Lower Bound	Upper Bound
Emg flexion	Asymptomatic males	Asymptomatic females	33.941(*)	10.5242	0.019	4.064	63.819
		Symptomatic males	-10.313	10.5242	1.000	-40.190	19.565
		Symptomatic females	25.504	10.5242	0.133	-4.374	55.381
	Asymptomatic females	Asymptomatic males	-33.941(*)	10.5242	0.019	-63.819	-4.064
		Symptomatic males	-44.254(*)	10.5242	0.001	-74.131	-14.376
		Symptomatic females	-8.438	10.5242	1.000	-38.315	21.440
	Symptomatic males	Asymptomatic males	10.313	10.5242	1.000	-19.565	40.190
		Asymptomatic females	44.254(*)	10.5242	0.001	14.376	74.131
		Symptomatic females	35.816(*)	10.5242	0.012	5.939	65.694
	Symptomatic females	Asymptomatic males	-25.504	10.5242	0.133	-55.381	4.374
		Asymptomatic females	8.438	10.5242	1.000	-21.440	38.315
		Symptomatic males	-35.816(*)	10.5242	0.012	-65.694	-5.939
Emg extension	Asymptomatic males	Asymptomatic females	29.530	10.7643	0.063	-1.029	60.089
		Symptomatic males	10.119	10.7643	1.000	-20.440	40.678
		Symptomatic females	28.726	10.7643	0.075	-1.833	59.285
	Asymptomatic females	Asymptomatic males	-29.530	10.7643	0.063	-60.089	1.029
		Symptomatic males	-19.411	10.7643	0.493	-49.970	11.148
		Symptomatic females	-.804	10.7643	1.000	-31.363	29.755
	Symptomatic males	Asymptomatic males	-10.119	10.7643	1.000	-40.678	20.440
		Asymptomatic females	19.411	10.7643	0.493	-11.148	49.970
		Symptomatic females	18.608	10.7643	0.569	-11.952	49.167
	Symptomatic females	Asymptomatic males	-28.726	10.7643	0.075	-59.285	1.833
		Asymptomatic females	.804	10.7643	1.000	-29.755	31.363
		Symptomatic males	-18.608	10.7643	0.569	-49.167	11.952

* The mean difference is significant at the .05 level.

4.4 Descriptive statistics and comparisons for peak torque and muscle activity ratios by subgroup

The ratios were generated by dividing the flexion by the extension measurement, multiplying by 100 and subtracting 100 to give a percentage increase in strength of the flexor muscle groups over the extensor muscle groups.

Table 4.4.1: Descriptive statistics for isokinetic and EMG ratios by subgroup (n=32)

SUBGROUP		Isokinetic ratio %	EMG ratio %
Asymptomatic males	Mean	60.8844	34.6263
	N	8	8
	Std. Deviation	43.28883	53.64474
Asymptomatic females	Mean	24.4054	35.5908
	N	8	8
	Std. Deviation	18.69088	71.21389
Symptomatic males	Mean	53.9372	78.3651
	N	8	8
	Std. Deviation	22.84579	88.25243
Symptomatic females	Mean	48.6174	101.5432
	N	8	8
	Std. Deviation	55.80182	171.10914
Total	Mean	46.9611	62.5313
	N	32	32
	Std. Deviation	38.95635	104.93146

The asymptomatic males' isokinetic wrist flexion was 60.88% stronger than the isokinetic wrist extension, while the asymptomatic females' isokinetic wrist flexion was only 24.41% stronger than the isokinetic wrist extension. The symptomatic males' isokinetic wrist flexion was 53.94% stronger than isokinetic wrist extension, while the symptomatic females' isokinetic wrist flexion was 48.61% stronger than isokinetic wrist extension.

The asymptomatic males' peak muscle activity of the wrist flexors was 34.62% stronger than the peak muscle activity of the wrist extensors, while the asymptomatic females' peak muscle activity of the wrist flexors was 35.59% stronger than the peak muscle activity of the wrist extensors. The symptomatic males' peak muscle activity of the wrist flexors was 78.37% stronger than the peak muscle activity of the wrist extensors, while the symptomatic females' peak muscle activity of the wrist flexors was 101.54% stronger than the peak muscle activity of the wrist extensors.

Although these ratios were not significantly different between the subgroups, which is shown in an ANOVA test in Table 4.4.2, Figure 14 shows that the mean isokinetic ratios were higher generally in males than in females, but similar in the symptomatic and asymptomatic groups.

Figure 14 also shows that the EMG ratios were higher in the symptomatic group and especially high in symptomatic females. Asymptomatic males and females had similar EMG ratios.

In a study by Callaghan et al. (2001) on examining the fatigue characteristics of the quadriceps in patellofemoral pain syndrome, it was found that a decrease in integrated EMG signal could be due to the subjects' apprehension to produce maximum force. This could explain why the wrist flexors in the symptomatic group seemed to be much stronger than the wrist extensors, as wrist extension could have caused some discomfort during the test.

Figure 14: Mean isokinetic and EMG ratios by subgroup

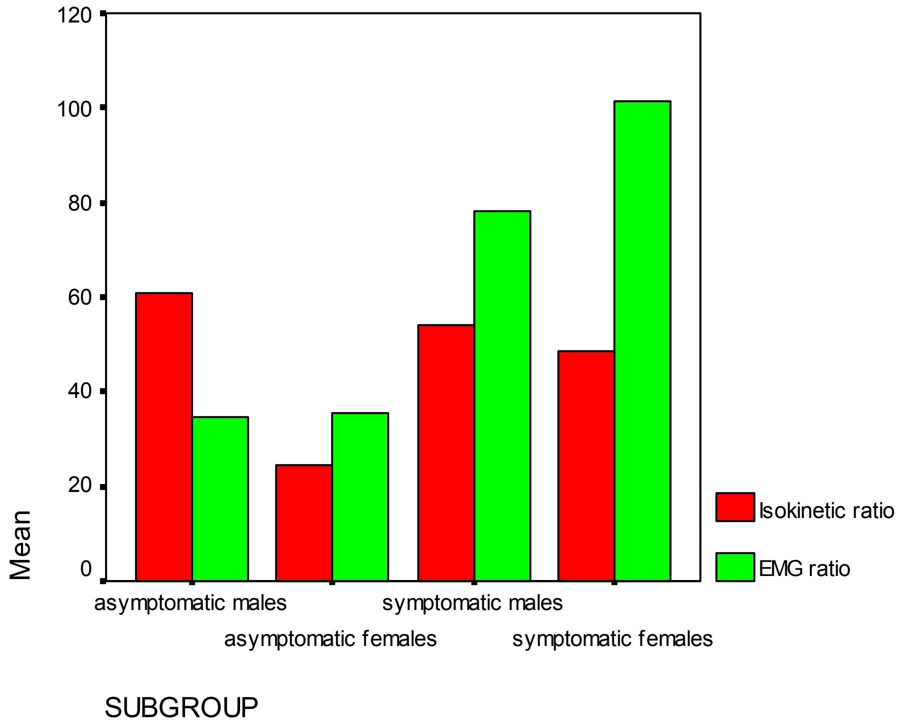


Table 4.4.2: ANOVA test for the comparison of mean isokinetic and EMG ratios between the subgroups

		Sum of Squares	df	Mean Square	F	P value
Isokinetic ratio	Between Groups	6032.201	3	2010.734	1.373	0.271
	Within Groups	41013.318	28	1464.761		
	Total	47045.520	31			
EMG ratio	Between Groups	26216.909	3	8738.970	.777	0.517
	Within Groups	315112.041	28	11254.001		
	Total	341328.950	31			

4.5 COMPARISON OF MEAN RATIOS TO EXPECTED VALUES

The expected mean ratio for wrist extensor strength is, as stated from the literature (Magee 2002:376, Reid 1992:1017), 45-50% of the wrist flexor strength (average 47.5%). This could also translate to the wrist flexors being 90-100% stronger than the wrist extensors (average 95%). Mean isokinetic ratios in the subgroups were tested using one sample t-tests for difference from this hypothesized value.

Overall there was a significantly lower mean isokinetic ratio observed compared with the expected ratio of 95% ($p<0.001$). This demonstrates that the overall ratio (including symptomatic and asymptomatic males and females) of the peak torque results was incorrect, according to the literature (Magee 2002:376, Reid 1992:1017), with the wrist flexors not being about twice as strong as the wrist extensors.

However, overall the EMG ratio was not significantly different from 95% ($p=0.090$). This demonstrates that the overall ratio (including symptomatic and asymptomatic males and females) of the muscle activity results was correct with the wrist flexors being about twice as strong as the extensors. However, these categories need to be analysed in more detail by comparing the subgroups.

4.5.1 RATIOS OF ASYMPTOMATIC MALES WHEN COMPARED TO THE EXPECTED VALUE

Within the subgroups, the EMG ratio in asymptomatic males was significantly lower than 95% ($p=0.015$) but the isokinetic ratio was not quite significantly lower than 95% ($p=0.061$). This means that the strength ratio according to muscle activity for this subgroup did not match the expected norm according to the literature but isokinetically it did.

The EMG testing may have been unreliable thereby producing these results that are inconsistent with the isokinetic readings and with what is expected.

4.5.2 RATIOS OF SYMPTOMATIC MALES WHEN COMPARED TO THE EXPECTED VALUE

The symptomatic males had a significantly lower isokinetic ratio than 95% ($p<0.001$), but their EMG ratio was not significantly lower than 95% ($p=0.610$). This means that the strength ratio according to muscle activity was as expected according to the literature for normal subjects but isokinetically it did not match the expected norms, therefore, showing an imbalance. Interestingly this is opposite to the findings in the asymptomatic males in 4.5.1. Again the EMG results may have been unreliable as they produced results that were different to the isokinetic readings and to what was expected. The isokinetic ratio of the symptomatic males was the only ratio that showed an imbalance in the symptomatic subjects. In this group there is weak flexion or strong extension, which produced this isokinetic ratio. The daily activities of this group need to be assessed in detail to find a possible explanation for this. It could be that not much of the daily activities consist of wrist flexion movements like gripping of small tools (Travell et al. 1999:762), while much of the daily activities could consist of wrist extension movements thereby increasing the strength of the wrist extensors but which may also lead to the overuse syndrome of lateral epicondylitis.

4.5.3 RATIOS OF ASYMPTOMATIC FEMALES WHEN COMPARED TO THE EXPECTED VALUE

In the asymptomatic females, both isokinetic and EMG ratios were significantly lower than 95% ($p<0.001$ for isokinetic and $p=0.050$ for EMG). This means that the strength ratio according to muscle activity and peak torque for this subgroup did not match the expected norms available in the literature. To create this ratio either the flexors were weak or the extensors were strong. The subjects' daily activity level was assessed in this study but the categories of active versus inactive were too broad and needed to be divided up further into what their particular daily activities consisted of. It could be that this asymptomatic group of females did not utilize their wrist flexors as much as the symptomatic females in activities like putting curlers in their hair and cutting with scissors (Travell et al. 1999:761-762) but did more activities like gripping, typing and driving, which exercise the wrist extensor group (Balance Systems Inc. 2003).

4.5.4 Ratios of symptomatic females when compared to the expected value

Symptomatic females had a borderline significantly lower isokinetic ratio (p=0.051) but their EMG ratio was not different to 95% (p=0.917). This shows that the strength ratio according to both muscle activity and peak torque matched the expected norms in the available literature for normal individuals. This is the only subgroup to confirm the ratio according to the literature in both the tests utilised. Interestingly though, it is the symptomatic group. A reason for the relatively strong flexion would be; if a patient suffers with pain when using the extensor muscles, they would possibly be resistant to use this muscle group therefore the flexors will compensate for this in the daily activities of, for example, typing and driving thereby becoming stronger. It could be that this symptomatic group did more activities daily that would have strengthened their flexors. Again, the daily activities needed to be looked at in more depth. This ratio could also present as such because of relatively weaker extensors. During the testing procedure the patient could have been resistant to produce maximum force on extension because of pain when performing that movement.

Although the reliability of isokinetic dynamometers is extremely high, an explanation for these results could be that when measuring the wrist there is a lower reliability probably due to small ROM and torque production. The variations in small torque values are obviously magnified particularly if the dynamometer does not register decimal places (Chan and Maffulli 1996). The Cybex Orthotron II used in this study did not measure decimal places. Surface EMG has been found to be inferior to needle EMG (Pullman et al. 2000). The inconsistencies found with the EMG readings between the subgroups in this study could be due to inaccuracies of the surface EMG testing. Furthermore, with subgroup sizes so small, type II errors could have been made.

4.6 SUMMARY AND CONCLUSION

In terms of the flexion and extension measurements, it appears that there was a difference between the genders, as expected, and not between the symptomatic and asymptomatic groups, with females having lower means than males. This is in keeping with the many isokinetic studies that have shown men to be significantly and consistently stronger than women (www.isokinetics.net)

The ratio of flexion to extension was not affected by tennis elbow or gender. The EMG ratio was higher in the symptomatic patients than in the asymptomatic subjects, but not significantly so.

The isokinetic ratio in the asymptomatic males and electromyographic ratios in the symptomatic males and females were the only ratios that were not significantly different from the expected value of the extensors being 50% of the flexor strength. The isokinetic ratio of the symptomatic males was the only ratio that showed an imbalance in the symptomatic subjects.

None of these results are consistent. As discussed above it could be due to the dynamometer not registering decimal places. Also, the possibility of type II errors is high due to the small sample size in each group. A larger study would be recommended to fully explore the statistical significance of the above findings.

Therefore, in the light of the preceding discussions the following becomes pertinent to the hypotheses developed at the outset of the study:

Hypothesis 1

There will be greater imbalances when assessing peak torque of the wrist flexor and wrist extensor muscle groups when comparing the asymptomatic patients to the lateral epicondylitis patients.

This hypothesis is rejected as the results of the study showed that there was no difference between the normal (asymptomatic) subjects and the lateral epicondylitis subjects.

There was however a difference between the genders but this was to be expected.

Hypothesis 2

There will be greater imbalances when assessing the muscle activity of the wrist flexor and wrist extensor muscle groups when comparing the asymptomatic patients to the lateral epicondylitis patients.

The hypothesis is rejected as the results of the study showed that there was no significant difference between the normal (asymtomatic) subjects and the lateral epicondylits subjects.

There was however and difference between the genders but this was to be expected.

CHAPTER FIVE

5.0 RECOMMENDATIONS AND CONCLUSION

5.1 RECOMMENDATIONS

To attain more statistically significant results, future similar studies should utilize a statistically significant sample size. This will decrease the chance of type II errors and increase the power of the study. The small sample size in this study was due to the budget restrictions imposed upon the researcher. Financial resources are essential if significant research in this area is to be carried out in the future.

If doing isokinetic assessments on the wrist it would be advisable to make use of a dynamometer that registers decimal places. Due to the limited ROM and small torque production, the reliability of the isokinetic readings is decreased i.e. the dynamometers that do not register decimal places are not sensitive enough, therefore the chance of a nil result is increased as the differences are not great enough to make a difference on the current result.

At least 14 people were interested in participating in this study but had to be excluded because they were older than 50 years. In future studies on lateral epicondylitis, it would be advisable to include the age group of 50-55 years to get a larger response.

To improve sample homogeneity it would be recommended to restrict the population to one type in terms of work, exercise (type and amount), hobbies and specific daily activities for example, comparing asymptomatic weightlifters to symptomatic weightlifters or asymptomatic housewives to symptomatic housewives. This would eliminate many of the variables that were present in this study. The only exclusion in terms of activity in this study was professional sports people.

As the correction of muscle imbalances is important in injury prevention, there may be some benefit in researching the effect that improving the muscle imbalance has on chronic symptoms of a condition, with the use of isokinetic rehabilitation.

Many people were also excluded because the symptoms were present in their non-dominant arm. An improvement to this baseline study would be to investigate the difference between the muscle strength ratios of the dominant and non-dominant arms, using the patients' asymptomatic arm as the control. Differences have been reported between torque values in dominant and non-dominant upper extremities during concentric isokinetic activity (Albert 1991:102) and research has not clearly demonstrated that the muscle torque produced by both left and right extremities should be similar (Albert 1991:102). This investigation would lead to an explanation as to why some patients have the condition in their dominant arm and others in their non-dominant arm and is another method of testing if muscle imbalances are in fact associated with lateral epicondylitis. A study was done in overhead athletes to provide descriptive data for terminal range eccentric antagonist/ concentric agonist rotator cuff strength. They compared dominant arm to non-dominant arm and found that the muscle torque ratios were different between dominant and non dominant. This information could be useful in preventative exercise programs. (Yildiz et al. 2005.)

In future studies, the idea of the dynamic control ratio should be investigated. This is the eccentric/concentric torque ratio instead of the concentric agonist/antagonist ratio. The dynamic control ratio is the best way to evaluate the quadriceps/hamstring ratio according to Dvir (2004:150) and is a newer way of evaluating shoulder strength (Dvir 2002:228). According to Albert (1991:102-104) as yet there are no normative values for the upper extremity with regards to the dynamic control ratio and he states that further studies are needed in this area.

Many patients in this study presented with concurrent pain on palpation on the medial aspect of the elbow. It could be worthwhile to compare the differences between golfer's elbow and tennis elbow in terms of muscle strength ratios to note if there is a relationship between the two conditions.

A literature review by Pullman et al. (2000), found that surface electromyography is substantially inferior to needle electromyography for the evaluation of patients with neuromusclular disorders. Some of the important diagnositic parameters cannot be evaluated by surface EMG. Even though surface EMG is effective, perhaps to get more accurate results, needle electromyography should be utilised.

The quadriceps/hamstring ratio is velocity dependent when measuring it isokinetically (Dvir 2004:150). No normal reference values could be found at a test of concentric 60˚/s for the wrist flexors and extensor ratio so perhaps other velocities should be investigated.

One major factor influencing maximum muscle tension is the total cross-sectional area of the muscle, perpendicular to the direction of the fibres (Harries et al. 1996). There may be worth in using size-matched subjects to ensure homogeneity.

Pronation and supination are two other opposing movements around the elbow. The Supinator muscle refers pain to the lateral elbow (Travell et al. 1999:728), therefore it may be worthwhile testing these movements for muscle imbalances in the presentation of lateral epicondylitis. However, care must be taken in the testing procedure as these movements on the Cybex have been less tolerated by patients with lateral epicondylitis (Davies 1992:484).

5.2 CONCLUSION

The purpose of this investigation was to determine whether imbalances in the wrist flexor and extensor muscle groups are an associated factor in the presentation of lateral epicondylitis, by measuring the peak torque and muscle activity of these specific muscle groups.

The results showed no statistically significant consistent correlation between muscle imbalances and lateral epicondylitis in the subjects tested.

Therefore, hypothesis 1 stating that there will be an overall greater imbalance when assessing peak torque of the wrist flexor and wrist extensor muscle groups when comparing the asymptomatic patients to the lateral epicondylitis patients, is rejected.

Hypothesis 2 stated that there would be a greater imbalance when assessing the muscle activity of the wrist flexor and wrist extensor muscle groups when comparing the asymptomatic patients to the lateral epicondylitis patients. This hypothesis is therefore also rejected.

There was however, a strength difference noted between the genders but this was to be expected.

There were also no conclusive results when comparing the ratios to the expected value of the wrist extensors being 45-50% of the wrist flexor strength.

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APPENDIX A:

PATIENT INFORMATION LETTER

<u>LETTER OF INFORMATION</u>

Dear Patient

Welcome to this study!

<u>Title of study:</u>

An investigation into the role of muscle imbalances within the wrist flexor and extensor muscle groups as an associated factor in the presentation of lateral epicondylitis.

<u>Supervisor:</u>
Dr Andrew Jones (031 9034467)

<u>Co-Supervisor:</u>
Mr Dennis Jackson (031 5662165)

<u>Research student:</u>
Nicky du Coudray (031 2042205 or 2042512)

<u>Institution:</u>
Durban Institute of Technology

<u>Purpose of the study:</u>

Sixteen asymptomatic patients and sixteen “tennis elbow” patients will have their wrist flexor and extensor muscle groups (muscles around the elbow) measured in terms of strength and muscle activity to evaluate the possibility of muscle imbalances being associated with tennis elbow.

<u>Procedures:</u>

Initial visit--

The first consultation will take place at the DIT Chiropractic Day Clinic. Here the patients will be screened for suitability for the study. This will be determined by a case history, physical examination, cervical spine and elbow regional examinations. Thereafter the muscle activity will be measured. This appointment will take approximately 1½ hours.

Second visit--

This consultation will take place at the Medigate Medical Centre in Umhlanga Rocks and is subject to the availability of the biokinetist, Mr Dennis Jackson. These premises have the relevant facilities for isokinetic testing.

<u>Risks/Discomforts:</u>
The testing is relatively harmless, however some muscle stiffness may be experienced after the testing.

Benefits:

- You will receive free assessments of the muscle balances in your forearm muscles.

- On completion of your participation in the study, you are eligible for two free treatments at the Durban Institute of Technology Chiropractic Day Clinic, which will be valid for three months after completion of the study.

New Findings:

You have the right to be made aware of any new findings that are made pertaining to this study.

Reasons why you can be withdrawn from this study without your consent:

- If you experience any discomfort during the isokinetic or EMG testing sessions.

- If you change any lifestyle habits during your participation in this study that may affect the outcome of this research. (eg. Change in medication, supplementation or treatment of any kind)

PLEASE NOTE: You are free to withdraw from the study at any time without giving a reason.

Remuneration:

You will not receive a travel allowance to get to the Medigate Medical Centre in Umhlanga.

Cost of the study:

All treatments will be free of charge and your participation is voluntary.

Confidentiality:

All patient information is confidential and the results will be used for research purposes only. Supervisors and senior clinic staff may however be required to inspect the records.

Persons to contact with problems or questions:

Should you have any further queries and you would like them answered by an independent source, you can contact my supervisor on the number above.

Thank you for your participation in the study.

Nicky du Coudray
(Chiropractic Intern)

Dr Andrew Jones
(Supervisor)

APPENDIX B:

INFORMED CONSENT FORM

APPENDIX B:
INFORMED CONSENT FORM

(to be completed by patient/subject)

Date **:**

Title of Research Project	**:**An investigation into the role of muscle imbalances within the wrist flexor and extensor muscle groups as an associated factor in the presentation of lateral epicondylitis.
Name of supervisor	**:Dr Andrew Jones**
Telephone	**:031 9034467**
Name of research student	**:Nicky du Coudray**
Telephone	**:031 2042205**

<u>Please circle the appropriate answer</u> **YES/NO**

1. Have you read the research information sheet? Yes No
2. Have you had an opportunity to ask questions regarding this study? Yes No
3. Have you received satisfactory answers to your questions? Yes No
4. Have you had an opportunity to discuss this study? Yes No
5. Have you received enough information about this study? Yes No
6. Do you understand the implications of your involvement in this study? Yes No
7. Do you understand that you are free to withdraw from this study: Yes No
   At any time?
   Without having to give a reason?
   Without affecting your future health?
8. Do you agree to participate voluntarily in this study? Yes No
9. Who have you spoken to?____

Please ensure that the researcher completes each section with you.
If you have answered NO to any of the above, please obtain the necessary information before signing.

<u>Please print in BLOCK letters:</u>

Patient/Subject Name:_________________________Signature:__________________

Witness Name:_______________________________Signature:__________________

Research Student Name:_______________________Signature:__________________

APPENDIX C:

CASE HISTORY

APPENDIX D:

PHYSICAL EXAMINATION

APPENDIX E:

CERVICAL SPINE REGIONAL

APPENDIX F:

ELBOW REGIONAL

APPENDIX G:

ADVERT REQUESTING PARTICIPATION

Would you like to participate in a research study?

Are you right-handed and between the ages of 25-50?

Are you suffering from

TENNIS ELBOW

(pain on the outside of your elbow)?

OR

Do you NOT have pain around the elbow joint but would like to

evaluate your forearm muscle strength?

Research is currently being done at the Durban Institute of Technology Chiropractic Day Clinic. All consultations and treatment will be

FREE OF CHARGE

if you meet the criteria for the research.

FOR FURTHER INFORMATION contact

NICKY

on 031 204 2205/2512

APPENDIX H:

MUSCLE ACTIVITY AND PEAK TORQUE RECORDING SHEET

MUSCLE ACTIVITY READINGS (SUFACE EMG) AND PEAK TORQUE READINGS (ISOKINETICS)

Name: ____

File No: ________________

Group: *tick appropriate box*

	Male	Female
Control		
Symptomatic		

Surface EMG readings:

Date: ____________

Measurement	Wrist Flexors	Wrist Extensors
Baseline		
Contraction 1		
Contraction 2		
Contraction 3		
Average		

Isokinetic readings:

Date: ____________

FORCE

	WRIST FLEXORS	WRIST EXTENSORS
AVERAGE		

APPENDIX I:

LETTER OF PERMISSION FROM DENNIS JACKSON

APPENDIX J:

QUOTE FROM DENNIS JACKSON FOR THE USE OF THE CYBEX

JOURNAL ARTICLE

(According to the guidelines for authors set out by the *Journal of Orthopaedic and Sports Physical Therapy* 2005, 35(12):877-881)

An Investigation into the Role of Muscle Imbalances within the Wrist Flexor and Extensor muscle groups as an Associated Factor in the Presentation of Lateral Epicondylitis.

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Study design: This is an investigative, prospective, controlled clinical trial.

Objectives: To assess the peak torque and muscle activity of the wrist flexor and extensor muscle groups of right-hand dominant, asymptomatic subjects. To assess the peak torque and muscle activity of the wrist flexor and extensor muscle groups of right-hand dominant, lateral epicondylitis patients. To integrate this information, compare the two groups and sub-groups and statistically analyse the difference between them.

Background: It has been found that keeping muscle balances around a joint play an important role in protecting the soft tissue structures. No effective treatment protocol or a specific cause has been found for lateral epicondylitis making it a troubling condition for practitioners and patients alike.

Methods and Measures: Thirty-two subjects between the ages of 25-50 years were selected following a screening examination. These individuals were divided up into asymptomatic and symptomatic groups, with eight males and eight females in each. Each individual underwent muscle activity and peak torque testing for the movements of wrist flexion and extension.

Results: There was no statistically significant difference found in the isokinetic ratios when comparing asymptomatic to symptomatic groups. The muscle activity ratios were found to be better in the symptomatic groups than in the asymptomatic groups.

Conclusion: The hypotheses were rejected in this study and the results attained were inconsistent with each other therefore, no deductions can be made about muscle imbalances in the wrist flexor and extensor muscle groups being associated with lateral epicondylitis. Further investigation is necessary.

Key Words: tennis elbow, tendonitis, torque, muscle activity.

Introduction

Lateral epicondylitis is a disabling, common, overuse condition of the elbow with an incidence of 1%-3% of all adults[17]. In a study of world class tennis players 13% had current symptoms and more than 50% had suffered from this condition at one time or another[15]. Lateral epicondylits is caused by a multiple factors and presents in a variety of different ways in different patients[16]. It is a frequent occupational hazard in individuals carrying out repetitive wrist flexion and extension movements[4] and most often manifests itself as pain in the elbow and lateral proximal forearm[13]. In reviewing the literature it is evident that there is still debate as to the specific cause of the condition and the most effective treatment for this condition[17].

The precise aetiology of this condition is unknown, but the syndrome is often ascribed to a combination of degenerative changes and chronic overuse[7]. Nirschl and Kraushaar[12] state that the word “epicondylosis” should be substituted for “epicondylitis” because degeneration rather than inflammation is thought to exist.
In a literature review by Noteboom et al[13], it was found that the chronic symptoms are commonly associated with inadequate muscle power and endurance. It is found in many cases that there are poorly conditioned muscles surrounding the lateral epicondyle[10]. The synergic actions of the wrist flexor and extensor groups in functional activities have been well documented[15]. Muscle imbalances, in general, may lead to pain and chronic injury by interfering with the natural movement of the joint[9]. Loss of muscular protection when there is disruption of normal agonist to antagonist force ratios can produce abnormal shear and compression loads to the tendon tissue[2]. In a study by Crosier et al[5] they concluded that correction of agonist/antagonist imbalances should represent a primary goal in rehabilitation.

In studies done previously it has been shown that the wrist flexors should be twice as strong as the wrist extensors[8,11,15]. No research could be found stating that an imbalance in the above ratio was an associated factor in the presentation of lateral epicondylitis.

Methods

It has been found that isokinetic dynamometers[6] and surface electromyography[1] can effectively and accurately measure the maximal capacity of muscles.

Applicants were screened for inclusion to the study by conducting a case history, physical examination and regional elbow examination. A cervical spine regional was performed to exclude the possibility of pain referral from the cervical spine. After a diagnosis of lateral epicondylitis was made, they were assigned to the symptomatic group, which consisted of eight males and eight females in each. The eight males and eight females in the asymptomatic group did not have any subjective or objective symptoms of lateral epicondylitis or have ever previously been diagnosed with this condition.

All ethical aspects were taken into consideration and the rights and welfare of the patient were protected at all times.

All participants had the muscle activity of their wrist flexors and extensors measured by using surface EMG[*]. The subjects were seated with their elbow flexed to 90˚ and in forearm supination. The subject performed three voluntary contractions in wrist flexion and extension with maximal strength. The average amplitude of the spike was analysed. All participants then had the average torque of their wrist flexors and extensors measured by using an isokinetic dynamometer[†]. The patients were lying prone with the elbow flexed to 90˚ and in forearm supination. The protocol included concentric contractions of both the wrist flexors and extensors at an angular speed of 60˚/s. The average torque was recorded for each muscle group after six repetitions.

Data were captured in MS Excel and exported into SPSS (Statistical Package for Social Sciences) version 11.5 for data analysis‡. Ratios and measurements were described and compared between the subgroups using parametric statistics. One-way ANOVA and Bonferroni post hoc tests were used to compare mean values between subgroups. A p value of <0.05 was considered as statistically significant.

*PowerLab/410 (137) unit (AD Instruments Pty Ltd, unit 6, Gladstone Rd, Castle Hill, NSW 2154, Australia).
†Cybex Orthotron II device
‡ SPSS Inc, Chicago, Ill, USA

Results

No significant relationships between any of the isokinetic or EMG measurements or ratios were noted. Weight was positively related to the isokinetic and EMG measurements. Thus as weight increased so did the isokinetic and EMG values increase. This was to be expected because in normal individuals, muscle mass rises with body weight, therefore heavier subjects produce higher isokinetic moments[18]. There were no significant differences in means of the flexion, extension or ratio measurements. Therefore nothing can be extrapolated about the effect of race on the results.

TABLE 1. Descriptive statistics for isokinetic flexion and extension by subgroup (n=32)

SUBGROUP		Isokinetic Flexion at 60˚/s	Isokinetic Extension at 60˚/s
Asymptomatic Males	Mean	32.63	20.50
Asymptomatic Females	Mean	17.13	14.00
Symptomatic Males	Mean	31.63	20.25
Symptomatic Females	Mean	17.00	12.25
Total	Mean	24.59	16.75

Table 1 shows that the peak torque for isokinetic flexion in the asymptomatic males is 32.63 Nm and for isokinetic extension is 20.50 Nm, with the asymptomatic females being considerably less at 17.13 Nm for isokinetic flexion and 14.00 Nm for isokinetic extension.

The peak torque for isokinetic flexion in the symptomatic males is 31.63 Nm and for isokinetic extension is 20.25 Nm, with the symptomatic females again being considerably less at 17.00 Nm for isokinetic flexion and 12.25 Nm for isokinetic extension.

The average peak torque for male wrist flexion is 32.13Nm and wrist extension is 20.38Nm, while the average peak torque for female wrist flexion is 17.06Nm and wrist extension is 13.13Nm. No normal reference values could be found in the literature regarding a concentric strength test on the wrist flexors and extensors at 60˚/s. However, these findings are in keeping with the other isokinetic studies that have shown that men are consistently and significantly stronger than women[18].

The combined values (males, females, symptomatic and asymptomatic) for isokinetic flexion shows a mean of 24.59 Nm and the isokinetic extension shows a mean of 16.75 Nm.

Table 2. Descriptive statistics for EMG flexion and extension by subgroup (n=32)

SUBGROUP		**Integrated EMG Flexion in ųV.s**	**Integrated EMG Extension in ųV.s**
Asymptomatic Males	Mean	78.964	65.670
Asymptomatic Females	Mean	45.023	36.140
Symptomatic Males	Mean	89.276	55.551
Symptomatic Females	Mean	53.460	36.944
Total	Mean	66.681	48.576

Table 2 shows that the peak muscle activity measured for EMG flexion in the asymptomatic males is 78.964ųV.s and for EMG extension is 65.67ųV.s, with the asymptomatic females being slightly less at

45.023ųV.s for EMG flexion and 36.140ųV.s for isokinetic extension.

The peak muscle activity measured for EMG flexion in the symptomatic males is 89.276ųV.s and for EMG extension is 55.551ųV.s, with the symptomatic females again being slightly less at 53.46ų.V.s for EMG flexion and 36.944ųV.s for EMG extension.

The average peak muscle activity for male wrist flexion is 84.12ųV.s and wrist extension is 60.61ųV.s, while the average peak muscle activity for female wrist flexion is 49.242ųV.s and wrist extension is 36.542ųV.s. No normal reference values could be found in the literature regarding muscle activity of the wrist flexors and extensors. However, these findings are in keeping with the other isokinetic studies that have shown that men are consistently and significantly stronger than women[18].

The combined values for EMG flexion (males, females, symptomatic and asymptomatic) shows a mean of 66.681ųV.s and the EMG extension shows a mean of 48.576ųV.s. This is consistent with the wrist flexors being stronger than the wrist extensors.

An ANOVA statistical test comparing the mean isokinetic and EMG flexion and extension values between the subgroups showed that the differences between the subgroups were statistically significant for isokinetic flexion and extension ($p<0.001$), and for EMG flexion ($p=0.001$) and EMG extension ($p=0.025$). A Bonferroni multiple comparison test was then carried out for pairwise comparisons between the subgroups, which showed that the statistical differences found in, the ANOVA test lay between the genders and not between the symptomatic and asymptomatic groups.

The ratios were generated by dividing the flexion by the extension measurement, multiplying by 100 and subtracting 100 to give a percentage increase in strength of the flexor muscle groups over the extensor muscle groups.

Table 3. Descriptive statistics for isokinetic and EMG ratios by subgroup (n=32)

SUBGROUP		Isokinetic ratio %	EMG ratio %
Asymptomatic males	Mean	60.8844	34.6263
Asymptomatic females	Mean	24.4054	35.5908
Symptomatic males	Mean	53.9372	78.3651
Symptomatic females	Mean	48.6174	101.5432
Total	Mean	46.9611	62.5313

Table 3 shows that the asymptomatic males' isokinetic wrist flexion was 60.88% stronger than the isokinetic wrist extension, while the asymptomatic females' isokinetic wrist flexion was only 24.41% stronger than the isokinetic wrist extension. The symptomatic males' isokinetic wrist flexion was 53.94% stronger than isokinetic wrist extension, while the symptomatic females' isokinetic wrist flexion was 48.61% stronger than isokinetic wrist extension.

The asymptomatic males' peak muscle activity of the wrist flexors was 34.62% stronger than the peak muscle activity of the wrist extensors, while the asymptomatic females' peak muscle activity of the wrist flexors was 35.59% stronger than the peak muscle activity of the wrist extensors. The symptomatic males' peak muscle activity of the wrist flexors was 78.37% stronger than the peak muscle activity of the wrist extensors, while the symptomatic females' peak muscle activity of the wrist flexors was 101.54% stronger than the peak muscle activity of the wrist extensors.

Although these ratios were not significantly different between the subgroups, which was shown in an ANOVA test, it was shown that the mean isokinetic ratios were higher generally in males than females, but similar in the symptomatic and asymptomatic groups.

The EMG ratios were higher in the symptomatic group and especially high in symptomatic females. Asymptomatic males and females had similar EMG ratios.

The expected mean ratio for wrist extensor strength is, as stated from the literature[11,15], 45-50% of the wrist flexor strength (average 47.5%). This could also translate to the wrist flexors being 90-100% stronger than the wrist extensors (average 95%). Mean isokinetic ratios in the subgroups were tested using one sample t-tests for difference from this hypothesized value of the flexors being 90-100% stronger than the extensors.

Overall there was a highly significantly lower mean isokinetic ratio observed compared with the expected ratio of 95% ($p<0.001$). This demonstrates that the overall ratio (including symptomatic and asymptomatic males and females) of the peak torque results was incorrect.

However, overall the EMG ratio was not significantly different from 95% ($p=0.090$). This demonstrates that the overall ratio (including symptomatic and asymptomatic males and females) of the muscle activity results was correct with the wrist flexors being about twice as strong as the extensors. However, these categories needed to be analysed in more detail by comparing the subgroups.

Within the subgroups, the isokinetic ratio in asymptomatic males was not quite significantly lower than 95% ($p=0.061$). This means that the strength ratio according to isokinetics was correct.

The symptomatic males had a significantly lower isokinetic ratio than 95% ($p<0.001$). This means that the strength ratio according to isokinetics was incorrect. The isokinetic ratio of the symptomatic males was the only ratio that showed an imbalance in the symptomatic subjects.

In the asymptomatic females, both isokinetic and EMG ratios were significantly lower than 95% ($p<0.001$ for isokinetic and $p=0.050$ for EMG). This means that the strength ratio according to muscle activity and peak torque for this subgroup were incorrect.

Symptomatic females had a borderline significantly lower isokinetic ratio (p=0.051) but their EMG ratio was not different to 95% (p=0.917). This shows that the strength ratio according to both muscle activity and peak torque were correct according to the expected normal. This is the only subgroup to confirm the ratio according to the literature in both the tests utilised. Interestingly though, it is the symptomatic group.

Although the reliability of isokinetic dynamometers is extremely high, an explanation for these results could be that when measuring the wrist there is a lower reliability probably due to small ROM and torque production. The variations in small torque values are obviously magnified particularly if the dynamometer does not register decimal places[3]. The Cybex Orthotron II used in this study did not measure decimal places. Surface EMG has been found to be inferior to needle EMG[14], the inconsistencies found with the EMG readings between the subgroups in this study could be due to inaccuracies of the surface EMG testing. Furthermore, with subgroup sizes so small, type II errors could have been made.

Conclusion

The isokinetic ratio in the asymptomatic males and electromyographic ratios in the symptomatic males and females were the only ratios that were not significantly different from the expected value of the extensors being 50% of the flexor strength. The isokinetic ratio of the symptomatic males was the only ratio that showed and imbalance in the symptomatic subjects.

None of these results are consistent; therefore the hypotheses of this study were rejected. As discussed above it could be due to the dynamometer not registering decimal places but also the possibility of type II errors is high due to the small sample size in each group. A larger study would be recommended to fully explore the statistical significance of the above findings.

No deductions can therefore be made about muscle imbalances in the wrist flexor and extensor muscle groups being associated with lateral epicondylitis. Further investigation is necessary.

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