

https://dspace.org/

Functional outcomes post total knee arthroplasty following electrical muscle stimulation on the quadriceps muscle at Chris Hani Baragwanath Academic Hospital

Rajcoomar, Riona

2017
https://hdl.handle.net/10539/24913

Downloaded from a DSpace repository. https://dspace.org/

FUNCTIONAL OUTCOMES POST TOTAL KNEE ARTHROPLASTY FOLLOWING ELECTRICAL MUSCLE STIMULATION ON THE QUADRICEPS MUSCLE AT CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

Riona Rajcoomar

A dissertation submitted to the Faculty of Health Sciences, University of the Witwatersrand, in fulfilment of the requirements for the degree of Master of Science in Physiotherapy
Johannesburg, 2017

DECLARATION

I, Riona Rajcoomar, declare that this dissertation is my own work. It is being submitted for the degree of Master of Science in Physiotherapy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

_____

Signature of Candidate

_____ day of _____ 2017 in _____

DEDICATION

I dedicate my work to my family, friends and colleagues who have encouraged, motivated, supported and believed in me throughout this process, more especially the patients who have participated in this study. Without them this study could have not been possible.

Functional Outcomes Post Total Knee Arthroplasty Following Electrical Muscle Stimulation on the Quadriceps Muscle at Chris Hani Baragwanath Academic Hospital

ABSTRACT

Background: Known as the largest hospital in the southern hemisphere, Chris Hani Baragwanath Academic Hospital caterers to a large volume of patients daily. Many of those patients need surgical procedures and a high turnover rate in relation to postoperative length of stay in hospital is the norm. However, some elective surgical procedures, such as total knee arthroplasty, have a prolonged hospital stay possibly due to the physiotherapy rehabilitation protocol being practiced.

Aim: The aim of this study is to determine whether electrical muscle stimulation on the quadriceps muscle in addition to the normal physiotherapy rehabilitation protocol will influence the short-term functional outcomes at six weeks and length of stay in hospital post total knee arthroplasty when compared with the normal physiotherapy rehabilitation protocol at Chris Hani Baragwanath Academic Hospital.

Method: A single blinded randomized controlled trial was conducted at Chris Hani Baragwanath Academic Hospital. Participants were selected from the patients, between 50 and 80 years of age, requiring total knee arthroplasty due to osteoarthritis during the period of September 2013 to August 2015. The study sample consisted of 52 participants who were randomly allocated into two groups to which the researcher was blinded. Both groups received the normal physiotherapy rehabilitation protocol. In addition, the experimental group (group one) started receiving electrical muscle stimulation 48 hours post-surgery, twice a day for ten minutes until discharge. Participants were measured for knee range of motion and quadriceps lag preoperatively, on discharge and at six weeks, using a standard goniometer. Quadriceps muscle strength was measured preoperatively and at six weeks using a hand-held dynamometer. Functional assessments were conducted using the Oxford Knee Score pre-operatively and at six weeks, and the Iowa Level of Assistance Scale performed daily until discharge.

Results: All 52 (n=48 females and n=4 males) participants who met the inclusion and exclusion criteria consented to participate in this study. One participant, in the control group, demised due to medical complications whilst in hospital and no measurements were obtained on discharge and was therefore excluded from this study. The loss to follow up in both groups was particularly high at 38.1% (n=16 from a total of n=42) and 36.6% (n=15 from a total of n=41) for groups one (experimental group) and two (control group) respectively.

The Oxford Knee Score showed no significant difference between the two groups pre-operatively (p=0.55), and at six weeks (p=0.98). The Iowa Level of Assistance scale showed no significant clinical difference between the two groups on discharge (p=0.38).
There was no significant clinical difference in length of stay in hospital between the two groups (p=0.38). There was no significant difference in active range of motion between the two groups pre-operatively (p=0.91), on discharge (p=0.80), and at six weeks (p=0.61). This study showed the same outcome for passive range of motion between the two groups preoperatively (p=0.89), on discharge (p=0.87), and at six weeks (p=0.63).
The data revealed no significant clinical difference in quadriceps muscle strength between the two groups pre-operatively (p=0.31), and at six weeks (p=0.71).
It was shown there was no significant difference in quadriceps lag between the two groups preoperatively (p=0.5). However, it was shown that the experimental group (group one), who had a median of 0° (0°-0°) quadriceps lag, yielded a significantly better outcome of quadriceps lag on discharge, than the control group (group two) who had a mean of 0° (0°-5°) quadriceps lag (p=0.0019). There is also a significant difference in quadriceps lag at six weeks, with a mean of 0° (0°-0°) in the experimental group (group one) and 0° (0°-0°) in the control group (group two) (p=0.04).
There was a significant difference between the two groups with regard to days to reach 90° active and passive flexion (p<0.001), and 0° extension range of motion (p=0.0012).

Conclusion: The addition of electrical muscle stimulation on the quadriceps muscle to the practiced protocol does not significantly influence the short-term functional

outcomes post total knee arthroplasty and did not significantly reduce the length of stay in hospital. The introduction of physiotherapy rehabilitation over the weekend did however, see a significant reduction in length of stay compared to previous statistics. Although there were some significant findings in this study, for now, electrical muscle stimulation should not be incorporated into the protocol currently being used a Chris Hani Baragwanath Academic Hospital, but with further research it could be re-looked.

More research with electrical muscle stimulation should be done with more extended treatment sessions and follow ups at three and six months to determine the long-term effects of electrical muscle stimulation in this population, and, to determine if the results of this study is maintained or rendered unchanged.

ACKNOWLEDGEMENTS

I would like to thank the following people for their contribution toward this study, without whom this dissertation would not have been possible.

My supervisors, Dr Wendy-Ann Wood and Dr Lonwabo Godlwana, for their patience, support and guidance.

My mentor, Dorothy Shead, for her continued support.

My parents, sister and brother for their unconditional love, faith and encouragement.

My friends for their unwavering faith in me.

My colleagues at CHBAH for assisting me with data collection.

The Arthroplasty unit at CHBAH for accommodating my study.

Dr Michel Muteba, Dr Steve Olorunju, and Prof Jonathan Levin for help with statistical analysis.

The patients who willingly participated in this study.

TABLE OF CONTENTS

DECLARATION	ii
DEDICATION	iii
ABSTRACT	iv
ACKNOWLEDGEMENTS	vii
TABLE OF CONTENTS	ix
LIST OF APPENDICES	xii
LIST OF TABLES	xiii
LIST OF ABBREVIATIONS	xiv

Table of Contents

1. CHAPTER ONE – INTRODUCTION **1**
1.1 Introduction **1**
1.2 Problem statement **3**
1.3 Aim **3**
1.4 Objectives **3**
1.5 Significance of the study **4**
1.6 Hypothesis **4**

2. CHAPTER TWO: LITERATURE REVIEW **5**
2.1 Introduction **5**
2.2 Osteoarthritis **6**
2.2.1 Impact and burden of Osteoarthritis 6
2.2.2 Predisposing factors 7
2.2.3 Pathology, process and progression 10
2.2.4 Grading 10
2.3 The Osteoarthritic Knee **12**
2.3.1 Biomechanics of Gait 12
2.3.2 Quadriceps muscles in relation to function and strength 13
2.3.3 How OA leads to muscles weakness due to physiological inhibition 14
2.4 Management of OA **14**
2.4.1 Conservative management 15
2.4.1.1 Non-pharmacological management 15
2.4.1.2 Pharmacological management 15
2.4.1.3 Intra-articular injections 16
2.4.1.4 Diet and nutrition 16
2.4.2 Surgical management 16
2.4.2.1 Total knee arthroplasty 16
2.4.2.2 Other surgical options 17
2.5 Pre and post operative physiotherapy management associated with total knee arthroplasty **17**
2.5.1 Preoperative 17
2.5.2 Postoperative physiotherapy 18
2.5.2.1 Early mobilisation 20
2.5.2.2 Neuromuscular Electrical Stimulation 20
2.5.2.3 Exercise versus electrical stimulation 21
2.5.2.4 Continuous passive motion 21
2.5.2.5 Balance training 21
2.5.2.6 Aquatic therapy 22
2.6 Outcomes **22**
2.6.1 Range of motion 23
2.6.2 Muscle strength 23
2.7 Factors influencing functional outcomes and QoL **24**

3. CHAPTER THREE: METHODOLOGY **25**
3.1 Study design **25**
3.2 Study Setting **26**
3.3 Variables **26**
3.3.1 Dependent variables: 26
3.3.2 Independent variable: 27
3.4 Sample selection **27**
3.4.1 Participants 27
3.4.2 Sample size 27
3.4.3 Inclusion Criteria 27
3.4.4 Exclusion Criteria 27
3.4.5 Ethical consideration 28
3.5 Outcome measures: **28**
3.5.1 Range of Motion: Goniometer 28
3.5.2 Muscle strength: Quadriceps Lag /Dynamometer 29
3.5.3 Oxford Knee Score (OKS) 29
3.5.4 Iowa Level of Assistance (ILOA) Scale 29
3.6 Procedure **30**
3.6.1 Consent 30
3.6.2 Allocation of patients 30
3.6.3 Pilot study 30
3.6.4 Treatment procedure 31
3.6.5 Data collection 32
3.7 Statistical Analysis **37**

4. CHAPTER FOUR- RESULTS **38**
4.1 Introduction **38**
4.2 Demographic data of participants **38**
4.3 Clinical profile of participants **39**
4.4 Outcomes **40**
4.4.1 Short term functional outcomes 43
4.4.2 Range of motion of knee flexion 43
4.4.3 Quadriceps lag 44
4.4.4 Muscle strength 44
4.5 Conclusion **44**

5. CHAPTER FIVE: DISCUSSION **46**
5.1 Introduction **46**
5.2 Short term functional outcomes **46**
5.2.1 The Oxford Knee Score 47
5.2.2 The Iowa Level of Assistance Scale 47
5.3 Range of motion of knee flexion **48**
5.4 Quadriceps lag **49**
5.5 Muscle strength **49**
5.6 Length of stay in hospital **50**
5.7 Days to reach milestones **51**

5.8 Gender differences **51**
5.9 Feasibility of EMS **52**
5.10 Loss to follow up **53**
5.11 Conclusion **53**

6. CHAPTER SIX: CONCLUSION **54**
6.1 Conclusion **54**
6.2 Limitations **54**
6.3 Recommendations **55**

7. REFERENCES **56**

8. APPENDICES **70**

LIST OF APPENDICES

Appendix 1: Human Research Ethics Committee clearance certificate 69

Appendix 2: Permission to conduct research 70

Appendix 3: Information Sheet 71

Appendix 4: Consent Form 74

Appendix 5: Iowa Level of Assistance Scale 75

Appendix 6: Cumulative Illness Rating Scale 77

Appendix 7: The Oxford Knee Score 79

Appendix 8: Normally Practiced Physiotherapy Rehabilitation Protocol 83

Appendix 9: Data Collection Sheet 86

Appendix 10: Letter of Permission 89

Appendix 11: Summary of variables 91

Appendix 12: Turnitin report 92

LIST OF TABLES

Table 3.1:	Parameter settings	31
Table 3.2:	Outline of the procedure of the study	35
Table 4.1:	Clinical profile of study sample	37
Table 4.2:	Demographics of study sample	38
Table 4.3:	Outcome measures pre-operatively	39
Table 4.4:	Outcome measures on discharge	40
Table 4.5:	Outcome measures at six weeks	41

LIST OF ABBREVIATIONS

ADLs	Activities' of daily living
CHBAH	Chris Hani Baragwanath Academic Hospital
CIRS	Cumulative Illness Rating Scale
CPM	Continuous passive motion
EMS	Electrical muscle stimulation
HREC	Human Research Ethics Committee
ICC	Intra-class correlations coefficients
ILOA	Iowa Level of Assistance Scale
ISK	Index of Severity for Osteoarthritis of the Knee
K	Kappa
KOOS	Knee injury and Osteoarthritis Outcome Score
LoS	Length of stay
NMES	Neuromuscular Electrical stimulation
OA	Osteoarthritis
OKS	Oxford Knee Score
PROs	Patient Related Outcomes
PROMs	Patient Related Outcomes Measures
PRP	Physiotherapy rehabilitation protocol
QoL	Quality of life

QL	Quadriceps lag
QM	Quadriceps muscle
MS	Muscle strength
QS	Quadriceps strength
ROM	Range of motion
r	Pearson product-moment correlation coefficients
SF	Short Form
SLR	Straight leg raise
TKAs	Total knee arthroplasties
TKA	Total knee arthroplasty
WOMAC	Western Ontario and McMaster University of osteoarthritis index

1. CHAPTER ONE – INTRODUCTION

1.1 Introduction

Knee osteoarthritis (OA) results in continued pain and clinically significant functional limitations that reduce quality of life (QoL) and impair the ability to perform activities of daily living (ADLs) (Dandees 2011, Petterson et al 2009). Total knee arthroplasty (TKA) surgery has considerably changed the method of care of patients suffering from degenerative or inflammatory arthritis of the knee (Garrett and Walters 2010) and is becoming one of the most commonly performed orthopaedic procedures (Palmieri-Smith et al 2010). It is often the treatment of choice when other conservative therapeutic approaches have failed (Palmieri-Smithet al 2010). The goal of TKA is to create a pain-free, stable knee joint which allows good function for ADLs (Dandees 2011 and Garrett and Walters 2010).

In the United States of America, more than 687,000 total knee arthroplasties (TKAs) are performed each year for severe knee OA and future projections reflect that approximately 3,48 million TKAs will be performed annually by the year 2030 (Stevens-Lapsley et al 2012), as this procedure effectively reduces pain and improves self-reported function (Petterson et al 2009). Informal information from the Orthopaedic Department at Chris Hani Baragwanath Academic Hospital (CHBAH) shows the gradual increase in the number of TKA being performed each year. The anecdotal evidence reflected that in 2015 there were a total of 115 TKAs performed at CHBAH, which is a significant increase from the 102 TKA surgeries performed in 2011. During January and June of 2012, 41 TKAs were carried out, with OA being the biggest indicator for this surgery. In 2011 and 2012, 86% and 80%, respectively, of all TKAs performed at CHBAH were performed due to OA of the knee.

After a TKA, at least 90° of knee flexion is necessary to safely complete ADLs such as stair climbing, walking, and rising from a chair (Dandees 2011). Undergoing TKA implies

a long period of rehabilitation starting from the first day after the operation and can sometimes last for years (Dandees 2011). However, patients continue to show significant deficiencies in voluntary muscle activation, quadriceps strength, and functional performance (e.g., walking, stair climbing) (Petterson et al 2009).
It has been recognized by Garrett and Walters (2010) that some patients, for whom the results were expected to be excellent after a nominally 'simple and straightforward' TKA, had more pain and swelling than was expected. This delayed their rehabilitation, decreased their range of motion (ROM), prolonged their hospital stay, and resulted in a poor outcome.

Although TKA effectively alleviates pain and improves function in older adults with knee OA, the predominant impairment is a characteristic reduction in quadriceps strength (QS) that has been associated with a limitation in post-operative functional activity (Stevens-Lapsley et al 2012, Walls et al 2010, Meier et al 2009). The recovery of quadriceps muscle (QM) force and function is below par and predisposes patients to disability as they age (Stevens-Lapsley et al 2012). Stevens-Lapsley, et al (2012) have also deduced that even a month after TKA, the quadriceps muscle strength drops between 50% and 60% of pre-operative levels, even after commencing rehabilitation within 48 hours following surgery.

Electrical muscle stimulation (EMS) offers a novel way to potentially diminished quadriceps muscle voluntary activation deficits and prevents early muscle atrophy after surgery (Stevens-Lapsley et al 2012). It has been used in other populations to effectively target quadriceps dysfunction (Petterson et al 2009) and to reestablish normal quadriceps muscle function more successfully than voluntary exercise alone (Stevens-Lapsley et al 2012).

In addition to being important for good general functional ability, QM strength determines the patients' readiness for discharge as defined by the treatment protocol used at CHBAH. This protocol includes a discharge criterion which states that a patient must have at least 90˚ of knee flexion and be able to perform a straight leg raise (SLR)

without a quadriceps lag (QL) on discharge, inevitably prolonging length of stay (LoS) in hospital (appendix 8). Unpublished statistics from the physiotherapy department at CHBAH show that the LoS in hospital, from the day of surgery, varies from 4 to 25 days, with the average LoS in hospital being 9.67 days during the period of January to August 2012, depending on when post-operative milestones were achieved.

Prolonged LoS does not only have negative implications for the patient personally, bio-medically as well as their psychosocial well-being, but it also has economic implications due to cost incurred by keeping a patient in hospital.

1.2 Problem statement

Chris Hani Baragwanath Academic Hospital, being the largest hospital in the southern hemisphere, sees a large number of patients on a daily basis for surgical procedures. Although a high turnover rate in relation to post-operative LoS in hospital is normal. Some types of elective surgical procedures, such as TKA, have a longer hospital stay. This could possibly be due to the physiotherapy rehabilitation protocol (PRP) (appendix 8) in place.

1.3 Aim

The aim of this study is to determine whether EMS on the QM in addition to the normally PRP will influence the short-term functional outcomes at six weeks and LoS in hospital post TKA when compared with the normal PRP (appendix 8) at CHBAH.

1.4 Objectives

- To compare the short term functional outcomes at six weeks in patients who receive EMS on the QM in addition to the normal PRP post TKA to that in patients who receive the normal PRP only.
- To compare the ROM of knee flexion and extension, at discharge and six weeks, in patients who receive EMS on the QM in addition to the standard practiced PRP post TKA and to that in patients who receive the PRP only.

- To compare the QS, at six weeks, in patients who receive EMS on the QM in addition to the standard practiced PRP post TKA and to that in patients who receive the PRP only.
- To compare the LoS in patients who receive EMS on the QM in addition to the standard practiced PRP post TKA and to that in patients who receive the PRP only.

1.5 Significance of the study

This study may potentially influence the way physiotherapy is practiced at CHBAH as well other centers similar to CHBAH. It may assist in deciding whether EMS should be included in the standard PRP in order to increase the turnover rate in the elective surgery wards regarding TKAs.

1.6 Hypothesis

Hypothesis$_0$: The addition of EMS on the QM to the practiced protocol will not significantly influence the short term functional outcomes post TKA and will not significantly reduce the LoS in hospital.

Hypothesis$_1$: The addition of EMS on the QM to the practiced protocol will significantly influence the short-term functional outcomes post TKA and will significantly reduce the LoS in hospital.

2. CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This literature review aims to provide a basis for this research. This review discusses current literature regarding OA of the knee, the impact, pathology and progression of the disease, predisposing factors, grading, the effects of OA on biomechanics and muscle strength of the knee, both conservative and surgical management, physiotherapy management, including pre and post-operative management, outcomes used in this study, conventional rehabilitation versus NMES, NMES and factors influencing functional outcomes.

Various searches were conducted during the time period from March 2012 onwards, using popular publication sites, such as PubMed, PEDro, EBSCOhost, Elsevier and the Cochrane database, via Google Scholar. Over 150 articles, with the phrases and keywords such as “functional outcomes post total knee arthroplasty”, “osteoarthritis of the knee” “electrical muscle stimulation on the quadriceps muscle”, “neuro electrical muscle stimulation”, “quadriceps muscle weakness’, quadriceps muscle recovery”, “effects of osteoarthritis”, “quality of life”, “physiotherapy management post total knee arthroplasty”, “physiotherapy rehabilitation post total knee arthroplasty”, “outcome measures for total knee arthroplasty”, “factors influencing outcomes of total knee arthroplasty” and “management of knee osteoarthritis” formed part of the inclusion criteria, and were used to conduct this search.

This review will explore OA including its impact and burden, predisposing factors, pathology, process and progression of this disease, as well as the grading of this disease. This will be followed by a review on the osteoarthritic knee including the biomechanics of gait, quadriceps muscles in relation to function and strength and how

OA leads to muscles weakness due to physiological inhibition. The review discusses the management of OA, which looks at various types of conservative and surgical options including TKA. This follows on with a review on pre and post-operative physiotherapy management associated with TKA and explores the most common practices. The outcomes of this study are then reviewed looking at ROM, MS (muscle strength), function and mobility and the OKS. This is followed by a review on NMES, which is major component of this study. The review is then concluded with a brief section on factors influencing functional outcomes and QoL.

2.2 Osteoarthritis

Osteoarthritis (OA), as defined by Solomon et al (2005) and Litwic et al (2013), is a chronic joint disorder that causes a progressive degeneration and softening of the articular cartilage, most frequently affecting the knee. This disorder is usually accompanied by osteophyte formation, capsular fibrosis, ligament laxity and weakness of surrounding muscles (Litwic et al 2013, Hutton 1989). This is gradual progressing but ultimately debilitating condition that leads to pain, joint failure and disability (Litwic et al 2013).

2.2.1 Impact and burden of Osteoarthritis

Almost 80% of patients with OA suffer with constant pain, which limits ADLs and functional activities (Kon et al 2012). OA is a common disorder that affects a number of joints in the body, mostly affecting the knee, hip, hands, feet and facet joints, making it a debilitating disorder not only affecting the body physically but also having a major social, economic, as well as psychological impact on those affected (Litwic et al 2013, Buckwalter et al 2004, Woolf and Pfleger 2003).

According to Buckwalter et al (2004), the frequency of OA is proportional with increasing age. This, together with the increased life expectancy, will see a profound number of people suffering from OA in the near future. It becomes a major burden especially in developing countries where life expectancy is prolonged and access to joint replacements is limited (Woolf and Pfleger 2003).

OA disables approximately 10% of the American population over 60 years of age, affecting the QoL of over 20 million people and impacting on the economy greatly. Reginster (2004) predicted that approximately 18.2% of Americans or 60 million people will be affected by arthritic disorders. Usenbo et al (2015) looked at data, from 1975 to 2014 in a review, which it showed OA was the most prevalent form of arthritis in urban South Africa, with figures as high as 55.1% in adults over the age of 65 years. Knee OA had the highest prevalence in rural South Africa with 33.1% (Usenbo et al 2015).
An international initiative by the presidents of the British, American, Australian, Canadian, New Zealand and South African Orthopaedic Associations, and of the American Academy of Orthopaedic Surgeons have started, encouraging national joint registries to be kept in an effort to monitor the growing number of replacements being placed worldwide (Horan 2010). However, statistics based on the South African population proved difficult to find due to the poor registry keeping.

The impact and burden of OA on QoL is of great significance as it yields the poorest QoL problems, especially related to joint pain and physical functioning (Reginster 2004). The burden of musculoskeletal disorders, like OA, can be gauged in relation to the issues related to it, such as pain and disability or physical function, with pain being an important indicator of disability (Woolf and Pfleger 2003).

2.2.2 Predisposing factors

According to Felson et al (2000), research is leaning towards intrinsic biomechanical factors such as muscle weakness, joint laxity and obesity, as well as, systemic factors such as oestrogen use, genetics, bone density, and dietary intake, as risk factors predisposing to OA.

Coggon (2001) and Abramson and Attur (2009) found that obesity was a large contributing factor of severe knee OA. The first National Health and Nutrition Examination survey carried out in the USA between 1971 and 1975, showed women with a BMI of 30 and 35 kg/m^2 were four times more at risk of developing knee OA than

those with a BMI of less than 25 (Coggon 2001, Anderson 1988). The overloading effect experienced in single-leg stance phase explains most of the increased risk of OA of the knee and hip in obese individuals, therefore a reduction in weight can reduce the risk of OA in women by 50% (Felson et al 2000).

More recent studies have shown a link between obesity and OA, stating that OA is not just a disease of age or wear and tear but also has components of systemic metabolic disorder or metabolic syndrome (King et al 2013, Sellam and Berenbaum 2013, Issa and Griffon 2012). Sellam and Berenbaum (2013) describes metabolic syndrome as a "combination of disorders that increase the cardiovascular risk, including dyslipidemia, hypertension, diabetes or insulin resistance, and obesity". Adipokine, a soluble, pro-inflammatory, cytokine mediator produced by adipose tissue (King et al 2013, Sellam and Berenbaum 2013, Issa and Griffon 2012), is released into the blood stream (Sellam and Berenbaum 2013). Adipokines then cause a destructive and remodeling effect on joint tissues such as bone, cartilage and synovium, thereby relating OA to obesity (King et al 2013, Sellam and Berenbaum 2013, Issa and Griffon 2012).

Osteoarthritis of the knee is a significant source of impaired mobility, frequently affecting more women than men (Woolf and Pfleger 2003). The increased prevalence of OA in women may be attributed to the oestrogen deficiency post menopause. Previous studies have shown a decline in the incidence and prevalence of OA in women taking supplemental oestrogen (Abramson and Attur 2009, Felson et al 2000). Felson et al (2000) also reported an inverse relationship between OA and osteoporosis as women with knee OA have a rather high bone density. A study by Zhang et al in 2000, suggested that high bone mineral density increased the risk of knee OA but also slows down the disease progression.

Micronutrient antioxidants provide defence against tissue injury and can then be assumed to protect against OA if the dietary intake of these micronutrients is high (Felson et al 2000). High levels of intake of vitamins C and D protected against the

progression of OA as well as its incidence, with vitamin C seeing a threefold reduction in the progression of the disease as well as the risk of knee pain (Felson et al 2000).

There is evidence of a strong genetic link with all forms of heterogeneous arthritis as found by Abramson and Attur (2009), and Spector et al (1996). This has been linked to the chromosomes 2q and 11q (Felson et al, 2000). Genetics are responsible for almost 50 of all OA%(Abramson and Attur 2009, Spector et al 1996) of hands and hips, but account for a smaller % of knee OA (Spector et al 1996). Spector et al (1996) deduced this in twin study screening 130 identical and 120 non-identical female twins using radiological findings of the knee and hands.

Varus-valgus laxity in non-arthritic knees suggests that increased laxity leads to the development of OA and influences the disease onset in a study that looked at 25 young participants with knee laxity, 24 older participants with no clinical and radiological evidence of OA, and no history of previous knee trauma and 164 participants with knee OA (Sharma et al 1999). Changes in the mechanical environment of the joint can cause complications of the disease progression due to the altered load distribution on the joints (Felson et al 2000).

In a study to determine the prevalence of quadriceps weakness, with 462 subjects over the age of 65, conducted by Slemenda et al (1998), using the WOMAC and dynamometry, it was found that 14.88kg/m increase in quadriceps strength yielded a 20% and 29% decline in the chances of prevalent radiographic and symptomatic OA respectively. Small increases in quadriceps strength yielded a 20% to 30% decline in the chances of developing knee OA. It is thus evident that quadriceps weakness contributes to knee pain as well as increasing the likelihood of structural damage to the knee, leading to deformity (Felson et al 2000).

On a smaller scale, injury to the articular surfaces of the knee, ligaments and menisci may lead to joint instability, predisposing the knee to OA. The risk of developing

posttraumatic OA increases with high BMI, high active levels, ongoing joint instability and alignment, as well as incongruence of articulating joint surfaces Felson et al (2000).

2.2.3 Pathology, process and progression

Osteoarthritis is described as a progressive disease in which there is a disturbance in the dynamic balance between destruction and repair of joint tissue, which starts at the cartilage with an inconsistency between cartilage production and degradation (Maldonado and Nam 2013, Hart and Spector 1995). This degenerative process also affects the menisci, ligaments, subchondral bone and surrounding muscles (Hart and Spector 1995). Cartilage matrix degradation together with chronic inflammation aggravates the degeneration process by causing changes in biomechanical conditions, which affect the surrounding tissues in the joint (Maldonado and Nam 2013). Joint changes also occur as a result of abnormal mechanical strain on otherwise healthy tissue or physiological mechanical strain on pathologically compromised tissue (Paradowski, 2014). Inflammatory factors and structural changes of extra cellular matrix contribute to the progression of OA as it causes changes in the microenvironments (Maldonado and Nam 2013).

2.2.4 Grading

Kellgren and Lawrence first described the classification for OA in 1957 and is the most common radiological classification used to identify and grade radiographic OA. However, there is no clear indication on how to interpret the grades (Schiphof et al 2008). Kellgren and Lawrence (1957) defined the severity of OA in five grades (0, normal to 4, severe). Grade one being doubtful narrowing of joint space and possible osteophytic lipping, whilst grade four includes large osteophytes, marked narrowing of joint space, severe sclerosis and definite deformity of bone ends.

The World Health Organization graded eight joints, including the knee, and then clarified this grading scale as the appropriate use of the Kellgren and Lawrence (K and L) classification system proved challenging due to confusing descriptors (Schiphof et al 2008). Schiphof et al (2008) reported the most significant changes for the knee should be based on the lesions of OA, which are narrowing, osteophytes, sclerosis, cysts and

deformity, as individual factors. These changes include: (a) formation of osteophytes on the joint margins or in ligamentous attachments, as on the tibial spines, (b) narrowing of joint space associated with sclerosis of subchondral bone, (c) cystic areas with sclerotic walls situated in the subchondral bone, and (d) altered shape of the bone ends. The scoring of lesions as described by Schiphof et al (2008), should be used in conjunction with different descriptions of the Kellgren and Lawrence's grading scale.

There are four widely used tools for the assessment of joint function, symptoms and disability, the Index of Severity for Osteoarthritis of the Knee (ISK), the Western Ontario and McMaster University of osteoarthritis index (WOMAC), the Knee injury and Osteoarthritis Outcome Score (KOOS) and Patient Related Outcomes (PROs) (Paradowski, 2014).

The Index of Severity for Osteoarthritis of the Knee (ISK), which can be used interchangeably to score OA of the hip, was originally developed by Lequesne et al (1987). This scale assesses the long-term effectiveness of therapeutic interventions, such as new drugs, and is also used as an indicator for the need for surgery. The ISK is based on three sections, which includes: (1) pain or discomfort, (2) maximum distance walked, and (3) activities of daily living (Lequesne et al 1987).

The Western Ontario and McMaster University of Osteoarthritis Index or WOMAC was developed by Nicolas Bellamy in 1981 to assess pain, stiffness, and physical function (Bellamy et al 2005) in to relation treatment effects in patients with OA (Roos and Toksvig-Larsen 2003). Validation and implementation of this 24-item questionnaire occurred between 1982-1999 and it has since been revised, translated and linguistically validated in over 65 alternate language forms (Bellamy et al 2005). The WOMAC is a 24 item, self-administered questionnaire that is divided into 3 subscales, namely pain, stiffness and physical function.

The Knee injury and Osteoarthritis Outcome Score (KOOS) was originally developed, by Ewa M Roos in 1995, as an extension of the WOMAC Osteoarthritis Index to evaluate the short-term and long-term symptoms and function in patients with knee

injury and OA (Roos and Toksvig-Larsen 2003), which unlike the WOMAC Osteoarthritis Index, is specific to knees (Roos and Lohmander 2003). This tool assesses the patients' opinion about their knee and related problems, with a 42-item questionnaire, in 5 subscales, namely pain, other symptoms, function in daily living, function in sport and recreation and knee-related quality of life (Roos and Lohmander 2003).

The Knee Society Score, WOMAC, KOOS, Short Form (SF-) 12 and 36 scores, and the OKS are the most widely use Patient Related Outcomes Measures (PROMs) to evaluate outcomes following TKA (Clement et al 2014). Using a joint specific PROM, such as the Oxford Knee Score (OKS), has been shown to be more sensitive to changes in symptoms as opposed to generic health assessment such as the SF 12, which measures a patient's general physical and mental well-being (Clement et al 2014).

2.3 The Osteoarthritic Knee

2.3.1 Biomechanics of Gait

The reliability of the sensorimotor systems is important to perform a seamless and stable gait pattern. Proprioceptive perception warrants precise timing and placement of the lower limb at heel strike, and eccentric quadriceps activity after heel strike decrease the effect of joint loading. Changes in sensory input from articular mechanoreceptors can decrease proprioceptive perception and QMS, weakening the neuromuscular protective mechanisms that can possibly lead to destructive impact overloading after heel strike, thereby speeding up articular damage (Hurley et al 1997).

Overloading the knee and hip joints could lead to destruction of cartilage and ligamentous and other structural support failure, for each 0.45kg increase in weight, the total force across the knee in a single-leg stance increases 0.91kg to 1.36kg (Felson et al 2000). This is attributed to the failure of executing full knee extension during single leg stance phase of gait which causes an increase in reaction forces and stress as there is a greater need for knee stabilization during weight bearing (Farrokhi et al 2015). This

load effect is the most likely reason for the increased risk of OA of the knee and hip in overweight people (Felson et al 2000).

2.3.2 Quadriceps muscles in relation to function and strength

The quadriceps muscle is important for functional knee stability and an impairment of the quadriceps sensorimotor function will cause the feeling of weakness, postural instability and poor confidence in performing functional activities and ADLs (Hurley et al 1997). Hurley et al (1997) used 128 participants of which 25 had no OA of the knee, to determine QS, voluntary activation, proprioceptive acuity and functional outcomes. Hurley et al (1997) is as it looked at the effect knee OA had on QMS and the performance of ADLs, who used outcome measures similar to those in the current study. These outcome measures involved, getting up from a seated position, timed ambulation, and climbing up and down stairs. Hurley et al (1997) determined participants with knee OA did, in fact, perform less favorably than the participants who had no knee OA. Quadriceps muscle strength is related to functional tasks, such as standing up from a chair, level surface walking, and going up and down stairs (Alnahdi et al 2012, Maly et al 2006, Hurley et al (1997).

In Maly's et al (2006) study, these researchers used PROMS, such as the WOMAC and the Medical Outcomes Study SF-36, as well as, functional performance measures included the Six-minute Walk Test, Timed Up and Go test, and a standardized stair-climbing task. Similar to the current study which also used functional performance measures and PROMs. Maly's et al (2006) used 54 participants with medial compartment knee OA, to deduce how problems with quadriceps muscle activation influence the relationship between QMS and physical function (Maly et al 2006, Fitzgerald et al 2004).

It is reported there is a 60% loss of quadriceps muscle strength (QMS) during the acute phase following TKA (Stevens et al 2004), resulting in poor recovery in the long term (Silva et al 2003). In a study using 40 participants with a mean age of 63, it has been widely stated that QMS plays a vital role in performing ADLs as well as contributing to the progression of knee OA (Mizner et al 2005 A). This study included QS, knee ROM,

functional assessments and PROMs two weeks pre-operatively and one year post-operatively. In another study by Mizner et al B (2005), using only 20 participants with knee OA, explained that muscle atrophy and, more so, failure of voluntary quadriceps muscle activation was responsible for the significant loss of QMS in the acute phases following TKA after assessing QS and voluntary muscle activation at 10 and 27 days' post primary TKAs.

2.3.3 How OA leads to muscles weakness due to physiological inhibition

Joint damage stimulates articular mechanoreceptors promoting abnormal sensory information, which impairs motor control and sensory appreciation (Hurley et al 1997). The decrease in voluntary muscle activation is credited to arthrogenic muscle inhibition. This is a reduction in the excitability of the alpha motor neuron pool responsible for muscle activation (Rice and McNair 2010, Hurley et al 1997).

Failure of voluntary muscle activation was evident prior to the TKA (Mizner et al 2005 B), and failure of voluntary quadriceps muscle activation is the facilitator between QMS and physical function (Fitzgerald et al 2004). This relationship between poor voluntary quadriceps muscle activation, QMS and physical function in turn limits the recovery of QMS.

Voluntary quadriceps muscle activation prior to TKA is not a predictor of QMS three months following surgery and recovery of QMS is not limited by pre-operative voluntary quadriceps muscle activation (Marmon et al 2014). The study by Marmon and Synder-Mackler (2014 B), is similar to a study conducted by Stevens et al (2004), who included a six-week post-operative progressive strength training of the lower limb with increases in resistance and ROM exercise programme, as well as using neuromuscular electrical stimulation on the experimental group. Both studies yielded significant improvements in QMS and functional activities regardless of the pre-operative status.

2.4 Management of OA

Conservative and surgical management of OA knee are directed at preserving QoL of patients by reducing symptoms and improving function (Kon et al 2012).

2.4.1 Conservative management

Conservative management is usually the first choice of treatment when dealing with knee OA. Conservative management of knee OA comprises of a large variety of treatment options such as pharmacological therapy, dietary supplements, non-pharmacological therapy and minimally invasive intra-articular injections for the early stages of knee OA (McAlindon et al 2014, Kon et al 2012, Bennell and Hinman 2001).

2.4.1.1 Non-pharmacological management

Non-pharmacological management includes exercise and physiotherapy. Based on the vastly available literature advocating exercise and physiotherapy, it has been deemed the cornerstone of the conservative management of OA by Bennell and Hinman (2011). These methods have shown to have a positive impact on patients with knee OA (Deyle et al2012). Evidence showing that exercise and physiotherapy can modify the progression of the disease is not conclusive (Bennell and Hinman 2011).

However, physiotherapy interventions, such as taping, bracings, orthotics and manual therapy, have been reported to help reduce symptoms and improve function in patients with knee OA by dispersing the load on the knee joint, temporarily correcting misaligned joints, increasing ROM and improving neuromuscular function (Page et al 2011).

2.4.1.2 Pharmacological management

Pharmacological therapy includes non-steroidal anti-inflammatory drugs (NSAIDs), acetaminophen and cyclooxygenase-2-selective inhibitors (paracetamol) (McAlindon et al 2014, Deyle2012, Kon et al 2012).

Paracetamol is the first choice of oral analgesia whilst NSAIDs are used when patients do not get adequate pain relief from analgesia alone. However, it is not uncommon for patients with significant pain to be prescribed opioids when surgical intervention is not indicated (McAlindon et al 2014, Kon et al 2012).

2.4.1.3 Intra-articular injections

Intra-articular injections have shown to reduce pain and increase function in patients with knee OA (Ishijima et al 2014, Kon et al 2012). The effects of Hyaluronic acid (HA), a natural component of joint fluid, has been found to be similar to that of NSAIDs, without the adverse effects that are usually associated with the use of oral NSAIDs in older patients (Bannuru et al 2014, Ishijima et al 2014). The use of intra-articular corticosteroids also showed to have similar effects to that of intra-articular HA by four weeks but intra-articular HA has a longer lasting effect of up to eight weeks (Bellamy et al 2006).

2.4.1.4 Diet and nutrition

Studies regarding the influence of diet and nutrition on OA are still lacking but there has evidence showing diet and nutrition can improve symptoms of OA but there is evidence indicating that diet and nutrition plays a role in slowing down the progression of OA (Ameye and Chee 2006). Dietary supplementation S-adenosylmethionine (SAMe), however, has shown to reduce pain and inflammation in patients with OA, although its mechanism of action is still unknown (Kon et al 2012).

2.4.2 Surgical management

2.4.2.1 Total knee arthroplasty

Total knee arthroplasty (TKA) is fast becoming a successful, safe and popular procedure for the management of severe degenerative conditions of the knee (Murphey 2013). This procedure has been shown to improve functional outcomes for individuals with end stage knee OA (Astephen et al 2015).

The medial parapatellar approach is the preferred TKA approach as it provides more than adequate access to the knee joint, but disrupts the extensor mechanism and blood supply to the patella, which can affect early rehabilitation (Harwin 2003).

2.4.2.2 Other surgical options

Arthroscopic lavage and debridement has shown to provide only a short-term benefit to patients with mild radiographic OA and knee effusion (Ronn et al 2012). This is described as shaving or smoothening of the degenerated meniscus, and can remove torn meniscal bodies and loose cartilage flaps thereby reducing pain by removing debris and inflammatory cytokines that cause synovitis (Ogivile-Harris and Fitsialos 1991). It was shown that this procedure has no benefit on OA caused by from mechanical or inflammatory factors (Ronn et al 2012).

Osteotomy around the knee is a choice of treatment for unicompartmental OA with associated varus or valgus deformity (Ronn et al 2012). The purpose of an osteotomy is to unload the affected compartment and to redistribute the load from the affected areas by slightly overcorrecting into a valgus or varus axis to delay joint replacement surgery by slowing down the degenerative process and reducing pain (Ronn et al 2012).

Another technique used to manage unicompartmental OA of the knee is a unicompartmental knee arthroplasty (UKA). This advantageous technique is less invasive and preserves the extensor mechanism, there by permitting a faster recovery and reduced LoS in hospital (Borus and Thornhill 2008).

2.5 Pre and post-operative physiotherapy management associated with total knee arthroplasty

Early physiotherapy intervention aims to get patients ready for discharge from the hospital timeously following surgery, with the success of a TKA largely being based on the physiotherapy management and rehabilitation (Lenssen et al 2008).

This section aims to discuss the pre and early post-operative physiotherapy management of TKA.

2.5.1 Preoperative physiotherapy

Pre-operative physiotherapy management has been developed for patients who have a long waiting period for a TKA. It aims to improve physical function and functional

outcomes post-surgery, as well as decreasing pre-operative anxiety (Ackerman and Bennel 2004).

Pre-operative physiotherapy management compromising of exercise and education (Jordan et al 2014, Wallis and Taylor 2011, Ackerman and Bennel 2004) has shown to have little evidence of post-operative benefits but it has shown to have some effect on decreasing pre-operative anxiety (Wallis and Taylor 2011).

Pre-operative physiotherapy consisted of between three to six-week rehabilitation programmes including the issuing of educational hand-outs, educational sessions or videos and an exercise regime (Jordan et al 2014). Unlike the inconsistent practice at CHBAH, which includes the issuing of an educational hand-out, a 15min educational session and a review of exercises, if the patient is admitted a day or two before their surgery. If patients are admitted a day or two prior to their surgery, they will be issued with an educational hand-out, given a 15min educational session and have the post-operative exercises is demonstrated. Due to the high demand of hospital beds, patients are often only admitted the evening before or the morning of their surgeries, which makes it difficult for pre-operative physiotherapy to be conducted.

2.5.2 Postoperative physiotherapy

The purpose post-operative physiotherapy rehabilitation after arthroplasty procedures aims to prepare patients for discharge in terms of function, in the shortest possible time to reduce the LoS in hospital (Lenssen et al 2008, Naylor et al 2006). The practices at CHBAH were seen to be similar to that of those in a review by Naylor et al (2006), who showed that post-operative gait re-education, an exercise programme and independent mobilisation are criterions for discharge from hospital. Although Naylor et al (2006) sited independent mobilisation as the main criterion for discharge, factors such as independent ADLs, zero degrees QL, independent transfers and compliance with the home exercise programme, were also taken into account on discharge. These discharge criteria are very similar and in keeping with those practiced at CHBAH (appendix 8).

Intervention methods for post-operative rehabilitation vary vastly (Naylor et al 2006), therefore, for the purpose of this study early mobilisation, neuromuscular electrical stimulation (NMES), exercise, continuous passive motion, balance training and aquatic therapy will be discussed.

The evidence regarding efficacy of physiotherapy in patients with TKA in South Africa is extremely limited and there is no clinical practice guideline available for physiotherapy rehabilitation following TKA for the South African population using public facilities (Wood 2010). Naylor et al (2006) reported a similar problem in Australia. The CHBAH physiotherapy department developed a protocol that is used internally, focusing on improving ROM, MS and mobility in the shortest possible time to minimize the LoS in hospital. This protocol is similar to the rehabilitation guidelines following a TKA as described by Meier (2008). Meier's (2008) protocol is made up of four phases, with the first phase being most similar to the protocol being practiced at CHBAH. Meier's (2008) phase one protocol consisted of seated or supine knee active ROM exercises, alternated ankle dorsiflexion and plantar flexion, quadriceps sets, SLR, hamstring sets, standing leg curls seated knee extension, supported single standing for balance, repeated sit-to-stand transfer training and ambulation with an appropriate assistive device. Meier's (2008) stipulates the exercises should be performed two to three times a week for two to three weeks before progressing to phase two. This is far less than stipulated in the protocol CHBAH protocol (appendix 8), which requires patients to perform the exercise three times a day.

For the purpose of this study, ROM, MS and mobility will be discussed.

2.5.2.1 Early mobilisation

In a systematic review by Guerra et al (2015), mobilisation as early as 24-48 hours following TKA, similar to the protocol being practiced at CHBAH, showed increases in ROM, MS and QoL. In that review, patients were mobilized to sit out of bed within 24 hours following surgery and were ambulated within 48 hours following surgery, similar to the practice at CHBAH. Guerra et al (2015) results showed LoS in hospital saw a reduction of about 1.8 days.

2.5.2.2 Neuromuscular Electrical Stimulation

Improvements in muscle strength in using protocols that include only voluntary exercises may be limited by significant voluntary activation shortfalls due to the lack of production of muscle contractions of necessary intensity to encourage an increase in muscle strength (Stevens-Lapsley et al 2012).

Neuromuscular electrical stimulation is proposed to have the capability to override voluntary activation shortfalls in an effort to re-educate the QM to contract normally for better function than just voluntary exercises alone. (Stevens-Lapsley et al 2012, Stevens et al 2004). Electrically stimulated muscle contractions allow for more significant activation of the larger type II muscle fibres than voluntary exercises. Activation of type II muscle fibres magnifies the production of force as compared to the smaller type I muscle fibres (Stevens-Lapsley et al 2012).

Neuromuscular electrical stimulation is also thought to have an effect on functional measures of motor performance by peripheral afferent inputs that change motor cortex excitability. Stimulation of peripheral afferent nerves has shown to bring extended changes in the excitability of the human motor cortex (Stevens-Lapsley et al 2012, Mintken et al 2007).

2.5.2.3 Exercise versus electrical stimulation

Stevens et al (2004) found that NMES, when included to a voluntary exercise programme, shortfalls in QMS and activation recovered rapidly after TKA and were maintained over a 6-month follow-up period, whilst Avramidid (2011) showed an increase in functional outcome scores when NMES is incorporated into regular physiotherapy protocols than just regular physiotherapy.

The introduction of NMES as early as 48 hours following TKA reduced the loss of QMS and improved functional outcomes when added to regular physiotherapy. The effects were most significant within the first month after surgery and evident but not as significant at 52 weeks following TKA (Stevens-Lapsley et al 2012).

Levine's et al (2013) study showed, a NMES protocol with self-performed ROM exercises performed for a duration of two weeks before and 60 days after TKA, to have similar outcomes in quadriceps strength and patient satisfaction at six weeks and six months in comparison to a regular physiotherapy programme delivered by a physiotherapist.

2.5.2.4 Continuous passive motion

The use of a continuous passive motion (CPM) versus standard physiotherapy to improve knee ROM has been vastly studied. This practice is only used at CHBAH if required specifically from the surgeon. Lenssen et al (2008) showed the use of CPM yielded more ROM than standard physiotherapy in the short term at 17 days but found no significant difference in functional outcome measures at six weeks and three months. It was also found that regular passive ROM exercise conducted by a physiotherapist did not prove superior to other methods of increasing knee ROM and functional outcomes, therefore, suggesting active ROM exercises and functional rehabilitation should be encouraged to prepare for return to ADLs (Kim et al 2009).

2.5.2.5 Balance training

Balance training should be included in standard rehabilitation protocols following TKA as muscles weakness and decreased balance is a significant post-operative deficit

(Pozzi et al 2013).

Balance training together with intensive functional six-week rehabilitation protocol has shown to have faster self-selected walking speed and accomplished superior outcomes on a single leg stance test as compared to those who received the intensive functional six-week rehabilitation protocol only (Piva et al et al 2010).

In another study with an eight-week post-operative rehabilitation programme, participants who had balance training showed significantly superior outcomes in functional forward reach, single leg stance, sit-to-stand test, stair climbing time, 10m walk time, timed up and go scores and the WOMAC than those who didn't receive balance training (Liao et al 2013). In the study by Piya et al (2010), although there was an improvement the WOMAC compared to baseline, neither of the groups yielded better results compared to each other.

2.5.2.6 Aquatic therapy

In a systematic review, it was shown that aquatic therapy has shown to have no significant impact on functional outcomes and ROM when compared to land based exercises in a six-week programme (Pozzi et al 2013). It was found to improve knee flexion and extension power, walking speed and stair climbing time in those who participated in a 12 week programme, consisting of water based resistance exercises, compared to those who received no intervention at all, with knee flexion and extension power remaining significantly better at 12 months (Pozzi et al 2013).

2.6 Outcomes

Outcome measure has loosely been defined as a tool used to "determine the change in ability from before to after an intervention" (Jette et al 2009). For the purpose of this review, the outcomes to be discussed are those included in this study, namely ROM, MS and function and mobility.

2.6.1 Range of motion

Knee ROM is considered a primary indicator of a successful TKA due to its role on performing functional activities (Lenssen et al 2008). Knee flexion is required to perform activities such as walking, descending stairs and standing up from a seated position (Murphey 2013, Wood 2011). Rowe et al (2000) looked at 20 normal participants with a mean age of 67 in which their knee ROM was recorded whilst performing functional activities such as walking on slopes, navigating up and down stairs, sit to stand from standard and low chairs and getting in and out of a bath. Reports from this suggests adequate knee flexion up to 90°-120° is required to execute these tasks, with the optimum range being 0°-110°. Murphy (2013) and Wood (2011) reported that close to full knee extension is necessary during gait as the energy expenditure of walking increased with significant knee flexion contractures.

2.6.2 Muscle strength

Quadriceps muscle strength and function following TKA is dependent on many aspects. Patient factors, including demographics and comorbidities, surgical techniques, implant design, and rehabilitation, have all been shown to influence post-operative outcomes (Greene and Schurman 2008). Hurley et al 1997 showed, through a series of functional performance tests, the QM is plays a pivotal role in functional knee stability. Functional knee stability is required when performing tasks such as raising from a chair, ambulating, and climbing up and down stairs. Weakness, postural instability and poor confidence in performing functional activities and ADLs have been linked to impairments of the quadriceps sensorimotor function (Hurley et al 1997).

2.6.3 Function and mobility

Decreased MS, like ROM, has been associated with limitations in functional activities as well as slower walking speed, longer stair-climbing time, and increased risk of falling (Stevens et al 2003). Stevens et al (2003) study had a sample of 28 participants consisted of a four-day post-operative in hospital physiotherapy programme followed by two weeks of six home physiotherapy visits. The exercise programme included

isometric quadriceps exercises, ADLs training, ambulation with assistive devices and knee ROM exercises, and only commenced outpatient physiotherapy once their sutures or staples were removed (Stevens et al 2003). Recommendations to employ more progressive, high-intensity exercises in order to tackle lower limb muscle size should be performed two to three times a week, activation and strength deficits, functional mobility soon after surgery and aerobic training three times a week for 30 to 40 minutes have been published (Meier 2008). It is said to be that aerobic training should include walking on a flat surface with gradual increases in the incline as time goes and climbing up and down stairs, as well as higher-level aerobic exercises such as cycling, swimming, power walking and water aerobics, which reduces the force on the knee (Meier 2008).

The OKS is a validated, joint specific, PROM used to assess the outcome of TKA (Clement et al 2014 and Williams et al 2013). Although most studies use this PROM to assess outcomes in the long term, a study conducted by Boniforti et al (2014), showed that six weeks after surgery, the OKS had decreased below 30 points as compared to the pre-operative score of above 40 points. Recovery after TKA commences from six weeks and can take more than a year, and is said to be too soon to assess the outcome but signs of recovery are seen from the early weeks after surgery (Boniforti et al 2014).

2.7 Factors influencing functional outcomes and QoL

Reduced pain and function are among the most important predictors of improved QoL following TKA (da Silva 2014 and Judge 2012). While other adverse influences affecting QoL following TKA were obesity, advanced age, comorbidities, ongoing of pain following surgery and long waiting times for the surgery (da Silva 2014), all problems that are identifiable in the South African population.

Judge (2012) noted that those living in poorer areas had poorer outcomes than people living in wealthier areas and that pre-operative anxiety and depression yielded worse pain outcomes post-operatively.

Desmeules et al (2013) suggested that patients who were married or living in common law partnerships tend to have better functional outcomes and QoL as a result of the

coping skills provided by the spouse in comparison to those who were widowed, separated, divorced or single. It was also reported, in the same study, those who were employed were shown to have better functional outcomes and QoL six months following TKA. However, Kiefer (2011), reported that there was no difference in functional outcomes and QoL between patients who were married or living with someone and those who lived alone. This could be attributed to the social support from other family members, friend or neighbours (Papakostidou et al 2012).

3. CHAPTER THREE: METHODOLOGY

3.1 Study design

A single blinded randomised controlled trial.

A randomised controlled trial is the most rigid method of determining whether a cause-effect relation exists between an intervention and the outcome. This involved a random allocation to intervention groups. Both groups were treated identically except for the intervention that was tried. The researcher was screened to which group an individual is assigned, making the researcher blinded. The two groups were followed up to see if there were any differences in outcomes. The analysis of the results of the trial were used to assess the effectiveness of the intervention (Kendall 2003 and Sibbald 1998).

3.2 Study Setting

This study was conducted at the Chris Hani Baragwanath Academic Hospital, which is a tertiary hospital that services the greater Soweto and surrounding areas in the south of Johannesburg, in the province of Gauteng, South Africa.

3.3 Variables

3.3.1 Dependent variables:

- Short term functional outcomes
- ROM
- QS
- Days to achieve 0˚ QL
- LoS in hospital

3.3.2 Independent variable:

- The normal PRP (appendix 8) and EMS on the QM in addition to the normally practiced PRP.

3.4 Sample selection

3.4.1 Participants

Participants were selected from the patients admitted to the adult orthopaedic elective surgery wards (wards 47 and 48) at CHBAH, who required TKA due to OA during the period of September 2013 to August 2015. CHBAH is a tertiary hospital that services the greater Soweto and surrounding areas in the south of Johannesburg.

3.4.2 Sample size

The sample size was set using the outcome of knee ROM. The required sample size was 42 participants per group. This was set using 10° knee ROM as the detected change with the standard deviation of 10° (Wood 2010).

Alpha was set at 5%, the power was set at 80% with a confidence interval of ±3.08 and the dropout rate was set at 20%.

3.4.3 Inclusion Criteria

- Patients between the ages of 50 and 80 years
- Patients who required a TKA due to OA of the knee

3.4.4 Exclusion Criteria

- Patients who required unicompartmental knee arthroplasty
- Patients who required a revision of a previous TKA
- Patients who had neurovascular deficits
- Patients who were bed or wheelchair bound
- Patients who were unable to comprehend or follow instructions due to impaired cognitive function

- Patients who were deemed acutely medically unstable due to a high co-morbidity level by scoring 29 or more in the CIRS

3.4.5 Ethical consideration

Ethical clearance was applied for and granted by the Human Research Ethics Committee (HREC) of The University of Witswatersrand, Johannesburg, South Africa (appendix 1), before commencement of the research. Permission to conduct the study was obtained from the CHBAH Physiotherapy Department, CHBAH Orthopaedic Department, as well as, the CHBAH management (appendix 2 and 8).

All participants were given an information sheet (appendix 3) and written informed consent (appendix 4) was obtained from those participants included in the study. For those participants who do not read English, the study was verbally explained in English or in a language that was understood by the participant. Participants' anonymity was kept by allocating each participant a research number.
Participants were given a transportation fee, of R15, on the day of their follow up appointment regardless of whether or not they had other appointments on that day.

3.5 Outcome measures:

3.5.1 Range of Motion: Goniometer

Gogia et al (1987) describes goniometry as a widely practiced by physiotherapists as a way of objectively measuring the ROM of joints**.** Studies conducted by Gogia et al (1987) yielded results that show goniometric measurements of the knee joint are both highly reliable and valid when using bony landmarks such as the lateral malleolus, the head of the fibula, the lateral condyle of the femur and the greater trochanter. To ensure intra-rater reliability and validity, ROM was measured using the method described by Gogia et al (1987), who used Pearson product-moment correlation coefficients (r) and intra-class correlations coefficients (ICC) to show intra-rater reliability (r=0.98; ICC=0.99) and validity (r=0.97-0.98; ICC=0.98-0.99).

3.5.2 Muscle strength: Quadriceps Lag /Dynamometer

Although Koblbauer et al (2011) stated that isokinetic dynamometry for assessing muscle strength has been shown to be highly reliable tool and is being used as the golden standard, Gagnon et al (2005), showed that dynamometry is more accurate when used by trained physiotherapists on patients who have become familiar with the procedure over a period of time. Another measure of quadriceps strength is QL. A QL is described by Stillman (2004) as "an inability to actively move a joint to its passive limit". Stillman (2004) reported that a QL is often caused by an active deficiency of the QM. He also pointed out, in the same article, that an abnormal increase in muscle length (caused by trauma), neurological deficits, myopathy, disuse atrophy, and pain-induced or other arthrogenic muscle inhibition, are a few factors that influence QL. A study conducted by Gopal et al (2010), reported good intra-rater reliability (ICC=0.95 for one examiner and ICC=0.71 for the other), and moderate inter-rater reliability (ICC=0.67 for one test and ICC=0.66 for the other), using the QL component of the Knee Society Knee score when performed by experienced physiotherapists. In the current study, both, measuring the QL with a goniometer and the QMS with a dynamometer, was adopted.

3.5.3 Oxford Knee Score (OKS)

The OKS was developed by Dawson et al in 1998, to be a practically useful and time efficient tool. The OKS is made up a 12-part self-administered questionnaire on ADLs which was created to measure functional outcomes and pain following TKA beyond 6 weeks (Whitehouse et al 2005). The OKS has been proved to have good validity ($p=0.51$ and 0.41, respectively when compared against other tools), reliability (Cronbach's alpha of 0.896) and sensitivity to clinically significant changes over time, in patients following TKA in different countries (Xie et al 2011, Dawson et al 1998) (appendix 7).

3.5.4 Iowa Level of Assistance (ILOA) Scale

The ILOA Scale was first described by Shields et al in 1995. It was developed for use specifically on patients following joint replacement surgery (Oldmeadow et al 2002).

Shields et al (1995), also showed the ILOA scale to be reliable using the Kappa (K) statistic showing good intra-rater reliability (K=0.79-0.90) and moderate inter-rater reliability (K=0.48-0.78) and highly valid (r=-0.98 when compared to Harris Hip Rating Score) and responsive in a clinical setting. This scale is a measure of short-term functional ability before six weeks, which specifically rates five tasks such as transfers, mobility and stair climbing based on the amount of assistance or supervision required by the patient and the assistive devices being used (Oldmeadow et al 2002*).* A previous study conducted at CHBAH by Lally (2007) showed that this tool proved to be just as reliable, valid and responsive when performed in the acute phase following TKA. Lally (2007), in the same study, deduced that the ILOA Scale is not precise enough to be used at six weeks post TKA because it does not accommodate for higher functional activities (appendix 5).

3.6 Procedure

3.6.1 Consent

Patients who met the inclusion criteria were asked to sign an informed consent form stating the purpose and terms of the study (appendix 3 and 5).

3.6.2 Allocation of patients

Patients were randomly allocated, by manually picking, either the experimental or control group. Patients were required to pick a sealed envelope containing either the number one or the number two. Patients who selected the number one were included in the experimental group, whereas the patients who selected the number two were to be part of the control group.

3.6.3 Pilot study

A pilot study was conducted to ensure the researcher and one research assistant, a qualified physiotherapist, had adequate training on how to use the outcome measures and treatment equipment appropriately. The research assistant was trained on the use of the outcomes measures in order to be fimliarised with the research but was not involved in data collection at any point during the study. The physiotherapist who was

involved in the pilot study was not involved in the main study procedure. The main study procedure was not changed in any way following the pilot study.

3.6.4 Treatment procedure

All patients participating in this study were treated in accordance to the normal PRP (appendix 8). The participants in the experimental group received EMS stimulation over and above the normal practiced PRP (appendix 8). All treatments were carried out by a qualified physiotherapist employed at CHBAH. The researcher remained blinded to the treatment received by each participant. This involved five different physiotherapists carrying out the treatment. All the physiotherapists on the rotation were trained on carrying out the treatment. Patients were seen daily until discharge, which included weekends. Both groups received treatment in accordance to the normal PRP (appendix 8) whilst the experimental group received the additional EMS.

The experimental group started receiving EMS 48 hours post-surgery as described by Stevens-Lapsley et al (2012). Self-adherent, flexible 50x130mm rectangular electrodes were placed on the distal medial and proximal lateral portions of the anterior thigh and marked to ensure regularity of application (Stevens-Lapsley et al 2012).
When using NMES, the size of electrode is important because it has a direct impact on the density of the current. Small electrodes cause an increase in the current density, which may result in painful stimulation before reaching an effective muscle contraction that allows for muscle strengthening. Choosing the appropriate electrode size was therefore crucial for comfortable stimulation, and placement of the electrode over the motor point of the muscle decreases the current threshold needed (Stevens-Lapsley et al 2012). In the current study, large, rectangular electrodes were used to maximize tolerance to treatment.

The Odstock Dropped Foot Stimulator (Model ODFS- Pace V1.0), manufactured in the United Kingdom for Odstock Medical Limited, was used in this study. The machine will be used on the exercise stimulation mode, which in the Odstock Dropped Foot Stimulator user guide recommended this setting for muscle strengthening. This user

guide also suggested that EMS is to be started with short treatment sessions, therefore for the purpose of this study EMS was administered on the experimental group twice a day for 10 minutes until discharge. The patients were seated at approximately 45 degrees of trunk flexion to decrease any opposition by hamstring muscle tension (Stillman 2004). The patients were asked to actively straighten their knee while EMS device was turned on and set with the parameters, indicated in table 3.1, as stipulated in the user guide.

The parameter settings for the device are summarized in Table 3.1.

Table 3.1 Parameter settings

Parameter	**Setting ***
Current	10mA
Rising ramp	500ms
Falling ramp	500ms
Output waveform	Asymmetrical biphasic
Frequency	40Hz

*Settings taken from the Odstock Dropped Foot Stimulator user guide

The Odstock Dropped Foot Stimulator parameter settings used during the study procedure are indicated and summarised in table 3.1.

On discharge, all patients were given a home exercise programme. this during which they are expected to perform ten repetitions of each exercise thrice daily for six weeks until their follow up appointments. This programme comprised of circulatory ankle pumps, isometric quadriceps contractions, inner-range and through-range quadriceps drills, active and active-assisted heel-slides in supine and sitting, and SLRs.

3.6.5 Data collection

All pre-operative data, consisting of the Cumulative Illness Rating Scale (CIRS), ROM, QL, MS and OKS, were all collected on admission or the morning prior to the surgery by the researcher (table 3.2). The researcher, independently, collected all post-operative

data at the end of each day, which comprised of ROM, QL and the ILOA scale, as indicated on the table 3.2. Data at the six-week follow up was collected by the researcher during scheduled appointments, this data included ROM, QL, MS and OKS. All data collected was recorded on a patient data collection sheet (appendix 9). The researcher was blinded as to which group the participants are in to prevent bias.

3.6.5.1 Cumulative Illness Rating Scale

The CIRS was as first developed by Linn et al in 1968 and was later described and modified, by Miller et al in 1992, as a practical, reliable and quantitative tool for scoring the burden of chronic illness. The CIRS is a 14-item questionnaire that looks at impairments of multiple systems and organs, allowing one to gauge the medical stability for the purpose of this study. The higher the score the more medically ill a patient is with the minimum score of 14/70 and maximum score of 70/70.

The CIRS was administered by the researcher on admission to determine whether or not the patient is acutely medically stable to be able to participate in the study. Patients scoring more than 29/70 were excluded from this study (appendix 6).

3.6.5.2 Oxford Knee Score (OKS)

The OKS, a 12-item questionnaire based on the ease or difficulty of performing ADL, was filled in by the participants who were included in this study. A maximum score of 60 is attained if participants have great difficulties or are unable to perform ADLs. A minimum score of 12 is attained if participants have no difficulties performing ADLs. Scores of 0-19 indicate poor ability to perform ADLs, scores of 20-29 indicate moderated ability to perform ADLs, while scores of 30-39 indicate good ability to perform ADLs and scores of 40-48 indicate excellent ability to perform ADLs. The nursing staff and the researcher was available to assist those participants who had difficulty reading or understanding the questionnaire, as the questionnaire will be in English only (appendix 7).

3.6.5.3 Range of Motion: Goniometer

A standard plastic goniometer was used. Patients were positioned in a functional sitting position and the bony landmarks, the greater trochanter, the lateral condyle of the femur, the head of the fibula, and the lateral malleolus were used to align the goniometer during the measurement of ROM as described by Gogia et al (1987). Gogia et al (1987) suggested that the stationary arm of the goniometer be positioned parallel to the shaft of the femur along the imaginary line extending from the greater trochanter of the femur to the lateral condyle of the femur. Gogia (1987) stated the moveable arm should be positioned parallel to the shaft of the fibula in line with the head of the fibula and the lateral malleolus with the axis of the goniometer being placed on the lateral condyle of the femur. ROM was measured in degrees (˚) as calibrated on a standard plastic goniometer.

3.6.5.4 Muscle Strength: Quadriceps Lag /Dynamometer

The QL was measured in the same fashion as described by Gogia et al (1987) for measuring knee ROM. The patients were seated at approximately 45 degrees of trunk flexion to decrease any opposition by hamstring muscle tension (Stillman 2004). The patient was asked to actively straighten their knee as much as they can without any discomfort and this range was recorded in the patients' information sheet. The passive limit of knee extension was determined by the researcher or research assistant straightening the relaxed knee with a hand behind the heel until the patients' thigh is just lifted of the chair (Stillman 2004), and this range was recorded in the patients' information sheet. The difference between the passive and active ranges determined the QL in degrees (˚) as calibrated on a standard plastic goniometer.

Quadriceps muscle strength was measured using the Micro FET2 hand held dynamometer, manufactured by Hoggan Health Industries, West Jordon. The transducer was placed on the anterior surface of the lower leg, proximal to the ankle, as stipulated in the Micro FET2 user guide. The Micro FET2 is calibrated in kilogram force (kgf) and therefore the QM MS will be measured as such.

3.6.5.5 Iowa Level of Assistance (ILOA) Scale

A standard plastic tape measure was used to measure the distance the patients needed to ambulate. The time taken to carry out these tasks was determined using the stopwatch on a cellular phone (appendix 5). The procedure is as follows:

- Supine to sitting on the edge of the bed

Patients were asked to sit up in bed and transfer to sit over the edge of the bed with verbal cues, and assistance was provided when required.

- Sitting on the edge of the bed to standing

From being seated over the edge of the bed, patients were then asked to stand up from that position with verbal cues, and assistance was provided as required by the patient.

- Walking 4.57m

A standard plastic tape measure was used to measure the distance the patients needed to ambulate, the patients were then asked to walk this distance with an appropriate assistive device, as per the researcher's discretion, and assistance was provided as required by the patient. Patients were instructed to move the assistive device forward first, followed by the operated limb and lastly the un-operated limb.

- Climbing up and down 3 steps

Standard wooden or metal rehabilitation steps, with side rails were used. The patients were then asked to climb up and down the steps with an appropriate assistive device, as per the researcher's discretion, and assistance was provided as required by the patient. Patients were instructed climb up the steps by placing the un-operated limb step above, followed by the operated limb and lastly assistive device. Patients were then to climb down the steps by placing the assistive device step below, followed by the operated limb and lastly the un-operated limb.

- Walking speed over 13.4m

The patients were then asked to walk this distance, at a comfortable pace, with an appropriate assistive device, as per the researcher's discretion, with the same instruction as given for walking 4.75. Assistance was provided as required by the patient. The time taken to carry out this task was determined using the stopwatch on a cellular phone.

A minimum score of zero was attained if the patient is independent is all five tasks (i.e. level of assistance score=0) and did not require any assistive devices for the four tasks which involved standing or mobilising (i.e. assistive device score=0), the total score = (5×0) for the level of assistance score + (4×0) for assistive device score. Maximum score of 50 was attained if the patient is unable to attempt any of the five tasks because of medical reasons or reasons of safety (i.e. level of assistance score=6) and the assistive device for the four tasks which involved standing or mobilising would have been a frame (i.e. assistive device score=5), the total score = (5×6) for the level of assistance score + (4×5) for assistive device score.

3.6.5.6 Length of Stay in Hospital

The LoS was collected from the data collection sheet, counting from the first post-operative day until the day of discharge (appendix 9).

The outline of the procedure of the study is summarized in Table 3.2

Table 3.2 Procedure of the study

	CIRS	ROM	QL	MS with Dynamometer	OKS	ILOA scale
Pre-op	√	√	√	√	√	
Post op daily		√	√			√
6 weeks		√	√	√	√	

All tests, scales and scores carried out during the study procedure are indicated and summarised in table 3.2.

3.7 Statistical Analysis

Descriptive analysis was carried out and presented in frequency tables and graphs. A non-parametric Mann-Whitney test was used for independent variables, and for the variables measured as scores. All categorical data was tested using the Fishers Exact Test. Data collected from participants who withdraw at any time during the study was used as per protocol analysis. The data was analysed using Stata statistical software (version 14). Significance was set at $p \leq 0.05$.

4. CHAPTER FOUR- RESULTS

4.1 Introduction

Participants who met the inclusion and exclusion criteria consented to participate in this study. The demise of a participant in the control group, due to medical complications whilst in hospital, was excluded from this study as no measurements were obtained on discharge. The loss to follow up in both groups were particularly high at 38.1% (n=16 from a total of n=42) and 36.6% (n=15 from a total of n=41) for groups one (experimental) and two (control) respectively.

4.2 Demographic data of participants

The demographics of the study sample are summarized in Table 4.1.

Table 4.1 Demographics of study sample (n=52)

	Group 1(experimental) n=26	**Group 2 (control) n=26**	**p- Value**
Age median (p25-p75)	64 (59-70)	64 (60-71)	0.93*
Gender n (%) Female	25 (96.2%)	23 (88.5%)	0.30#

Male	1 (3.8%)	3 (11.5%)	
Side of surgery n (%) Left Right	 12 (46.5%) 14 (53.5%)	 12 (46.5%) 14 (53.5%)	1[#]
Day of surgery n (%) Monday Wednesday Friday	 9 (34.6%) 8(30.8%) 9 (34.6%)	 5 (19.2%) 9 (34.6%) 12 (46.2%)	0.25[#]

* Mann-Whitney test

[#] Fishers Exact test

Table 4.1 (page 37) shows no significant difference between the two groups with regard to the demographics of the participants at base line.

4.3 Clinical profile of participants

The clinical profiles of the study sample are summarized in Table 4.2.

Table 4.2 Clinical profile of study sample n=52

	Group 1(experimental) n=26	**Group 2 (control) n=26**	**p- Value**
CIRS median (p25-p75)	18.5(18-20)	18(18-20)	0.76*
Diabetes n (%) Yes No	 8 (30.8%) 18 (69.2%)	 2 (7.7%) 24 (92.3%)	**0.04[#]**
Thyroid n (%) Yes No	 0 (0%) 26 (100%)	 1 (3.8%) 25 (96.2%)	0.32[#]
Hypertension n (%) Yes No	 24 (92.3%) 2 (7.7%)	 22 (84.6%) 4 (15.4%)	0.39[#]

* Mann-Whitney test

[#] Fishers Exact test

Table 4.2 shows that more participants in the experimental group had diabetes (p=0.04). Analysis of the clinical profiles in table 4.2 showed hypertension is the most common comorbidity in this study (n=52).

4.4 Outcomes

All pre-operative, post-operative on discharge and six- week follow-up data for the study sample are summarized in Tables 4.3, 4.4 and 4.5.

The pre-operative outcome measures of the study sample are summarized in Table 4.3.

Table 4.3 Outcome measures pre-operatively of study sample n=52

Outcome measures	Group 1 (experimental) n=26 [‡]	Group 2 (control) n=26 [‡]	p- Value
ROM active flexion in degrees	102 (92-110)	101 (97-105)	0.91*
ROM passive flexion in degrees	106.5 (94-113)	105.5 (98-110)	0.89*
Quadriceps lag in degrees	0 (0-0)	0 (0-3)	0.5*
Muscle strength in kilogram force	3.8 (5-6.2)	4.95 (3.8-6.2)	0.31*
OKS	45.5 (38-49)	44 (39-47)	0.55*

* Mann-Whitney test

[‡] Median values taken from the 25th and 75th percentiles.

Table 4.3 shows that there was no significant difference in pre-operative outcome measures between the two groups.

The post-operative outcome measures on discharge of the study sample are summarized in Table 4.4.

Table 4.4 Outcome measures on discharge of study sample n=52

Outcome measures	Group 1 (experimental) n=26 ‡	Group 2 (control) n=26 ‡	p- Value
LoS in hospital	6 (5-7)	6 (5.5-7)	0.38*
ROM active flexion in degrees	91 (87-93)	91 (87-93)	0.80*
ROM passive flexion in degrees	93 (91-96)	93 (91-96)	0.87*
Quadriceps lag in degrees	0 (0-0)	0 (0-5)	**0.0019***
Days to reach 90° active flexion	4(4-6)	2.5 (2-4)	**<0.001***
Days to reach 90° passive flexion	4(5-6)	2 (2-2)	**<0.001***
Days to reach 0° extension	3 (5-5)	2 (2-4)	**0.0012***

ILOA Score	24 (20-26)	22 (20-24)	0.38*
Walking aid on discharge n (%) Elbow crutches Walking frame Axillary crutches	 23 (88.5%) 3 (11.5%) 0 (0%)	 23 (88.5%) 2 (7.7%) 1 (3.8%)	 1*

* Mann-Whitney test

‡ Median values taken from the 25th and 75th percentiles.

Table 4.4 shows the experimental group yielded a significantly better outcome than the control group with regard to the QL at discharge (p= 0.0019). There is also a significant difference between the experimental and control groups with regard to days to reach 90° active and passive flexion (p<0.001), and 0° extension ROM (p=0.0012). There was no significant clinical difference in LoS in hospital between the two groups with a median of 6 (5-7) in the experimental group and 6 (5.5-7) in the control group (p=0.38).

In table 4.4 (page 40), it can be seen that majority of the participants, in groups one and two respectively, were discharged with elbow crutches. Only 3.8% of control group were discharged with axillary crutches in comparison to the 0% in the experimental group.

The outcome measures at six weeks of the study sample are summarized in Table 4.5.

Table 4.5 Outcome measures at six weeks of study sample (n=52)

Outcome measures	**Group 1(experimental) n=26** ‡	**Group 2 (control) n=26** ‡	**p- Value**
ROM active flexion in degrees	93 (92-98)	95 (92-103)	0.61*
ROM passive flexion in degrees	96 (93-105)	99.5 (94-105)	0.63*
Quadriceps lag in degrees **	0 (0-0)	0 (0-0)	**0.04***

Muscle strength in kilogram force	6 (4.3-8.1)	5.75 (4.7-8.2)	0.71*
OKS	25.5 (22-28)	25.5 (21-29)	0.98*

* Mann-Whitney test (non-parametric variables)

‡ Median values taken from the 25th and 75th percentiles.

** This is explained by the difference in the means and more specifically the minimum and maximum values of the two groups (appendix 11).

The only parameter that was significantly different between the groups at six weeks, in table 4.5, was quadriceps lag (p=0.04). Although both groups had the same median values, the experimental group had a minimum and maximum value of 0°, whereas the control group had a minimum value of 0° and a maximum value of 20° (appendix 11).

4.4.1 Short term functional outcomes

The Oxford Knee Score was used to determine the functional ability of the participants pre-operatively and at six weeks. Both groups showed vast improvement in the OKS at 6 weeks post-surgery. As shown in table 4.5 (page 41), there was no significant difference between the groups at six weeks post-surgery.

The Iowa Level of Assistance Scale was used to determine the functional ability of the participants on discharge. The data revealed no significant difference between the two groups with a median of 24 (20-26) in the experimental group and 22 (20-24) in the control group (p=0.38), as seen in table 4.4 (page 40).

4.4.2 Range of motion of knee flexion

Table 4.3 (page 39) revealed no significant difference in active ROM between the two groups pre-operatively with a median of 102° (92°-110°) in the experimental group and 101° (97°-105°) in the control group (p=0.91) (table 4.3) (page 39). On discharge, table 4.3 (page 39), also showed no significant difference in active ROM between the two groups with a median of 91° (87-93) in both groups (p=0.80) (table 4.4) (page 40). At six weeks, with a median of 93° (92-98) in the experimental group and 95° (92°-103°) in

the control group (p=0.61), as seen in table 4.5 (page 41), showed no significant difference, either.

The data also showed no significant difference in passive ROM between the two groups pre-operatively with a median of 106.5° (94°-113°) in the experimental group and 105.5° (98°-110°) in the control group (p=0.89) (table 4.3) (page 39). On discharge, there was no significant difference with a median of 93° (91°-96°) in both groups (p=0.87) (table 4.5) (page 41). At six weeks there was also no significant difference noted, with a median of 96° (93°-105°) in the experimental group and 99.5° (94°-105°) in the control group (p=0.63) (table 4.5) (page 41).

4.4.3 Quadriceps lag

The data in table 4.3 (page 39) revealed no significant difference in QL between the two groups pre-operatively with a median of 0° (0°-0°) in the experimental group and 0° (0°-3°) in the control group (p=0.5). However, table 4.4 (page 40) showed the experimental group, who had a median of 0° (0°-0°) QL, yielded a better outcome on discharge, than the control group who had a median of 0° (0°-5°) which is very significant (p= 0.0019). There was also a significant difference in QL at six weeks, with a median of 0° (0°-0°) in the experimental group and 0° (0°-0°) in the control group (p=0.04), as seen in table 4.5 (page 41).

4.4.4 Muscle strength

The data revealed no significant clinical difference in QMS between the two groups pre-operatively with a median of 3.8kgf (5 kgf-6.2 kgf) in the experimental group and 4.95kgf (3.8 kgf-6.2 kgf) in the control group (p=0.31), and at six weeks with a median of 6kgf (4.3 kgf-8.1 kgf) in the experimental group and 5.75kgf (4.7 kgf-8.2 kgf) in the control group (p=0.71), as seen in tables 4.3 (page 39) and 4.5 (page 41).

4.5 Conclusion

The addition of EMS on the QM to the practiced protocol did not significantly influence the short-term functional outcomes post TKA and did not significantly reduce the LoS in hospital.

There was no difference in the short term functional outcomes at six weeks in patients who received EMS on the QM in addition to the standard practiced PRP post TKA to that in patients who received the standard PRP only.
There was no difference in ROM of knee flexion, QS and LoS, in patients who received EMS on the QM in addition to the standard practiced PRP post TKA and to that in patients who received the PRP only.

There was, however, a difference in QL in patients who received EMS on the QM in addition to the standard practiced PRP post TKA, to that in patients who received the PRP only, is particularly evident at six weeks. From the results, it can also be noted the control group reached their post-operative ROM milestones sooner than the experimental group, who EMS and the standard practiced PRP post TKA.

5. CHAPTER FIVE: DISCUSSION

5.1 Introduction

This study aimed to identify if the addition of EMS on the QM to the practiced protocol at Chris Hani Baragwanath Academic Hospital, a high volume institution, would significantly influence the short term functional outcomes post TKA at six weeks and significantly reduce the LoS in hospital. In this study, the addition of EMS on the QM to the normal PRP post TKA appears to have no clinically significant influence on short-term functional outcomes and hospital stay. However, the control group who received the PRP only had a greater QL on discharge and at six weeks compared to patients in the experimental group who received EMS on the QM in addition to the standard practiced PRP post TKA.

5.2 Short term functional outcomes

Osteoarthritis is a chronic gradually progressing degenerative disorder (Solomon et al 2005, Litwic et al 2013) resulting in a debilitating condition that leads to pain, joint failure, disability (Litwic et al 2013), and weakness of surrounding muscles (Litwic et al 2013, Hutton 1989). At CHBAH, patients wait up to seven years before having an elective arthroplasty procedure and often present with severe knee OA with substantial deformities which may have affected outcomes. In studies conducted by Marmon and Synder-Mackler (2014 B) and Stevens et al (2004), yielded significant improvements in QMS and functional activities regardless of the pre-operative status. These studies, however, do not describe the severity of the knee OA prior to surgery or how long

patients waited for surgery. In keeping with Stevens-Lapsley's et al (2012) study, six-week post-operative progressive strength training of the lower limb, with increases in resistance, and ROM exercise programme, was given to patients in the current study, as well as using NMES, but only for the duration of admission.

5.2.1 The Oxford Knee Score

In the current study, there was no significant difference between the two groups at six weeks following surgery. In keeping with the study conducted by Boniforti et al (2014), the

current study showed that six weeks after surgery, the OKS had decreased below 30 points as compared to the pre-operative score of above 40 points, which is evident in table 4.3 (page 39). However, being an observational study, Boniforti et al (2014), had no added interventions, but merely looked at patients' satisfaction and functional outcomes following TKA at six weeks. Although showing vast improvements, it is in the opinion of Boniforti et al (2014) that recovery begins six weeks after surgery, and is therefore too soon to evaluate the outcomes of joint arthroplasty surgery. This is why studies with NMES using the OKS may be limited.

5.2.2 The Iowa Level of Assistance Scale

Literature on use of the ILOA scale in the context of the current study setting is limited. The difference in scores between the two groups was insignificant (table 4.3) (page 39) possibly due to the discharge criterion used at CHBAH. This discharge criterion stipulates the patient must have at least 90˚ of knee flexion and be able to do a straight leg raise (SLR) without a quadriceps lag (QL), get in and out of bed independently, stand up from sitting and mobilise independently with a walking aid on a flat surface and navigate steps (if indicated for the patient) on discharge (appendix 8). This scale is based on the patients' ability to perform these functional tasks with or without assistance. In the current study setting, the ILOA scale was found not to be a very sensitive tool to detect change between the groups. Because of these discharge criterion patients were expected to perform these tasks with little or no assistance in order to be discharged.

5.3 Range of motion of knee flexion

Similar to the study by Stevens-Lapsley et al in 2012, the introduction of EMS started 48 hours post-surgery but was only performed twice a day for ten minutes until discharge, opposed to twice a day over a period of six weeks. The insignificant results from this study could be owed to the assumption that the NMES works to strengthen the QM and not influence knee flexion ROM and hamstring activation or strength. Electrically stimulated muscle contractions allow for more the significant activation of the larger type II muscle fibres magnifying the production of force as compared to the smaller type I muscle fibres (Stevens-Lapsley et al 2012) which could be over stimulating the QM, explaining the outcome of this result.

Stevens-Lapsley et al (2012) mainly focused on results at three and a half, and 52 weeks post-operatively. Although NMES was administered for six weeks, they saw a tremendous improvement with early NMES and both groups seemed to have equivalent outcomes after three weeks. At six weeks Stevens-Lapsley et al (2012), reported 107.3° (10.6) (n=31) in the active knee flexion experimental group and 103.8° (12.1) (n=26) active knee flexion in the control group which higher than the values yielded in this study as seen in table 4.5 (page 41). In the current study, it can be noted that both groups yielded better outcomes at six weeks compared to pre-operatively and on discharge.

Again, this could be due to the post-operative protocol which differed greatly from the one used in this study, which saw NMES being performed twice a day for ten minutes until discharge, whereas Stevens-Lapsley et al (2012) continued for six weeks post-operatively.

Participants in Stevens-Lapsley's et al (2012) had better pre-operative active knee flexion ranges compared to those in the current study. This could be as a result of the severe disease progression due to the seven-year waiting list at CHBAH although it is unclear in Stevens-Lapsley's et al (2012) study how severe the knee OA was at the time preceding the TKA. Stevens-Lapsley's et al (2012) study showed active knee ROM

post-operatively does in fact depend on active ROM pre-operatively and therefore, there may be a need to introduce a prehabilitation programme.

5.4 Quadriceps lag

There was a significant difference in QL on discharge and at six weeks (tables 4.4 (page 40) and 4.5 (page 41)). The experimental group fared better and yielded similar results to the study by Stevens et al (2004) and Stevens-Lapsley et al, 2012. Similar to the study by Stevens-Lapsley et al in 2012, the introduction of EMS started 48 hours post-surgery but was conducted for a shorter period in the current study.

Stevens et al (2004), looked at QMS in patients with bilateral TKAs, and concluded that when NMES is added to a voluntary exercise programme, shortfalls in QMS and activation recovered rapidly after TKA. Intervention in that study only commenced after the surgical staples were removed between three to four weeks after surgery. Therapy sessions continued for six weeks including three sessions a week for a total of 18 sessions.

When compared to the results of Stevens-Lapsley et al, 2012, at six weeks, the participants of the current study had better active knee extension on discharge and six weeks in both groups. This could be due to the discharge criteria used at CHBAH, which states the patient needs to have a no QL on discharge. Therefore, the exercise programme used at CHBAH focuses on QM strengthening exercises, performed once daily under physiotherapist supervision and the patients are expected to do it twice more daily on their own.

5.5 Muscle strength

When looking at the results of QMS in this study in tables 4.3 (page 39) and 4.5 (page 41), it is noted there is no significant difference between the two groups but there is a difference between the pre-operative and six weeks follow up results, which was expected. The usual practice at CHBAH is, that on discharge, all patients received a home exercise programme, during which they are expected to perform ten repetitions of

each exercise thrice daily for six weeks until their follow up appointments. This programme comprised knee extension and flexion range, circulatory and MS exercises. These results are not comparable to those of study, whose patients received six sessions at home for a duration of two weeks and then a further ten to twelve outpatient sessions, which is abundantly more than the patients in the current study. The practices of Stevens-Lapsley's et al (2012) is not practical in the current study setting due the high patient volume and shortage of physiotherapists which does not allow for such. In Stevens-Lapsley's el at (2012) study, participants in the experimental group received a pre-operative testing session for the stimulation dose to be tested and patients were allowed used the NMES device at home before the TKA in order for patients to familiarise themselves with it. It was not specified how often or long prior to surgery the NMES device was used. This could have contributed to the favourable results of that study. The testers in that study were not blinded due to the constraints on resources of hiring more testers. That was not the practice in the current study for two reasons, the researcher was blinded throughout the study and there was no pre-operative stimulation testing due to time, budget and staff constraints.

Stevens-Lapsley et al (2012) and Stevens et al (2004) both noted a marked improvement at three weeks. Stevens-Lapsley et al (2012) also stated that three weeks of NMES may just be enough for sustained results.

5.6 Length of stay in hospital

Although there was no clinically significant difference in LoS in hospital between the two groups. However, there was a marked reduction in LoS (table 4.4) (page 40) when compared with the average LoS in hospital being 9.67 days during the period of January to August 2012, to 6.52 days for the duration of the study. This was an average reduction of 3.15 days. This is a far better result than of those shown in the systematic review conducted by Guerra et al (2015), who saw a reduction of 1.8 days with early mobilisation which consisted of sitting out of bed within 24 hours and walking within 48 hours following arthroplasty surgery. This is routinely practiced at CHBAH. The significant reduction in LoS, compared to previous statistics, can be owed to the

introduction of physiotherapy rehabilitation over the weekends for both groups, which was, and is not the common practice at CHBAH.

In Stevens-Lapsley's et al (2012) study it is stated that inpatient rehabilitation consisted of twice daily treatment sessions for three days but it not clear if the patients remained in hospital longer than three days.

5.7 Days to reach milestones

Literature on how soon patients receiving NMES reached their post-operative milestones is extremely limited and it is therefore difficult to explain these results. The current study showed the control group reached their post-operative milestones far sooner and had a more progressive recovery (chapter 4) than the experimental group, which showed to be very significant in the current study (table 4.4) (page 40). This could be owed to the assumption that the NMES works to strengthen the QM and not influence knee flexion ROM and hamstring activation or strength (section 5.3).

5.8 Gender differences

The addition of EMS on the QM to the practiced protocol did not significantly influence the short-term functional outcomes post TKA but it did see an expected improvement in the OKS when compared to baseline findings. The males in the experimental group did do better with ILOA scale on discharge but showed no difference at six weeks. Males being the gender minority of this study showed to have no bearing on the outcome of this study.

The addition of EMS showed no effect on QMS or ROM of knee flexion but it did increase the knee extension range, and decrease the QL, at discharge and was maintained at the six-week follow up.

Table 4.1 (page 37) showed that 92% of the entire study population consisted of females. This is in keeping with global norms which dictates more women than men are affected by OA (Woolf and Pfleger 2003). Studies suggest that this phenomenon maybe

caused by a post-menopausal oestrogen deficiency (Woolf and Pfleger 2003). Even though there was a large gender difference, where there were more female participants in the study, it did not influence the outcome of this study. Generally, in keeping with Stevens-Lapsley et al (2012), the current saw no differences between the groups in terms of gender.

5.9 Feasibility of EMS

The feasibility of implementing EMS at CHBAH can be debated due to the insignificant findings of the study. The institution is under major budget, staff and time constraints. In the study, EMS was administered for ten minutes, twice a day, which excludes the time involved in applying the electrodes and setting the stimulator, and carrying out the usual PRP. This process usually took anything from 40 minutes to an hour, daily, for each patient. In this institution, it is not practical in an eight-hour work day for one therapist to carry out. Without the application of EMS, the normal PRP usually takes about twenty to thirty minutes, allowing the therapist to, theoretically, see double the number of patients in the time it takes to apply EMS.

A new pair of electrodes was used on each patient, and was discarded on discharge, to prevent contamination and the spread of infection. More than a hundred TKAs were performed last year at CHBAH, with figures steadily climbing year on year, it will not be cost effective to run the stimulator on that scale. This is not taking into account the cost of batteries to run the stimulator, electrodes or the maintenance involved.

Having an extended EMS programme into discharge, as performed by Stevens-Lapsley et al (2012), may have yielded different outcomes in the current study. However, self-administered home-based application of EMS will not be a viable or feasible option because of the high cost of the machine and electrodes. Administering EMS on an outpatient basis will also not be a feasible option either for two factors. One, the high transportation cost may further increase the non-attendance rate and two, the already thinly stretched outpatient staff may not have accommodation to administer EMS.

5.10 Loss to follow up

The loss to follow up rate is higher than the 33% found in the study by Asvat (2011), during February and March 2010, who looked at patients' adherence to attending physiotherapy appointments at CHBAH. This was a decline from the 38% in an audit conducted in 2009 (Asvat 2011), but in keeping with the loss to follow up rate of this study. Asvat (2011) sited issues with transport and patients forgetting their appointments to be the biggest contributing factors for non-attendance, which more than likely to explain the high loss to follow up rate.

5.11 Conclusion

The addition of EMS on the QM following TKA has shown to be ineffective in the current study with both groups having similar outcomes, but also showing the control group had a swifter recovery compared to the experimental group (chapter 4). The major influencing factor has been pinned to the shorter application time of EMS compared to the literature, but logistically, meeting global trends will not be feasible in the current study setting.

The high rate of loss to follow up, is another factor greatly impacting the outcome of the current study, making the sample size smaller, therefore limiting the study.

Demographics, such as age, gender, side of surgery, day of surgery and comorbidities, have been proved to have no bearing on the outcome and outcome measures of the study.

6. CHAPTER SIX: CONCLUSION

6.1 Conclusion

The number of arthroplasty cases in South Africa is following the global trend and is seeing a steady annual increase. Having a standardised, cost effective and sustainable protocol to reduce the LoS in hospital is a desirable goal.

The introduction of EMS during the time of admission did not significantly reduce the LoS in hospital or influence functional outcomes. However, the introduction of physiotherapy rehabilitation over the weekend did however, see a significant reduction in LoS compared to previous statistics.

Although there were some significant findings in this study, for now, EMS should not be incorporated into the protocol currently being used at CHBAH. Further research, including analysis of the costs and logistics, would need to be conducted to justify the use of NMES in standard postoperative care. Thereby accepting the $Hypothesis_0$ which stated, the addition of EMS on the QM to the practiced protocol will not significantly influence the short term functional outcomes post TKA and will not significantly reduce the LoS in hospital.

6.2 Limitations

The prime limitation of this study is the high dropout rate and small sample size at follow up, which affects the results of the study making it impossible to generalize.

6.3 Recommendations

The addition of EMS, as practiced in the current study, is not recommended, but in conjunction with a more extended programme, possibly extending into the post-discharge phase, could warrant further research.

If extended protocols are implemented, follow ups at three and six months, should be performed to determine the long term effects of EMS in this population and to determine if the results of this study is maintained or rendered unchanged.

Further research looking at the effects of physiotherapy rehabilitation over the weekend should be conducted to determine if there is a significant reduction in LoS in hospital following arthroplasty procedures at CHBAH.

7. REFERENCES

Abramson, S.B., Attur, M. (2009) Developments in the scientific understanding of osteoarthritis, *Arthritis Research and Therapy*, 11(3): 227.

Ackerman, I.N., Hinman, K.L. (2004) Does pre-operative physiotherapy improve outcomes from lower limb joint replacement surgery? A systematic review. *The Australian Journal of Physiotherapy*, 50(1):25-30.

Alnahdi, A.H., Zeni, J.A., Snyder-Mackler, L. (2012) Muscle impairments in patients with knee osteoarthritis. *Sports Health: A Multidisciplinary Approach*, 4(4):284-92.

Ameye, L.G., Chee, W.S.S. (2006) Osteoarthritis and nutrition. From nutraceuticals to functional foods: a systematic review of the scientific evidence. *Arthritis Research and Therapy*, 8(4): R127.

Astephen, W. J.L., Dunbar, M.J., Hubley-Kozey, C.L. (2015) Knee joint biomechanics and neuromuscular control during gait before and after total knee arthroplasty are sex-specific. *The journal of arthroplasty*, 30(1):118-125.

Asvat, H. (2011) Adherence to attending appointments at Chris Hani Baragwanath Hospital outpatient physiotherapy department. *MSc Physiotherapy, University of the Witwatersrand, Johannesburg*.

Avramidis, K., Karachalios, T., Popotonasios, K., Sacorafas, D., Papathanasiades, A.A,

Malizos, K.N. (2011) Does Electric Stimulation of the Vastus Medialis Muscle Influence Rehabilitation After Total Knee Replacement? *Orthopaedics*, 34(3): 175.

Bannuru, R.R., Vaysbrot, E.E., Sullivan, M.C., McAlindon , T.E. (2014) Relative efficacy of hyaluronic acid in comparison with NSAIDs for knee osteoarthritis: a systematic review and meta-analysis. *Seminars in Arthritis and Rheumatism*, 43(5):593-599.

Bellamy, N. (2005) The WOMAC Knee and Hip Osteoarthritis Indices: development, validation, globalization and influence on the development of the AUSCAN Hand Osteoarthritis Indices. *Clinical and Experimental Rheumatology*, 23(5 Supplement 39): S148-53.

Bellamy, N., Campbell, J., Robinson, V., Gee, T., Bourne R., Wells, G. (2006) Intraarticular corticosteroid for treatment of osteoarthritis of the knee. *Cochrane Database of Systematic Reviews*, 19;(2):CD005328.

Bennell, K.L., Hinman, R.S. (2011) A review of the clinical evidence for exercise in osteoarthritis of the hip and knee. *Journal of Science and Medicine in Sport*, 14 (1): 4-9.

Boniforti, F., Macaione, A., Gagliardi, S., Giangrasso, F., DI Marzo, D., Giacco, F. (2014) Early assessment of patient perception of outcome in total knee replacement. *Joints, Official Journal of SIGASCOT (Italian Society of the Knee, Arthroscopy, Sports traumatology, Cartilage and Orthopaedic Technology),* 8;2(2):71-75.

Borus, T., Thornhill, T. (2008) Unicompartmental Knee Arthroplasty. *Journal of the American Academy of Orthopaedic Surgeons*, 16 (1): 9-18.

Buckwalter, J.A., Saltzman C., Brown, T. (2004) The impact of osteoarthritis: implications for research. *Clinical Orthopaedics and Related Research*, (427 Suppl): S6-15.

Cebrian, R., Lizaur, A., Marco L. (1997) Pre-operative Factors Influencing the Range of Movement After Total Knee Arthroplasty for Severe Osteoarthritis. *The Journal of Bone and Joint Surgery,* 79: 626-629.

Clement , N.D., MacDonald, D., A. H. R. W. Simpson, A. H. R. W. (2014) The minimal clinically important difference in the Oxford knee score and Short Form 12 score after total knee arthroplasty. *Knee Surgery, Sports Traumatology and Arthroscopy*, 22 (8): 1933-1939.

Deyle, G.D., Gill, N.W., Allison, S.C., Hando, B.R., Rochino, D.A. (2012) Knee OA: which patients are unlikely to benefit from manual PT and exercise? *The Journal of Family Practice,* 61(1):1-8.

Dandees, H.M. (2011) Evidence-based physiotherapeutic management for knee osteoarthritis: A knowledge translation study. *MSc Physiotherapy, Stellenbosch University, Stellenbosch.*

da Silva, R.R., Santos, A.A., de Sampaio Carvalho Júnior, J., Matos, M.A. (2014) Quality of life after total knee arthroplasty: systematic review. *Revista Brasileira de Ortopedi*, 19;49(5):520-527.

Desmeules, F., Dionne, C.E., Belzile, E.L., Bourbonnais, R., Champagne, F., Frémont, P. (2013) Determinants of pain, functional limitations and health-related quality of life six months after total knee arthroplasty: results from a prospective cohort study. *BioMED Centeral Sports Science, Medicine and Rehabilitation,* 28;5:2.

Farrokhi, S., O'Connell, M., Fitzgerald, G.K. (2015) Altered gait biomechanics and increased knee-specific impairments in patients with coexisting tibiofemoral and patellofemoral osteoarthritis. *Gait and Posture*, 41(1):81-85.

Felson, D.T., Lawrence, R.C., Dieppe, P.A., Hirsch, R., Helmick, C.G., Jordan, J.M.,

Kington, R.S., Lane, N.E., Nevit, M.C., Zhang, Y., Sowers, M.F., McAlindon, T., Spector, T.D., Poole, A.R., Yanovski, S.Z., Ateshian, G., Sharma, L., Buckwalter, J.A., Kenneth, D., Brandt, K.D., Fries, J.F. (2000) Osteoarthritis: New Insights. Part 1: The Disease and
Its Risk Factors. *Annals of Internal Medicine*, 133(8):635-646.

Fitzgerald, G.K., Piva, S.R., Irrgang, J.J., Bouzubar, F., Starz, T.W. (2004) Quadriceps activation failure as a moderator of the relationship between quadriceps strength and physical function in individuals with knee osteoarthritis. *Arthritis and Rheumatism (arthritis care and research)*, 51(1):40-48.

Gagnon, D., Nadeau, S., Gravel, D., Robert, J., Bélanger, D., Hilsenrath, M. (2005) Reliability and Validity of Static Knee Strength Measurements Obtained with a Chair-Fixed Dynamometer in Participants with Hip or Knee Arthroplasty. *Archives of Physical Medicine and Rehabilitation*, 86 (1): 1998-2008.

Garrett, B.R., Walters, J. (2010) Knee pain, swelling and stiffness after total knee replacement: a survey of South African knee surgeons. *South African Orthopaedic Journal,* 9 (2): 59-66.

Gogia, P.P., Braatz, J.H., Rose, S. J., Norton, B. J. (1987) Reliability and Validity of Goniometric Measurements at the Knee. *Journal of the American Physical Therapy Association*, 67 (2): 192-195.

Gopal S, Wood W, Myezwa H, Stewart A. (2010) Intra- and inter-rater reliability of the Knee Society Knee Score when used by two physiotherapists in patients post total knee arthroplasty. *South African Journal of Physiotherapy*, 66 (1): 21-25.

Greene, K.A.,Schurman, J.R. (2008) Quadriceps muscle function in primary total knee arthroplasty. *The Journal of Arthroplasty*, 23 (7):15-19.

Guerra, M.L., Singh, P.J., Taylor, N.F. (2015) Early mobilisation of patients who have had a hip or knee joint replacement reduces length of stay in hospital: a systematic review. *Clinical Rehabilitation*, 29(9):8448-54.

Hart, D.J., Spector, T.D. (1995) The classification and assessment of osteoarthritis. *Bailliere's Clinical Rheumatology*, 9(2):407-432.

Harwin, S.F. (2003) The medial parapatellar approach to the knee. *The Journal of Knee Surgery*, 16(1):43-47.

Horan, F.T. 2010 Joint Registries. *The Journal of Bone and Joint Surgery*, 92-B (6):749-750.

Hudon, C., Fortin, M., Soubhi, H. (2007) Abbreviated guidelines for scoring the Cumulative Illness Rating Scale (CIRS) in family practice. *Canada Journal of Clinical Epidemiology*, 60 (021): 212 e1-e3.

Hurley, M.V., Scott, D.L., Rees, J., Newham, D.J. (1997) Sensorimotor changes and functional performance in patients with knee osteoarthritis. *Annals of the Rheumatic Diseases*, 56(11):641-648.

Hutton, C.W. (1989) Osteoarthritis: the cause not result of joint failure? *Annals of the Rheumatic Diseases*, 48(11): 958–961.

Ishijima, M., Nakamura, .T, Shimizu, K., Hayashi, K., Kikuchi, H., Soen, S., Omori, G., Yamashita, T., Uchio, Y., Chiba, J., Ideno, Y., Kubota, M., Kurosawa, H., Kaneko, K. (2014) Intra-articular hyaluronic acid injection versus oral non-steroidal anti-inflammatory drug for the treatment of knee osteoarthritis: a multi-center, randomized, open-label, non-inferiority trial. *Arthritis Research and Therapy*, 21;16(1): R18.

Issa, R.I. and Griffin, T. M. (2012) Pathobiology of obesity and osteoarthritis: integrating biomechanics and inflammation. *Pathobiology of Aging & Age-related Diseases*, 2:114-118.

Jette, D.U., Halbert, J., Iverson, C., Miceli, E., Palak Shah, P. (2009) Use of Standardized Outcome Measures in Physical Therapist Practice: Perceptions and Applications. *Journal of the American Physical Therapy Association*, 89 (2):125-135.

King, L.K, March, L., Anandacoomarasamy, A. (2013) Obesity & osteoarthritis. *Indian Journal of Medical Research,* 138(2): 185–193.

Jordan, R.W., Smith, N.A., Chahal, G.S., Casson, C., Reed, M,R., Sprowson. A.P. (2014) Enhanced education and physiotherapy before knee replacement; is it worth it? *A systematic review. Physiotherapy*, 100(4):305-12.

Judge, A., Arden, N. K., Cooper, C., Javaid, M. K., Carr, A. J., Field, R. E., Dieppe, P. A. (2012) Predictors of outcomes of total knee replacement surgery. *Rheumatology*, 51, (10): 1804-1813.

Kellgren, J.H., Lawrence, J.S. (1957) Radiological assessment of osteo-arthrosis. *Annals of the Rheumatic Diseases*, 16(4):494-502.

Kendall, J. M. (2003) Designing a research project: randomised controlled trials and their principles. *Emergency medicine Journal*, 20:164-168.

Kiefer, R.A. (2011) The Effect of Social Support on Functional Recovery and Well-Being in Older Adults Following Joint Arthroplasty. *Rehabilitation Nursing*, 36 (3):120-126.

Kim, T.K., Park, K.K., Yoon, S.W., Kim, S.J., Chang, C.B., Seong, S.C., 2009. Clinical value of regular passive ROM exercise by a physical therapist after total knee arthroplasty. *Knee Surgery, Sports Traumatology and Arthroscopy: Official Journal of ESSKA (European Society of Sports Traumatology, Knee Surgery and Arthroscopy),*

17(10):1152-1158.

Koblbauer, I.F.H., Lambrecht Y., Van der Hulst, M., L. M., Neeter, C., Engelbert, R. H. H., Poolman, R.W., Scholtes, V.A. (2011) Reliability of Maximal Isometric Knee Strength Testing with Modified Hand-Held Dynamometry in Patients Awaiting Total Knee Arthroplasty: Useful in Research and Individual Patient Settings? A Reliability Study. *BioMED Centeral Musculoskeletal Disorders*, 12(1): 249.

Kon, E., Filardo, G., Drobnic, M., Madry, H., Jelic, M., van Dijk, N., Della Villa, S. (2012) Non-surgical management of early knee osteoarthritis. *Knee Surgery, Sports Traumatology and Arthroscopy*, 20 (3):436-449.

Lally, C. (2007) The relationship between knee integrity and function post total knee replacement. *MSc (Physiotherapy) University of the Witwatersrand, Johannesburg.*

Lequesne, M.G., Mery, C., Samson, M., Gerard, P. (1987) Indexes of severity for osteoarthritis of the hip and knee. Validation-value in comparison with other assessment tests. *Scandinavian Journal of Rheumatology*, 65:85-89.

Lenssen, T.A., van Steyn, M.J., Crijns, Y.H., Waltjé, E.M., Roox, G.M., Geesink, R.J., van den Brandt, P.A., De Bie, R.A. (2008) Effectiveness of prolonged use of continuous passive motion (CPM), as an adjunct to physiotherapy, after total knee arthroplasty. *BioMed Central Musculoskeletal Disorders*, 29;9:60.

Levine, M., McElroy, K., Stakich, V., Cicco, J. (2013) Comparing conventional physical therapy rehabilitation with neuromuscular electrical stimulation after TKA. *Orthopedics*, 36(3): e319-324.

Liao, C.D., Liou, T. H., Huang, Y.Y., Huang, Y.C. (2013) Effects of balance training on functional outcome after total knee replacement in patients with knee osteoarthritis: a

randomized controlled trial. *Clinical Rehabilitation*, 27(8):697-709.

Litwic A. , Edwards, M., Dennison, E., Cooper, C. (2013) Epidemiology and Burden of Osteoarthritis. *British Medical Bulletin*, 105: 185–199.

Maldonado, M., Nam, J. (2013) The Role of Changes in Extracellular Matrix of Cartilage in the Presence of Inflammation on the Pathology of Osteoarthritis. *BioMed Research International*, Article ID 284873, 10 pages.

Maly, M.R., Costigan, P.A., Olney, S.J. (2006) Determinants of self-report outcome measures in people with knee osteoarthritis. *Archives of Physical Medicine and Rehabilitation*, 87(1):96-104.

Marmon, A. R., Milcarek, B. I., Snyder-Mackler, L. (2014) Associations Between Knee Extensor Power and Functional Performance in Patients After Total Knee Arthroplasty and Normal Controls without Knee Pain. *International Journal of Sports Physical Therapy*, 9(2): 168–178.

Marmon, A.R., Snyder-Mackler, L. (2014) Activation Deficits Do Not Limit Quadriceps Strength Training Gains in Patients After Total Knee Arthroplasty. *International Journal of Sports Physical Therapy*, 9(3): 329–337.

McAlindon, T.E., Bannuru, R.R., Sullivan, M.C., Arden, N.K., Berenbaum, F., Bierma-Zeinstra, S.M., Hawker, G.A., Henrotin, Y., Hunter, D.J., Kawaguchi, H., Kwoh, K., Lohmander, S., Rannou, F., Roos, E.M., Underwood, M. (2014) OARSI guidelines for the non-surgical management of knee osteoarthritis. *Osteoarthritis and Cartilage,* 22(3): 363-88.

Meier, W.A., Marcus, R.L., Dibble l.E., Foreman, K.B., Peters, C.L., Mizner, R.L., LaStay, P.C. (2009) The Long-Term Contribution of Muscle Activation and Muscle Size to Quadriceps Weakness Following Total Knee Arthroplasty. *Journal of Geriatric Physical Therapy*, 32 (2):35-38.

Meier, W., Mizner, R.L., Marcus, R.L., Dibble, L.E., Peters, C., Lastayo, P.C., (2008) Total Knee Arthroplasty: Muscle Impairments, Functional Limitations, and Recommended Rehabilitation Approaches. *Journal of Orthopaedic and Sports Physical Therapy,* 38 (5): 246-256.

Miller, M.D., Towers, A. (1991) A Manual of Guidelines for Scoring the Cumulative Illness Rating Scale for Geriatrics (CIRS-G). *University of Pittsburg School of Medicine, Department of Geriatric Psychiatry, Western Psychiatric Institute and Clinic 3811 O'Hara Street Pittsburgh, Pennsylvania 15213.*

Mintken, P.E., Carpenter, K. J., Eckhoff, D., Kohrt, W. M., D Stevens, J.E. (2007) Early Neuromuscular Electrical Stimulation to Optimize Quadriceps Muscle function Following Total Knee Arthroplasty: A Case Report. *Journal of Orthopaedic and Sports Physical Therapy,* 37 (7) :364–371.

A Mizner, R.L., Petterson, S.C., Stevens, J.E., Axe, M.J., Snyder-Mackler, L. (2005) Pre-operative quadriceps strength predicts functional ability one year after total knee arthroplasty. *The Journal of Rheumatology*, 32(8):1533-1539.

B Mizner, R.L., Petterson, S.C., Stevens, J.E., Vandenborne, K., Snyder-Mackler, L. (2005) Early Quadriceps Strength Loss After Total Knee Arthroplasty, the Contributions of Muscle Atrophy and Failure of Voluntary Muscle Activation. *The Journal of Bone and Joint Surgery (American),* 87(5): 1047–1053.

Murphy, M. (2013) Knee range of motion after total knee arthroplasty: evaluation of advances to improve flexion and the role of flexion and extension in functional outcome. *PhD Thesis, The University of Queensland, Australia*.

Naylor, J., Harmer, A., Fransen. M., Crosbie, J., Innes, L. (2006) Status of physiotherapy rehabilitation after total knee replacement in Australia. *Physiotherapy Research International,* 11(1):35-47.

Oldmeadow, L.B., McBurney, H., Robertson, V.J. (2002) Hospital stay and discharge outcomes after knee arthroplasty: Implications for physiotherapy practice. *Australian Journal of Physiotherapy*, 48:117-121.

Ogilvie-Harris, D. J., Fitsialos, D.P. (1991) Arthroscopic management of the degenerative knee. *Arthroscopy: The Journal of Arthroscopic and Related Surgery*, 7 (2): 151-157.

Page, C.J., Hinman, R.S., Bennell, K.L. (2011) Physiotherapy management of knee osteoarthritis. *International Journal of Rheumatic Diseases*, 14(2):145-15.

Papakostidou, I., Dailiana, Z.H., Papapolychroniou, T., Liaropoulos, L., Zintzaras, E., Karachalios, T.S, Malizos, K.S. (2012) Factors affecting the quality of life after total knee arthroplasties: a prospective study. *BioMed Central Musculoskeletal Disorders*,13:11

Paradowski, P.T. (2014) Osteoarthritis of the Knee: Assessing the Disease. *Health Care Current Reviews*, 2:2.

Palmieri-Smith, R.M., Thomas, A.C., Karvonen-Gutierrez, C., Sowers, M.F. (2010) A Clinical Trial of Neuromuscular Electrical and Moderate Osteoarthritis Strength and Activation Among Women with Mild Stimulation in Improving Quadriceps Muscle. *Journal of the American Physical Therapy Association*, 90 (10): 1441-1452.

Petterson, S.C., Mizner, R.L., Stevens, J.E., Raisis, L., Bodenstab, A., Newcomb, W., Snyder-Mackler, L. (2009) Improved Function from Progressive Strengthening Interventions After Total Knee Arthroplasty: A Randomized Clinical Trial With an

Imbedded Prospective Cohort. Arthritis and Rheumatism (Arthritis Care and Research). *American College of Rheumatology*, 61 (2): 174–183.

Piva, S.R., Gil, A.B., Almeida, G.J.M., DiGioia, A.M., Levison, T.J., Fitzgerald, G.K. (2010) A Balance Exercise Programme Appears to Improve Function for Patients with Total Knee Arthroplasty: A Randomized Clinical Trial. *The Journal of the American Physical Therapy Association*, 90(6):880–94.

Pozzi, F., Snyder-Mackler,L., Zeni, J. (2013) Physical Exercise After Knee Arthroplasty: A Systematic Review of Controlled Trials. *European Journal of Physical and Rehabilitation Medicine,* 49(6):877-92.

Reginster, J.Y. (2002) The prevalence and burden of arthritis. *Rheumatology (Oxford),* 41 Supp 1:3-6.

Rice, D.A., McNair, P.J. (2010) Quadriceps arthrogenic muscle inhibition: neural mechanisms and treatment perspectives. *Seminars in Arthritis and Rheumatism*, 40(3):250-66.

Ro¨nn, K., Reischl, N., Gautier, E., Jacobi, M. (2012) Current Surgical Treatment of Knee Osteoarthritis. *Arthritis*, Volume 2011, Article ID 454873, 9 pages.

Roos, E.M., Lohmander, L. S. (2003) The Knee injury and Osteoarthritis Outcome Score (KOOS): from joint injury to osteoarthritis. *Health and Quality of Life Outcomes*, 1:64.

Roos, E.M., Toksvig-Larsen, S. (2003) Knee injury and Osteoarthritis Outcome Score (KOOS) – validation and comparison to the WOMAC in total knee replacement. *Health and Quality of Life Outcomes*, 1:17.

Rowe, P.J., Myles, C.M., Walker, C., Nutton, R. (2000) Knee joint kinematics in gait and

other functional activities measured using flexible electrogoniometry: how much knee motion is sufficient for normal daily life? *Gait and Posture*, 12(2):143-155.

Schiphof, D. Boers, M. Bierma-Zeinstra, S.M.A. (2008.) Differences in descriptions of Kellgren and Lawrence grades of knee osteoarthritis. *Annals of the Rheumatic Diseases*, 67: 1034-1036.

Sellam, J., Berenbaum, F. (2013) Is osteoarthritis a metabolic disease? Is osteoarthritis a metabolic disease? *Joint Bone Spine*, 80(6):568–573.

Sharma, L., Lou, C., Felson, D.T., Dunlop, D.D., Kirwan-Mellis, G., Hayes, K.W., Weinrach, D., Buchanan, T.S. (1999) Laxity in healthy and osteoarthritic knees. *Arthritis and Rheumatism*, 42(5):861-70

Shields, R. K., Enloe, L.J., Evans, R.E., Smith, K.B., Steckel, S.D., Goldsmith, C.H. (1995) Reliability, Validity, and Responsiveness of Functional Tests in Patients with Total Joint Replacement. *Journal of the American Physical Therapy Association*, 75 (3):169-176.

Sibbald, B. (1998) Understanding controlled trials: Why are randomised controlled trials important? *The British Medical Journal*, 316:201.

Silva, M.,Shepherd, E.F., Jackson, W.O., Pratt, J.A., McClung, C. D., Phil (Cantab), M., Schmalzried,T.P. (2003) Knee strength after total knee arthroplasty. *The Journal of Arthroplasty*, 18(5):605-611.

Slemenda, C., Brandt, K.D., Heilman, D.K., Mazzuca, S., Braunstein, E.M., Katz, B.P., Wolinsky, F.D. (1997) Quadriceps weakness and osteoarthritis of the knee. *Annals of Internal Medicine,* 127(2):97-104.

Solomon, L., Warwick, D. J., Nayagam, S. (2005) Apley's Concise System of Orthopaedics and Fractures, Third Edition: 41.

Spector, T.D., Cicuttini, F., Baker, J., Loughlin, J., Spector, D. (1996) Genetic influences on osteoarthritis in women: a twin study. *The British Medical Journal*, 312(7036):940-943.

Stevens-Lapsley, J.E., Balter, J.E., Wolfe, P., Eckhoff, D.G., Kohrt, W.M. (2012) Early neuromuscular electrical stimulation to improve quadriceps muscle strength after total knee arthroplasty: a randomized controlled trial. *The Journal of the American Physical Therapy Association*, 92(2):210-226.

Stevens, J.E., Mizner, R.L., Snyder-Mackler, L. (2003) Quadriceps strength and volitional activation before and after total knee arthroplasty for osteoarthritis. *Journal of Orthopaedic Research*, 21 (5): 775–779.

Stevens, J.E., Mizner, R.L., Snyder-Mackler, L. (2004) Neuromuscular electrical stimulation for quadriceps muscle strengthening after bilateral total knee arthroplasty: a case series. *Journal of Orthopaedic and Sports Physical Therapy*, 34(1):21-29.

Stillman, B. C. (2004) Physiological quadriceps lag: Its nature and clinical significance. *Australian Journal of Physiotherapy*, 50: 237-241.

Usenbo, A., Kramer, V., Young, T., Musekiwa, A. (2015) Prevalence of Arthritis in Africa: A Systematic Review and Meta-Analysis. *PLoS One*, 10 (8).

Wallis, J.A., Taylor, N.F. (2011) Pre-operative interventions (non-surgical and non-pharmacological) for patients with hip or knee osteoarthritis awaiting joint replacement surgery--a systematic review and meta-analysis. *Osteoarthritis and Cartilage,* 19(12):1381-1395.

Walls, R.J., McHugh, G., J O'Gorman, D., Moyna, N.M., O'Byrne, J.M. (2010) Effects of pre-operative neuromuscular electrical stimulation on quadriceps strength and functional recovery in total knee arthroplasty. A pilot study. *BioMED Centeral Musculoskeletal Disorders,* 11:119.

Whitehouse, S.L., Taylor, A.H., Blom, A.W., Pattison, G. T. R., Bannister, G.C. (2005) The Oxford Knee Score; Problems and Pitfalls. *The Knee* 12(4): 287-291.

Williams, D.P., Blakey, C.M., Hadfield, S.G., Murray, D.W., Price, A.J., Field, R.E. (2013) Long-term trends in the Oxford knee score following total knee replacement. *The Bone and Joint Journal*, 95-B (1):45-50.

Wood, W.A. (2010) A Report to Inform the Development of a Clinical Practice Guideline for Rehabilitation Post Total Knee Arthroplasty in a South African Public Hospital. *MSc (Physiotherapy), University of the Witwatersrand, Johannesburg.*

Woolf, A. D., Pfleger, B. (2003) Burden of major musculoskeletal conditions. *Bulletin of the World Health Organ*, 81(9):646-656.

Xie, F., Ye, H., Zhang, Y., Liu, X., Lei, T., Li, S.C. (2011) Extension from Inpatients to Outpatients: Validity and Reliability of the Oxford Knee Score in Measuring Health Outcomes in Patients with Knee Osteoarthritis. *International Journal of Rheumatic Diseases*, 14 (2): 206–210.

Zhang, Y., Hannan, M.T., Chaisson, C.E., McAlindon, T.E., Evans, S.R., Aliabadi, P., Levy, D., Felson, D.T. (2000) Bone mineral density and risk of incident and progressive radiographic knee osteoarthritis in women: The Framingham Study. *The Journal of Rheumatology*, 27(4):1032-1037.

8. APPENDICES

Appendix 1: Human Research Ethics Committee clearance certificate

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M130566

NAME: (Principal Investigator)	Ms Riona Rajcoomar
DEPARTMENT:	Department of Physiotherapy Medical School
PROJECT TITLE:	Functional Outcomes Post Total Knee Arthroplasty following Electrical Muscle Stimulation on the Quadriceps Muscle at Chris Hani Baragwanath Academic Hospital
DATE CONSIDERED:	31/05/2013
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Mr Lonwabo Godlwana
APPROVED BY:	Professor PE Cleaton-Jones, Chairperson, HREC (Medical)

DATE OF APPROVAL: 27/09/2013

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10004, 10th floor, Senate House, University.

I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**.

Principal Investigator Signature M130566 Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix 2: Permission to conduct research



GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

MEDICAL ADVISORY COMMITTEE
CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

PERMISSION TO CONDUCT RESEARCH

Date: 28 October 2013

TITLE OF PROJECT: Functional outcomes post total knee arthroplasty following electrical muscle stimulation on the quadriceps muscle at Chris Hani Baragwanath Hospital

UNIVERSITY: Witwatersrand

Principal Investigator: R Rajcoomar

Department: Physiotherapy

Supervisor (If relevant): L Godlwana

Permission Head Department (where research conducted): Yes

Date of start of proposed study: October 2013
Date of completion of data collection: December 2014

The Medical Advisory Committee recommends that the said research be conducted at Chris Hani Baragwanath Hospital. The CEO /management of Chris Hani Baragwanath Hospital is accordingly informed and the study is subject to:-

- Permission having been granted by the Committee for Research on Human Subjects of the University of the Witwatersrand.
- the Hospital will not incur extra costs as a result of the research being conducted on its patients within the hospital
- the MAC will be informed of any serious adverse events as soon as they occur
- permission is granted for the duration of the Ethics Committee approval.

Recommended
(On behalf of the MAC)
Date: 28 October 2013

Approved/Not Approved
Hospital Management
Date: 31/10/13

Scanned by CamScanner

Appendix 3: Information Sheet

FUNCTIONAL OUTCOMES POST TOTAL KNEE ARTHROPLASTY FOLLOWING ELECTRICAL MUSCLE STIMUALTION ON THE QUADRICEPS MUSCLE AT CHRIS HANI BARAGWANTH ACADEMIC HOSPITAL

Hello, my name is Riona Rajcoomar. I am a physiotherapist at Chris Hani Baragwanath Academic Hospital and I am currently doing my Masters degree at the University of Witwatersrand.

In order for me to get this degree I have to carry out a research study. I would like to invite you to take part in this research study that looks at the effects of electrical muscle stimulation after having a total knee replacement.

In this study, there will be 2 groups. If you choose to be a part of this study you will be put into one of these 2 groups. If you are in group 1 you will be a part of the experimental group. This means you will be receiving electrical muscle stimulation (a machine that helps the muscles contract/work), as well as exercises that are normally done after a total knee replacement. If you are in group 2 you will be a part of the control group. This means that you will only be receiving the exercises that are normally done after a total knee replacement. Both groups will be asked to fill out a questionnaire before and after your total knee replacement. I will be asking you to perform a series of tests every day until you are discharged. These tests will involve you getting out of bed, walking and climbing steps. I will also be looking at how much you can bend and straighten you knee as well as looking at how strong the muscles on your legs are.

All treatment sessions will be carried out as per normal practice at Chris Hani Baragwanath Academic Hospital. I will be asking you to come back in 6 weeks after your operation for follow up treatment as is normally done after a total knee replacement. The only difference is you will be asked to fill in the same questionnaire as you did before your operation and I will be testing the strength of your leg muscles again.

Should you decide to be a part of this study, if you are in group 1, you need to understand there are some minor side effects that have been reported when using electrical muscle stimulation. These side effects may be skin irritation and burns under the electrodes. You should also be aware that electrical muscle stimulation may cause some discomfort, pain and some bleeding as well. In the event of these rare side effects, all treatment will be stopped immediately and you will be referred to see a doctor. If any of these side effects do occur. Because, I am using electrical stimulation, it is very important to tell me if you are pregnant, have/had cancer and/or have a cardiac pacemaker, as electrical stimulation can be harmful in these situations. Every care possible will be taken to ensure little or no adverse reactions occur. I will ensure this by strictly be following the guidelines and setting described in the user manual for this machine.

Participation in this study is completely voluntary. If you choose not to be a part of the study, there will be no consequence and it will not affect your treatment in any way. If you choose to take part in this study, it is important to remember that you may choose to withdraw at any time without any consequence or it will not affect your treatment in any way.

Please note that all the information that is taken from you for this study will be kept safe and all your personal information will be kept confidential. The information obtained from this study will be analysed, compiled and submitted for the purpose of obtaining a Masters degree. Please feel free to ask me any questions regarding this information or research study.

For further information during the study please don't hesitate to contact me or my supervisors Lonwabo Godlwana and Wendy-Ann Wood.

If you have any complaints, queries or concerns, please contact Dr. Mudzi of the University of Witwatersrand (Physiotherapy department) at 011 717 3718 or Prof Cleaton-Jones of the Witwatersrand, Human Research Ethics Committee established to help protect the rights of research participants at 011 717 2301/1234.

Thank you

Riona Rajcoomar

Email: riona_rajcoomar@yahoo.com

Cellphone: 0845802572

Work: 0119338309

Supervisors: Lonwabo Godlwana and Wendy-Ann Wood

Tel: 011 717 3707/072 373 2156

Fax: 011 717 3719

Email: Lonwabo.Godlwana@wits.ac.za
wendswood@gmail.com

Appendix 4: Consent Form

I _____, have read the information sheet. I was given the opportunity to ask questions and fully understand the information. I agree/disagree to partake in this study

Patient name: _____ [PRINT]

Patient signature: _____ GT/GP number: _____

Date: _____ Time: _____

Researcher name: _____

Researcher signature: _____

Date: _____ Time: _____

Researcher: Riona Rajcoomar

Cellphone: 0845802572 Work: 0119338309

Email: riona_rajcoomar@yahoo.com

Supervisors: Lonwabo Godlwana and Wendy-Ann Wood

Tel: 011 717 3707/072 373 2156

Fax: 011 717 3719

Email: Lonwabo.Godlwana@wits.ac.za
wendswood@gmail.com

Contact details of REC administration and chair for reporting complaints:

Prof Cleaton-Jones

Wits Research Office, 10th Floor Senate House, East Campus

Tel: 011 717 1234/2301 Fax: 011-339-5708

Appendix 5: Iowa Level of Assistance Scale

Tasks: Supine to sitting on the edge of the bed
Sitting on the edge of the bed to standing
Walking 4.57m
Climbing up and down 3 steps
Walking speed over 13.4m

Ordinal Scale and Definitions of Level of Assistance

Score	Assistance	Definition
0	Independent	No assistance or supervision is necessary to safely perform the activity with or without assistive devices, aids or modifications.
1	Standby	Nearby supervision is required for the safe performance of the activity, no contact is necessary.
2	Minimal	One point of contact is necessary for the safe performance of the activity including helping with the application of the assistive device (part of ambulation), getting leg(s) on or off the leg rest and stabilizing an assistive device
3	Moderate	Two points of contacts are necessary (by one or two persons) for the safe performance of the activity
4	Maximum	Significant support is necessary of a total of three or more points of contact (by one more people) for the safe performance of the activity
5	Failed	Attempted activity, but failed with maximal assistance
6	Not Tested	Due to medical reasons for reasons of safety, task was not attempted

*contact = any physical contact between the therapist and the patient or the assistive device (frame, crutches, etc)

Ordinal Scale for Assistive Device

Score	Assistive Device
0	No assistive device
1	One stick or crutch
2	Two sticks
3	Two crutches
4	Two elbow crutches
5	Frame (standard or rollator)

Ordinal Scale for Ambulation Velocity

Score	Time To Walk 13.4m
0	≤ 20 seconds
1	21-30 seconds
2	31-40 seconds
3	41-50 seconds

4	51-60 seconds
5	61-70 seconds
6	> 70seconds

Range of Scores
Minimal score: if the patient was independent is all five tasks (i.e. level of assistance score=0) plus did not require an assistive device for the four tasks which involved standing or mobilising (i.e. assistive device score=0) the total score = (5×0) for the level of assistance score + (4×0) for assistive device score, which = 0.
Maximal score: if the patient was unable to attempt any of the five tasks because of medical reasons or reasons of safety (i.e. level of assistance score=6) and the assistive device for the four tasks which involved standing or mobilising would have been a frame (i.e. assistive device score=5), the total score = (5×6) for the level of assistance score + (4×5) for assistive device score, which =50.

Task	Level of Assistance	Assistive device	Total
Supine to sitting on the edge of the bed		×	
Sitting on the edge of the bed to standing			
Walking 4.57m			
Climbing up and down 3 steps			
Walking speed over 13.4m			
Total			

Task	Score
Time to Walk 13.4m	

Appendix 6: Cumulative Illness Rating Scale

Participant number: _____

Date of admission: _____

Group: _____

Each system is rated as follows:

Effect on system	Severity of effect on system	Score
None	No impairment to that organ/system.	1
Mild	Impairment does not interfere with normal activity; treatment may not be required; prognosis is excellent (examples: skin lesions, hernias, haemorrhoids)	2
Moderate	Impairment interferes with normal activity; treatment is needed; prognosis is good (examples: gallstones, diabetes, fractures)	3
Severe	Impairment is disabling; treatment is urgently needed; prognosis is guarded (examples: respectable carcinoma, pulmonary emphysema, congestive heart failure)	4
Extremely severe	Impairment is life threatening; treatment is urgent or of no avail; prognosis is grave (examples: myocardial infarction, cerebrovascular accident, gastrointestinal bleeding, embolus)	5

Rate the following systems based on the above table:

	System	Score
a	Cardiac (heart only)**.**	
b	Hypertension (rating is based on severity; affected systems are rated separately).	
c	Vascular (blood, blood vessels and cells, marrow, spleen, lymphatic's)	
d	Respiratory (lungs, bronchi, trachea below the larynx).	
e	EENT (eye, ear, nose, throat, larynx).	
f	Upper GI (oesophagus, stomach, duodenum, biliary and pancreatic trees; do not include diabetes).	
g	Lower GI (intestines, hernias).	
h	Hepatic (liver only).	
i	Renal (kidneys only).	
j	Other GU (uterus, bladder, urethra, prostate, genitals).	
k	Musculo-skeletal-integumentary (muscles, bone, skin)	

l	Neurological (brain, spinal cord, nerves; do not include dementia).	
m	Endocrine-Metabolic (includes diabetes, diffuse infections, infections, toxicity)	
n	Psychiatric/Behavioural (includes depression, anxiety, agitation, psychosis, not dementia).	

Total Score	

Appendix 7: The Oxford Knee Score

Participant number: _____

Date of surgery: _____ Date of follow up: _____

Group: _____

1) How would you describe the pain you usually have from your knee?

		Pre op	Post op
None	1		
Very mild	2		
Mild	3		
Moderate	4		
Severe	5		

2) Have you had any trouble washing and drying yourself (all over) because of your knee?

		Pre op	Post op
No trouble at all	1		
Very little trouble	2		
Moderate trouble	3		
Extreme difficulty	4		
Impossible to do	5		

3) Have you had any trouble getting in and out of a car or using public?

Transport because of your knee? *(Whichever you tend to use)*

		Pre op	Post op
No trouble at all	1		
Very little trouble	2		
Moderate trouble	3		
Extreme difficulty	4		
Impossible to do	5		

4) For how long have you been able to walk before the pain from your knee becomes severe? *(With or without a stick)*

		Pre op	Post op
No pain/>30 min	1		
16 to 30 min	2		
5 to 15 min	3		
Around the house only	4		
Not at all – severe on walking	5		

5) After a meal (sat at a table), how painful has it been for you to stand up from a chair because of your knee?

		Pre op	Post op
Not at all painful	1		
Slightly painful	2		
Moderately painful	3		
Very painful	4		
Unbearable	5		

6) Have you been limping when walking, because of your knee?

		Pre op	Post op
Rarely/never	1		
Sometimes or just at first	2		
Often, not just at first	3		
Most of the time	4		
All of the time	5		

7) *Could* you kneel down and get up again afterwards?

		Pre op	Post op
Yes, easily	1		

With little difficulty	2		
With moderate difficulty	3		
With extreme difficulty	4		
No, impossible	5		

8) Have you been troubled by pain from your knee in bed at night?

		Pre op	Post op
No nights	1		
Only 1 or 2 nights	2		
Some nights	3		
Most nights	4		
Every night	5		

9) How much has pain from your knee interfered with your usual work/housework?

		Pre op	Post op
Not at all	1		
A little bit	2		
Moderately	3		
Greatly	4		
Totally	5		

10) Have you felt that your knee might suddenly ‘give way’ or let you down?

		Pre op	Post op
Rarely/never	1		
Sometimes or just at first	2		
Often, not just at first	3		
Most of the time	4		
All of the time	5		

11) Could you do the household shopping on your own?

		Pre op	Post op
Yes, easily	1		
With little difficulty	2		
With moderate difficulty	3		
With extreme difficulty	4		
No, impossible	5		

12) Could you walk down a flight of stairs?

		Pre op	Post op
Yes, easily	1		
With little difficulty	2		
With moderate difficulty	3		
With extreme difficulty	4		
No, impossible	5		

	Pre op	**Post op**
Total score		

Appendix 8: Normally Practiced Physiotherapy Rehabilitation Protocol

CHRIS HANI BARAGWANATH HOSPITAL
Directorate: PHYSIOTHERAPY DEPT.
Tel. number: (011) 933 -8309

ORTHOPAEDIC PROTOCOL: TOTAL KNEE REPLACEMENTS (TKR)

INDICATIONS:

- Decreased function or quality of life
- Severe pain affecting sleep
- Tricompartmental osteoarthritis

PRE-OPERATIVELY:

- Ascertain the patients level of mobility and any walking aids
- Check the level of support at home, and if there are any steps or stairs
- Go through the patient's understanding of the operation
- Talk through the post-operative protocol briefly
- Go through some of the basic exercises and give the patients an exercise sheet
- Explain discharge criteria to patient
- Order an appropriate walking aid for the patient

BASIC OPERATIVE PROCEDURE:

- GA and Femoral Block
- Anterior midline incision
- Knee debrided
- Tibial cut made across proximal tibia and femoral cut made across the distal femur
- Tibial component cemented in position *(or uncemented)*
- Femoral component cemented in position *(or uncemented)*
- Closed in layers
- Skin clips and dressing applied

COMPLICATIONS:

- Abnormal patella tracking
- Component loosening
- DVT
- Intra-operative fracture
- Knee stiffness or fixed flexion deformity
- Ligament Instability
- Peroneal nerve palsy
- Wound infection or sepsis

POST-OPERATIVELY:

On 1st day post op:

IMPORTANT INFORMATION TO CHECK BEFORE TREATING THE PATIENT:

- *Medical notes for any post-operative complications / information*
- *See if patient is stable for treatment (vitals and platelets)*
- *See if any post-operative X-rays are available*
- *Ensure an appropriate walking aid is ordered for the patient*

- Check the patient understands the operation and what was done (very basic format)
- Objective evaluation:
  - Patient will have a catheter and portovac (drain) as well as a Robert Jones bandage in situ (to control post-operative swelling)
  - Chest assessment, test sensation, ankle DF/PF (for foot drop), knee flexion and extension ROM, quadriceps strength (SLR – see if there is a quad lag)
- If post-operative X-ray available: mobilise patient to chair (if pain allows)
- Ward exercise programme (WEP): deep breathing exercises, footpumps, isometric quads, heelslides (can do A-A) and SLR (can do A-A), hip abduction in supine, 1 or 2 legged bridging (can do A-A), inner range quads (10 ×3 daily).

2nd day post op:

- Drains usually will be removed on the 1st or 2nd day post-surgery
- Robert Jones reduced to a primapore dressing
- If post-operative X-rays still unavailable: can mobilise patient if clinically stable and no signs of infection or DVT
- Mobilise PWB for uncemented prosthesis (or FWB as tolerated for cemented prosthesis) – start mobilising with walking frame and progress to elbow crutches as needed
- WEP: as for day 1. Include through range quads in sitting

Day 3 post-operatively until discharge:

- Monitor for post-operative complications
- Need to attain 0˚ – 90˚ knee ROM and 0˚quads lag before D/C
- Make sure patient is independently mobile with walking aid and exercises. Patient should be able to walk adequate distances to cope with normal ADLs
- Steps or stairs if appropriate for the patient

DISCHARGE CRITERIA:

- Independently mobile on crutches or appropriate aid
- Knee flexion 90 degrees
- Able to manage functionally at home e.g. do steps if appropriate, can get out of bed and chair independently
- SLR or good through range quads contraction with 0˚ quads lag
- Swelling controlled
- No DVT, infection other medical problems

CRITERIA FOR REFERRAL FOR OUT-PATIENT PHYSIOTHERAPY:

- Not independent with exercises
- Not achieving 90 degrees of flexion or not likely to maintain on D/C
- Weak quadriceps / at risk of developing a FFD
- Mobility problems

An OPD appointment can be arranged as necessary at most convenient location for patient

ORTHOPAEDIC FOLLOW UP:

- Patient has a wound check at 2 weeks
- They have a follow up in clinic at 6 weeks, 3 months, 6 months and 12 months

SOURCES OF INFORMATION:

Cook, J.R., Warren, M., Ganley, K., Prefontaine, P. & Wylie, J.W. 2008. A comprehensive joint replacement programme for total knee arthroplasty: a descriptive study. *BMC Musculoskeletal Disorders*, 154(9)

Kisner, C. & Colby, L.A. Therapeutic Exercise Foundations and Techniques, ed 5. F.A. Davis Company, U.S.A. 2007, 702-711

Meier, W., Mizner, R., Marcus, R., Dibble, L., Peters, C. & Lastayo, P.C. 2008. Total knee arthroplasty: Muscle impairments, functional limitations and recommended rehabilitation approaches. *Journal of Orthopaedic & Sports Physical Therapy*. 38(5), 246 - 256

Petterson, S.C., Mizner, R.I., Stevens, J.E., Raisis, L., Bodenstab, A., Newcomb, W. & Snyder-Mackler, L. 2009. Improved function from progressive strengthening interventions after Total Knee Arhtoroplasy: A randomized clinical trial with an imbedded prospective cohort. *Arthritis & Rheumatism*, 61(2), 174-183

Piva, S.R., Teixeira, P.E.P., Almeida, G.J.M., Gil, A.B., DiGioia III, A.M. & Fitzgerald, G.K. 2011. Contribution of Hip Abductor Strength to Physical Function in Patients with Total Knee Arthroplasty. *Physical Therapy*, 91(2), 225-233

Stevens-Lapsley, J.E., Balter, J.E., Kohrt, W.M. & Eckhoff, D.G. 2010. Quadriceps and Hamstrings Muscle Dysfunction after Total Knee Arthroplasty. *Clinical Orthopaedics and Related Research*, 468(9), 2460-2468

Date: _____

Consultant name: _____ **Signature:** _____

Physiotherapist: _____ **Signature:** _____

Review date: November 2013

Appendix 9: Data Collection Sheet

PARTICIPANT NUMBER: _____ AGE: _____ GENDER: _____

GROUP: _____ TELEPHONE NO: _____
GP/GT NUMBER: _____ FINANCIAL CLASSIFICATION: _____
ADDRESS_____
_____
_____
DATE OF ADMISSION: _____ DATE OF SURGERY: _____
DAY OF SURGERY: _____DATE OF DISCHARGE: _____
SURGEON: _____DATE OF FOLLOW UP: _____

Type of Prosthesis:

Cemented: ☐ Uncemented: ☐

Anaesthesia:

Spinal: ☐ Nerve Block: ☐ General: ☐

Current medical history:

MCIR Scale score: _____

Diabetes ☐ Epilepsy: ☐ Arthritis: ☐ Respiratory: ☐ Thyroidism: ☐

Hypertension: ☐

Medication:

_____
_____
_____
_____
_____
_____
_____
_____

Range of Movement:

	Pre Op	Post Op : Day 1	Post Op : Day 2	Post Op : Day 3	Post Op : Day 4	Post Op : Day5
Active						
Passive						
	Post Op : Day 6	**Post Op : Day 7**	**Post Op : Day 8**	**Post Op : Day 9**	**Post Op : Day 10**	**Post Op : Day 11**
Active						
Passive						
	Post Op : Day 12	**Post Op : Day 13**	**Post Op : Day 14**	**Post Op : Day 15**	**Post Op : Day 16**	**Discharge**
Active						
Passive						

Quadriceps Lag:

Pre Op	Post Op : Day 1	Post Op : Day 2	Post Op : Day 3	Post Op : Day 4	Post Op : Day5
Post Op : Day 6	**Post Op : Day 7**	**Post Op : Day 8**	**Post Op : Day 9**	**Post Op : Day 10**	**Post Op : Day 11**
Post Op : Day 12	**Post Op : Day 13**	**Post Op : Day 14**	**Post Op : Day 15**	**Post Op : Day 16**	**Discharge**

Days to achieve 0˚ quads lags: _____

Muscle Strength:

Pre op	
6 Weeks post op	

Oxford Knee Score:

	Pre op	6 Weeks post op
Total score		

Iowa Level of Assistance Scale:

	Post Op : Day 1		Post Op : Day 2		Post Op : Day 3		Post Op : Day 4		Post Op : Day 5	
LOA										
AD										
	Post Op : Day 6		Post Op : Day 7		Post Op : Day 8		Post Op : Day 9		Post Op : Day 10	
LOA										
AD										
	Post Op : Day 11		Post Op : Day 12		Post Op : Day 13		Post Op : Day 14		Post Op : Day 15	
LOA										
AD										
	Post Op : Day 16		Discharge							
LOA										
AD										

Time to walk 13.4m	Post Op : Day 1	Post Op : Day 2	Post Op : Day 3	Post Op : Day 4	Post Op : Day 5	Post Op : Day 6	Post Op : Day 7	Post Op : Day 8	Post Op : Day 9
Score									
	Post Op : Day 10	Post Op : Day 11	Post Op : Day 12	Post Op : Day 13	Post Op : Day 14	Post Op : Day 15	Post Op : Day 16	Discharge	
Score									

Appendix 10: Letter of Permission

Chris Hani Baragwanath Hospital
Chris Hani Road
Diepkloof Extension 6
Soweto

Dear Chris Hani Baragwanath Academic Hospital

I, Riona Rajcoomar, am a physiotherapist at Chris Hani Baragwanath Academic Hospital and I am currently doing my Masters degree at the University of Witwatersrand.

In order form me to get this degree I have to carry out a research study which will look at the functional outcomes post total knee arthroplasty following electrical muscle stimulation on the quadriceps muscle at Chris Hani Baragwanath Academic Hospital

In this study there will be an experimental and a control group. The experimental group will be receiving electrical muscle stimulation as well as excises that are normally done after a total knee replacement. The control group will only be receiving the exercises that are normally done after a total knee replacement. Both group groups will be asked to fill out a questionnaire before and after the total knee replacement. Participants will also be asked to perform a series of tests every day until discharge. These tests will involve getting out of bed, walking and climbing steps. I will also be looking at the components, such range of motion and muscle strength, involved in the above mentioned functional activities.

All treatment sessions will be carried out as per normal practice at Chris Hani Baragwanath Academic Hospital during regulated working hours (7:30-15:45. Participants will be asked to come back in 6 weeks following the operation for follow up treatment as is normally done after a total knee replacement. Participants will again be asked to perform the series of tests as done during admission.

All participants will be asked to sign informed consent and will be issued with and information sheet. Participation in this study is completely voluntary and all the information

acquired in this study will be kept safe and all personal information will be kept confidential.

Please find enclosed copies of all the necessary documentation related to this research study.

With this letter I seek permission to conduct this research study in your institution.

I hope this request meets with a favourable response.

Regards

Riona Rajcoomar

Email: riona_rajcoomar@yahoo.com

Cellphone: 0845802572 Work:0119338309

Supervisors: Lonwabo Godlwana and Wendy-Ann Wood

Tel: 011 717 3707/072 373 2156

Fax: 011 717 3719

Email: Lonwabo.Godlwana@wits.ac.za
wendswood@gmail.com

Contact details of REC administration and chair for reporting complaints:

Prof P Cleaton-Jones

Wits Research Office, 10th Floor Senate House, East Campus

Tel: 011-717-1234 Fax: 011-339-5708

Appendix 11: Summary of variables

The Mann-Whitney test shows a significant difference in QL between the two groups, even though the median (25p-75p) values are the same (table 4.5). This is explained by the difference in the means and more especially the minimum and maximum values of the two groups as shown below.

Summary of variables

	Group 1 (experimental) n=26		**Group 2 (control) n=26**	
	Mean (SD)	Range	Mean (SD)	Range
Pre-operatively	1.6° (±3.8°)	-3°- 13°	2.4° (±5.3°)	-1°- 19°
Discharge	0.1 (±0.4°)	0°- 2°	2.8° (±4.8°)	0°- 16°
Six weeks	0° (±0°)	0°- 0°	1.4° (±4.4°)	0°- 20°

The table above shows the mean and range of Quadriceps lag pre-operatively, at discharge and at six weeks of study sample (n=52).

Appendix 12: Turnitin report

FUNCTIONAL OUTCOMES POST TOTAL KNEE ARTHROPLASTY FOLLOWING ELECTRICAL MUSCLE STIMULATION ON THE QUADRICEPS MUSCLE AT CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

ORIGINALITY REPORT

13%	7%	10%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Sports Injuries, 2015. Publication	1%
2	Submitted to Charles Sturt University Student Paper	1%
3	www.physicaltherapyjournal.com Internet Source	1%
4	D Schiphof. "Differences in descriptions of Kellgren and Lawrence grades of knee osteoarthritis", Annals of the Rheumatic Diseases, 1/15/2008 Publication	1%
5	"2015 ACR/ARHP Annual Meeting Abstract Supplement", Arthritis & Rheumatology, 2015. Publication	1%
6	Karolin Rönn. "Current Surgical Treatment of Knee Osteoarthritis", Arthritis, 2011 Publication	<1%

7	M. V Hurley. "Sensorimotor changes and functional performance in patients with knee osteoarthritis", Annals of the Rheumatic Diseases, 11/01/1997 Publication	<1%
8	Zumrutdal, Aysegul, Mehmet Baltali, Hasan Micozkadioglu, Dilek Torun, Siren Sezer, F. Nurhan Ozdemir, and Mehmet Haberal. "Determinants of Coronary Artery Disease in Nondiabetic Hemodialysis Patients: A Matched Case-Control Study", Renal Failure, 2007. Publication	<1%
9	Stephanie C. Petterson. "Improved function from progressive strengthening interventions after total knee arthroplasty: A randomized clinical trial with an imbedded prospective cohort", Arthritis & Rheumatism, 02/15/2009 Publication	<1%
10	pdfs.semanticscholar.org Internet Source	<1%
11	www.ncbi.nlm.nih.gov Internet Source	<1%
12	Total Knee Arthroplasty, 2015. Publication	<1%
13	ptjournal.apta.org Internet Source	<1%

14	Volpato, Helena Bruna Bettoni, Paulo Szego, Mario Lenza, Silvia Lefone Milan, Claudia Talerman, and Mario Ferretti. "Femoral quadriceps neuromuscular electrical stimulation after total knee arthroplasty: a systematic review", Einstein (São Paulo), 2016. Publication	<1%
15	www.science.gov Internet Source	<1%
16	etheses.whiterose.ac.uk Internet Source	<1%
17	Osteoarthritis, 1999. Publication	<1%
18	Roos, E. M., L. Engelhart, J. Ranstam, A. F. Anderson, J. J. Irrgang, R. G. Marx, Y. Tegner, and A. M. Davis. "ICRS Recommendation Document: Patient-Reported Outcome Instruments for Use in Patients with Articular Cartilage Defects", Cartilage, 2011. Publication	<1%
19	dalspace.library.dal.ca Internet Source	<1%
20	ajp.physiotherapy.asn.au Internet Source	<1%
21	etheses.bham.ac.uk Internet Source	<1%

22	Ardali, Gunay. "A daily adjustable progressive resistance exercise protocol and functional training to increase quadriceps muscle strength and functional performance in an elderly homebound patient following a total knee arthroplasty", Physiotherapy Theory and Practice, 2014. Publication	<1%
23	Submitted to University of Central Lancashire Student Paper	<1%
24	Jennifer E Stevens-Lapsley. "Osteoarthritis in women: effects of estrogen, obesity and physical activity", Women s Health, 07/2010 Publication	<1%
25	Submitted to University of Essex Student Paper	<1%
26	Submitted to Rochester Institute of Technology Student Paper	<1%
27	www.nature.com Internet Source	<1%
28	europepmc.org Internet Source	<1%
29	Stevens-Lapsley, Jennifer E. Baiter, Jac. "Early neuromuscular electrical stimulation to improve quadriceps muscle strength after total	<1%

knee ar", Physical Therapy, Feb 2012 Issue
Publication

30	Bade, Michael J., and Jennifer E. Stevens-Lapsley. "Early High-Intensity Rehabilitation Following Total Knee Arthroplasty Improves Outcomes", Journal of Orthopaedic and Sports Physical Therapy, 2011. Publication	<1%
31	Submitted to Harding University Student Paper	<1%
32	lib.dr.iastate.edu Internet Source	<1%
33	Submitted to Texas State University- San Marcos Student Paper	<1%
34	eprints.utas.edu.au Internet Source	<1%
35	Clinical Trials in Rheumatoid Arthritis and Osteoarthritis, 2008. Publication	<1%
36	bmcmedicine.biomedcentral.com Internet Source	<1%
37	bmcmusculoskeletdisord.biomedcentral.com Internet Source	<1%
38	Submitted to Chester College of Higher	

	Education Student Paper	<1%
39	www.trialsjournal.com Internet Source	<1%
40	dagda.shef.ac.uk Internet Source	<1%
41	Submitted to St George's Hospital Medical School Student Paper	<1%
42	Eingereicht an Higher Education Commission Pakistan am 2011-05-30 Student Paper	<1%
43	Submitted to CSU Northridge Student Paper	<1%
44	www.chru.co.za Internet Source	<1%
45	Submitted to University of Glamorgan Student Paper	<1%
46	Submitted to University of Nottingham Student Paper	<1%
47	Submitted to University of Liverpool Student Paper	<1%
48	Submitted to Liverpool John Moores University Student Paper	<1%

49	Submitted to Cranfield University Student Paper	<1%
50	Submitted to Oxford Brookes University Student Paper	<1%
51	Submitted to University of Zululand Student Paper	<1%
52	springerplus.springeropen.com Internet Source	<1%
53	www.oarsi.org Internet Source	<1%
54	Submitted to Daemen College Student Paper	<1%
55	Submitted to Glasgow Caledonian University Student Paper	<1%
56	clinicaltrials.gov Internet Source	<1%
57	Submitted to The Robert Gordon University Student Paper	<1%
58	lra.le.ac.uk Internet Source	<1%
59	Hollén, Elisabet, Kajsa Holmgren Peterson, Tommy Sundqvist, Ewa Grodzinsky, Lotta Högberg, Pia Laurin, Lars Stenhammar, Karin Fälth-Magnusson, and Karl-Eric Magnusson.	<1%

"Coeliac children on a gluten-free diet with or without oats display equal anti-avenin antibody titres", Scandinavian Journal of Gastroenterology, 2006.
Publication

60	Blackburn, Julia, Adnan Qureshi, Rouin Amirfeyz, and Gordon Bannister. "Does preoperative anxiety and depression predict satisfaction after total knee replacement?", The Knee, 2012. Publication	<1%
61	Submitted to A.T. Still University - Arizona Student Paper	<1%
62	www.orthopeden.org Internet Source	<1%
63	Shull, Pete B., Rebecca Shultz, Amy Silder, Jason L. Dragoo, Thor F. Besier, Mark R. Cutkosky, and Scott L. Delp. "Toe-in gait reduces the first peak knee adduction moment in patients with medial compartment knee osteoarthritis", Journal of Biomechanics, 2013. Publication	<1%
64	Kumar, Praveen Cruziah, Reynold Bradley,. "Intra-rater and inter-rater reliability of ultrasonographic measurements of acromion-greater tuberos", Topics in Stroke Rehabilitation, June 2016 Issue	<1%

Publication

65	Levine, Michael, Karen McElroy, Valerie Stakich, and Jodie Cicco. "Comparing Conventional Physical Therapy Rehabilitation With Neuromuscular Electrical Stimulation After TKA", Orthopedics, 2013. Publication	<1%
66	Carmelita J. Colbert. "Knee confidence as it relates to physical function outcome in persons with or at high risk of knee osteoarthritis in the Osteoarthritis Initiative", Arthritis & Rheumatism, 05/2012 Publication	<1%
67	Wei, Min, Dongmei Duan, Yujie Liu, Zhigang Wang, and Zhongli Li. "Increased thymosin β4 levels in the serum and SF of knee osteoarthritis patients correlate with disease severity", Regulatory Peptides, 2013. Publication	<1%
68	Yaari, Lee, Yona Kosashvili, Ganit Segal, Shai Shemesh, Steven Velkes, Amit Mor, Ronen Debi, Benjamin Bernfeld, and Avi Elbaz. "A Novel Non-Invasive Adjuvant Biomechanical Treatment for Patients with Altered Rehabilitation after Total Knee Arthroplasty: Results of a Pilot Investigation", Clinics in Orthopedic Surgery, 2015. Publication	<1%

69	Xueyong Shen. "Effect of combined laser acupuncture on knee osteoarthritis: a pilot study", Lasers in Medical Science, 03/2009 Publication	<1%
70	mhealth.jmir.org Internet Source	<1%
71	www.alzheimers.org.au Internet Source	<1%
72	ijcv.org Internet Source	<1%
73	Volker, Dianne, and Peony Lee. "Osteoarthritis : Nutrition and Lifestyle Interventions", Modern Nutrition, 2006. Publication	<1%
74	di.ku.dk Internet Source	<1%
75	Submitted to Manchester Metropolitan University Student Paper	<1%
76	Das, A.. "Efficacy of a combination of FCHG49(TM) glucosamine hydrochloride, TRH122(TM) low molecular weight sodium chondroitin sulfate and manganese ascorbate* in the management of knee osteoarthritis", Osteoarthritis and Cartilage, 200009 Publication	<1%

77	publications.theseus.fi Internet Source	<1%
78	Submitted to Sheffield Hallam University Student Paper	<1%
79	Sheehy, Lisa. "Radiographic assessment of leg alignment and grading of knee osteoarthritis: A critical review", World Journal of Rheumatology, 2015. Publication	<1%
80	Young, J. L., and E. D. Lemaire. "Linking Bone Changes in the Distal Femur to Functional Deficits : Linking Bone Changes in the Distal Femur to Functional Deficits", International Journal of Osteoarchaeology, 2012. Publication	<1%
81	Leppavuori, J.. "Genome Scan for Predisposing Loci for Distal Interphalangeal Joint Osteoarthritis: Evidence for a Locus on 2q", The American Journal of Human Genetics, 199910 Publication	<1%
82	Englund, Martin. "Meniscal tear—a feature of osteoarthritis", Acta Orthopaedica Scandinavica, 2004. Publication	<1%
83	Ibrahim, Mazin S, Muhammad A Khan, Ikram	

Nizam, and Fares S Haddad. "Peri-operative interventions producing better functional outcomes and enhanced recovery following total hip and knee arthroplasty: an evidence-based review", BMC Medicine, 2013.
Publication

<1%

EXCLUDE QUOTES	ON	EXCLUDE MATCHES	OFF
EXCLUDE BIBLIOGRAPHY	ON		