

# Symptoms and quality of running experienced by road runners after a hip or knee replacement



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# Index

Index.....	2
List of tables .....	4
List of figures .....	5
Key terms.....	6
Abstract .....	7
Abstrak .....	8
Chapter 1 : Introduction.....	10
1 Problem statement.....	11
2 Aim of research .....	11
2 Objective .....	11
3 List of abbreviations .....	12
Chapter 2 : Literature review .....	13
1 Hip .....	13
a) Hip anatomy .....	13
b) Hip replacement.....	16
c) Surgical approaches and their influences .....	16
d) Rehabilitation after replacement.....	18
e) Symptoms after a hip replacement.....	19
2 Knee.....	22
a) Knee anatomy .....	22
b) Knee replacement .....	26
c) Surgical approaches and their influence .....	26
d) Rehabilitation after replacement.....	27
e) Symptoms after a knee replacement .....	28
3 Biomechanics during running.....	31
4 Conditions leading to a joint replacement.....	33
a) Osteoarthritis .....	33
b) Rheumatoid arthritis .....	36
c) Septic arthritis .....	36
d) Fracture .....	37
e) Other .....	37

5	Athlete running parameters.....	38
a)	Fitt VP .....	38
b)	Running.....	38
c)	Running shoes .....	40
d)	BMI .....	40
6	Return to running after a joint replacement.....	42
Chapter 3 : Methodology .....		56
1	Research design.....	56
2	Study sample .....	56
a)	Study population .....	56
b)	Study sample .....	57
c)	Inclusion criteria .....	57
d)	Exclusion criteria .....	57
3	Measuring instruments .....	58
4	Ethical clearance.....	59
5	Pilot study.....	60
6	Method.....	61
7	Data capturing and analysis .....	62
Chapter 4 : Results .....		63
Chapter 5 : Discussion .....		89
Chapter 6 : Limitations and Recommendations .....		102
Chapter 7 : Conclusion .....		104
References : .....		106
Appendices .....		119
1	Appendix A : English Questionnaire .....	119
2	Appendix B: Ethical clearance certificate .....	124
3	Appendix C : Information leaflet .....	125
4	Appendix D: Informed consent .....	128

# List of tables

- **Table 1** : A summary of the hip joint structures affected during a hip replacement (Pg 15)
- **Table 2** : A summary of the ligament structures and function (Pg 23)
- **Table 3** : A summary of the muscle structures and their function (Pg 24)
- **Table 4** : Possible causes of pain and stiffness after a knee replacement (Pg 30)
- **Table 5** : Terminology and the definition of the FITT-VP principle (Pg 38)
- **Table 6** : BMI ranges (Pg 41)
- **Table 7** : Classification of sport according to it's impact (Pg 43)
- **Table 8** : Benefits and risks of prosthesis options (Pg 50)
- **Table 9** : Influences on sports and athletics (Pg 51)
- **Table 10** : Symptoms and signs after a replacement (Pg 52)
- **Table 11** : Running parameters after a knee replacement (Pg 53)
- **Table 12** : Personal factors after a replacement influencing return to running (Pg 54)
- **Table 13** : Symptoms experienced according to surgery site (Pg 64)
- **Table 14** : The demographics and running information for each participant (Pg 66)
- **Table 15** : Running parameters for each participant (Pg 68)
- **Table 16** : Comments made by participants (Pg 86 & 87)

## List of figures

- **Figure 1** : Ligaments and the anatomy of the hip joint (Pg 14)
- **Figure 2** : The knee anatomy (Pg 25)
- **Figure 3** : Age distribution of sports participants with joint replacement (Pg 46)
- **Figure 4** : The survival rate of replaced joints when participating in high impact sports versus low impact sports (Pg 48)

## Key terms

**Hip replacement** – Hip replacement entails the removal of either the acetabulum / or and the femoral head and replacing it with an artificial part.

**Knee replacement** – Knee replacement entails the removal of either the femoral condyle/s and / or the tibial plateu and replacing it with an artificial part, though sometimes the patella is also replaced.

**Returning** – This implies that the participant were running before and started running again after the replacement, irrespective of the time passed in between picking up running after the replacement.

**Runners** – Any participant who runs for pleasure or competed in races of any distance, walkers were excluded.

**Sport** – For the purpose of this study sport refers to running unless otherwise described in the text.

**Symptoms** – Symptoms refer to pain, stiffness, swelling, etc. that a participant may experience.

**Quality of running** - For the purpose of this study the term 'quality of running' refers to the participants' satisfaction, running distance, running time and running pace while compared to the participant's own parameters by using the participant's pre-operative values.

# **Abstract**

## **Discussion**

The literature on the subject shows that return to running after a hip or knee replacement varies from 3.8% to 100%. The research regarding the symptoms patients experience when returning to running after a hip or knee replacement is limited while there is even less research regarding the quality of running when returning after a hip or knee replacement. The purpose of this study is to describe the symptoms and quality of running experienced by road runners after a hip or knee replacement. Several studies have found that the intensity of running and mileage decreased while the frequency and duration of training increased after a hip or knee replacement.

## **Data capturing and analysis**

Completed questionnaires were printed by the researcher and the data collected was captured on an Excel spread sheet. The Excel sheet was coded according to the responses to ensure that one language and format of capturing was utilised. The data received from the biostatistician were interpreted by the researcher. Results were divided into categories according to the type of surgery received (hip or knee replacement), the BMI and the rehabilitation participants received. Since the data is mostly descriptive, results were presented by means of frequencies and percentages for categorical data, and medians and means for continuous data.

## **Results**

During this study ten patients were questioned regarding their demographics, symptoms and quality of running after a hip or knee replacement with the use of a questionnaire. The results of this study indicated that running with a replacement is possible, but symptoms such as pain and stiffness are present during and after running. Fifty percent of the participants gave negative feedback regarding running with a hip or knee replacement. Runners experienced a higher intensity of pain while running when compared to walking, though the intensity of pain experienced was less when compared to before the replacement. The level of stiffness experienced was lower after the replacement.

## **Conclusion**

Running may not be safe in the long term when taking the results in account and is accompanied with discomfort and pain.

## **Keywords**

Running, replacement, knee, hip, symptoms.

# **Abstrak**

## **Bespreking**

Literatuur wat handel oor terugkeer na hardloop na 'n heup of knie vervanging wys dat die geval wat atlete terugkeer wissel van 3.8% tot 100%. Navorsing rakende simptome wat pasiënte ervaar met terugkeer na hul heup of knie vervanging is beperk alhoewel navorsing wat handel oor die kwaliteit van hardloop wanneer pasiënte terugkeer na 'n heup of knie vervanging selfs minder is. Die doel van hierdie navorsingstudie is om die simptome en kwaliteit van hardloop te bespreek wanneer 'n atleet terugkeer na sy / haar sport na 'n heup of knie vervanging. Verskeie navorsing studies het gevind dat die intensiteit van hardloop en die afstand het verminder terwyl die frekwensie en tydsduur van hul oefensessies vermeerder het na 'n heup of knie vervanging.

## **Data opname en analisering**

Die voltooide vraelyste was uitgedruk deur die navorser en die data was op 'n excel vorm ingesleutel. Die excel vorm was gekodeer op grond van die terugvoer wat ontvang is van die deelnemers om eenvormigheid in taal te verseker. Dit was aan die biostatistikus getuur en sy terugvoer was deur die navorser geïnterpreteer. Resultate was verdeel in kategorieë volgens die tipe vervanging wat hul ontvang het (heup of knie vervanging), hul BMI en die tipe rehabilitasie wat hul ontvang het. Aangesien die data meestal beskrywend is, was resultate voorgestel deur middel van frekwensies en persentasie vir data in kategorieë, en mediane en gemiddelde vir kontinue data.

## **Resulate**

Tien deelnemers het 'n vraelys voltooi wat hul demografie, simptome en kwaliteit van hardloop na 'n heup of knie vervanging ondersoek tydens die navorsing studie. Resultate van die studie dui daarop dat dit moontlik is om te hardloop met 'n heup of knie vervanging, alhoewel simptome soos pyn en styfheid steeds daar is tydens en na hardloop sessies. Vyftig present van die deelnemers het negatiewe terugvoer gehad rakende hardloop met 'n heup of knie vervanging. Hardlopers het 'n hoer intensiteit van pyn ervaar terwyl hul hardloop in vergelyking met terwyl hul loop, alhoewel die intensiteit van pyn laer was in vergelyking met die pyn voor die vervanging. Die vlak van styfheid wat deelnemers ervaar het was minder na die vervanging in vergelyking met voor die vervanging.

**Gevolgtrekking**

Hardloop mag dalk nie veilig wees op die langtermyn nie indien die resultate in ag geneem word en hardloop gaan gepaard met pyn en ongemak.

**Sleutelwoorde**

Hardloop, vervanging, heup, knie, simptome.

# Chapter 1 : Introduction

During this chapter the research question, aim and objectives will be discussed as well as why the need for this study exists. Limits in the current available research will be discussed to explain the role of this study.

Athletes participate in many countries in running and there is an increased participation in road running events seen in the United States of America (Running USA 2012). Common problems experienced by runners are degeneration and osteoarthritis of the hip and knee joints (Conaghan 2002) and treatment of severe cases of degeneration is a joint replacement. A common concern amongst athletes after a joint replacement is their ability to return to their sport. Return to running after a hip or knee replacement seems to be controversial though, as certain studies results indicate that it is not advisable to return to running (Ross and Brown 2010, p. 47, Vogel *et al.* 2011 and Bradbury *et al.* 1998) yet others have found that return to running does not influence the replacement (Jassim, Douglas and Haddad 2014, p. 923 and Abe *et al.* 2013, p. 133). The reason for this recommendation might be a lack of knowledge regarding what to expect when a runner returns to his/her sport. This lack of knowledge entails the quality of running, safety of running and the symptoms experienced by the individual when he or she returns to running after a hip or knee replacement, as well as the dangers associated with return to running. Despite the uncertainty and recommendation by surgeons, several runners still return to running (Ollivier *et al.* 2012, p. 3061 and Fouilleron *et al.* 2012, p. 4) providing challenges for both the medical team and the patient alike. It was found by Ollivier *et al.* (2012, p. 3061) that 36% of patients are involved in athletic activities at the time of surgery and this increases to 52% five years after surgery. Abe *et al.* (2013) investigated the quality of running after a hip replacement and indicated that no negative influences were observed during the short term.

Because runners are returning to running despite a lack of knowledge concerning the dangers associated with this, the importance of providing information is clear. The lack of knowledge includes information regarding the quality of running, safety of running and the symptoms experienced when return to running after a hip or knee replacement.

No similar study has been performed in South Africa or Africa thus far providing insight into the symptoms (or lack thereof) when a runner returns to his/her sport. The results of this study will aid health care professionals and runners regarding what is to be expected if a runner returns to his / her sport after a THR or TKR.

## *1 Problem statement*

Runners are returning to running despite a lack of knowledge concerning dangers associated with returning to running. Information regarding symptoms experienced after returning to running as well as the expected quality of running upon return creates a clear need for information, especially in South Africa as no study in South Africa was performed and running is very popular in South Africa.

## *2 Aim of research*

The aim of the research study was to describe the symptoms experienced by road runners as well as the quality of running experienced by runners after a hip or knee replacement.

## *2 Objective*

- 1) To describe the quality of running after a hip or knee replacement.
- 2) To describe the influence of BMI on symptoms and quality of running.
- 3) To describe the influence of the type of replacement on the symptoms and quality of running.
- 4) To describe the influence on rehabilitation on the symptoms and quality of running.

### *3 List of abbreviations*

- BMI – Body Mass Index
- FITT-VP – Frequency, Intensity, Time, Type, Volume and Preogression
- GRF – Ground Reaction Force
- M. – Muscle
- MIS – Minimal Invasive Surgery
- MRI – Magnetic Resonance Imaging
- OA – Osteoarthritis
- PRP –Platelet Rich Plasma
- QOL – Quality of Life
- RA – Rheumatoid Arthritis
- TKR – Total Knee Replacement
- THR – Total Hip Replacement
- USA – United States of America
- VAS – Visual Analog Scale
- WHO – World Health Organisation

As seen during this chapter the need for more information is vital seeing as runners are returning to their sport despite a lack of information regarding the symptoms experienced, the safety of running with a replaced joint as well as the quality of running to be expected when returning to running after a replacement.

## *Chapter 2 : Literature review*

The anatomy of the knee and hip joint will now be discussed as this will improve the understanding of the discussions which will follow. The conditions predisposing a joint to replacement will be discussed as well as hip and knee replacements. The surgical approaches, rehabilitation, symptoms after the replacement and biomechanics will also be reviewed according to a hip or knee replacement. This will provide the information on all the possible symptoms which may be expected, the rehabilitation suggested and how the biomechanics may be influenced. The athlete will be considered next explaining how the Frequency, Intensity, Time, Type, Volume and progression (FITT VP) principles apply and also how running patterns and shoes and how the athlete's body mass index (BMI) may influence the results of this study. Lastly the research within this field will be reviewed to outline the available research and findings.

### *1 Hip*

#### *a) Hip anatomy*

The hip joint is a synovial ball and socket joint of which the primary movements are hip flexion, extension, abduction, adduction, internal and external rotation. The hip joint is considered to be a fairly stable joint due to its anatomy. The acetabulum is a deep rim which is further deepened by the labrum, thus increasing the stability of the hip joint by increasing the contact area (Moore and Dalley 2006, p.675). Refer to Figure 1.

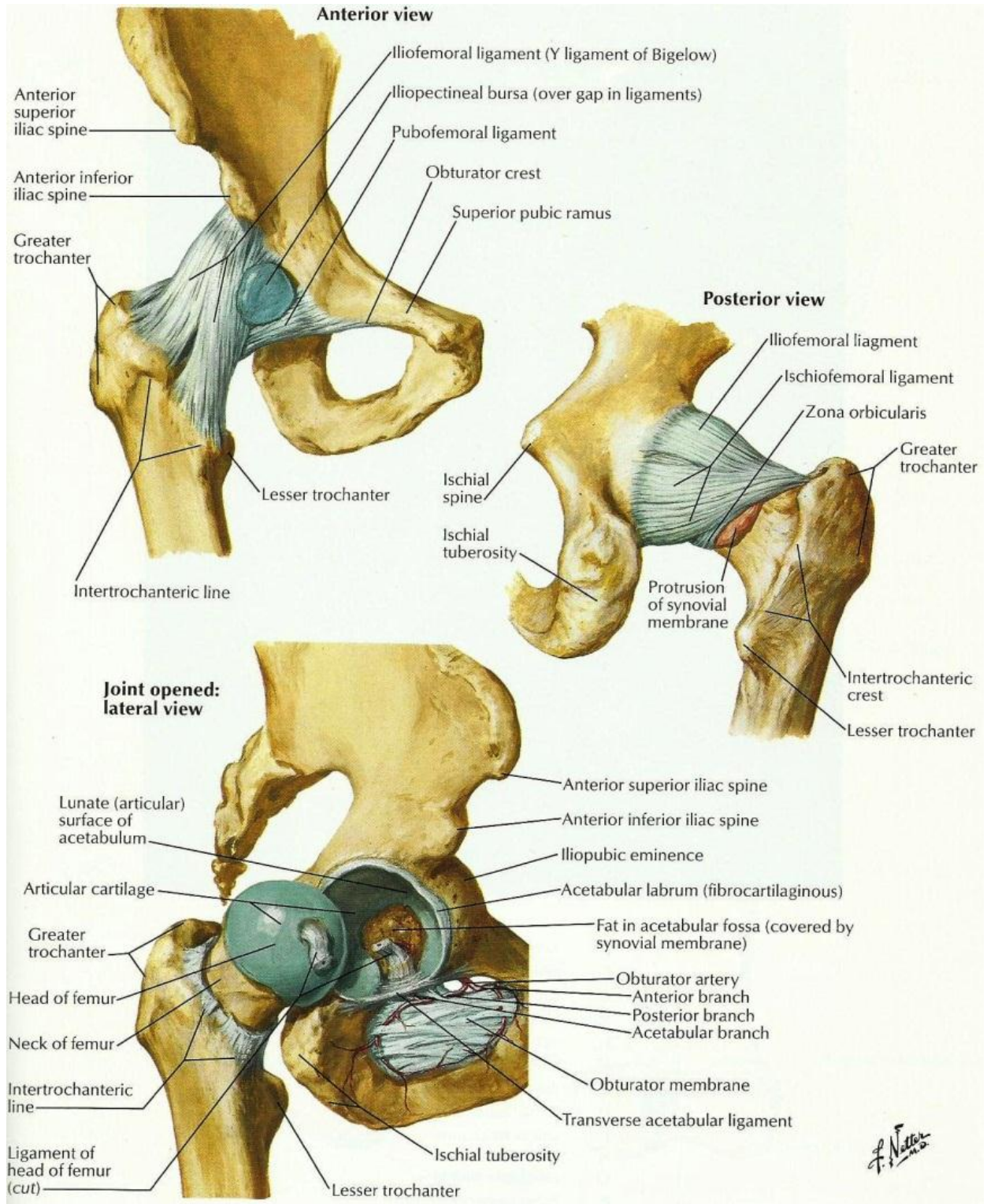


Figure 1 : Ligaments and the anatomy of the hip joint (Netter 2006, p. 487)

The ball part of the joint consists of the femoral head which is a convex object and fits into the concave acetabulum. The hip joint has a strong capsule and surrounding ligaments with large muscles surrounding the joint. These muscles include the m. gluteus, m. rectus femoris, m. iliopsoas, m. abductors and m. adductor. Posteriorly, m. gluteus and m. piriformis surround the hip where m. gluteus extends laterally along with m. tensor fascia lata. Muscles situated anteriorly include the m. iliopsoas and m. rectus femoris.

Structures that are damaged or incised during a hip replacement include the anterior and posterior capsule, the short external rotators as well as gluteus medius and minimus. Their functions are discussed in the table 1 below (Netter 2006, p.609, 612, 622, 678).

**Table 1 : A summary of the hip joint structures affected during a hip replacement**

<b>Structure</b>	<b>Anatomy</b>	<b>Function</b>
Anterior capsule	Two layers form the capsule, a fibrous layer and a synovial membrane. The capsule is strengthened antero-superiorly by the iliofemoral ligament ant antero-inferiorly by the pubofemoral ligament.	Provide stability to the hip joint
Posterior capsule	Two layers form the capsule, a fibrous layer and a synovial membrane. The capsule is strengthened posteriorly by the ischiofemoral ligament.	Provide stability to the hip joint
Short external rotators	Piriformis, obturator internus, superior and inferior gemelli and quadratus femoris muscles.	Laterally rotates femur and steadies femoral head in the acetabulum.
Gluteus medius	Fan shaped muscles deep to the gluteus maximus muscle with insertion onto the greater trochanter. Gluteus minimus is deeper to gluteus medius	Abduction and medial rotation of femur, prevents trendellenburg
Gluteus minimus		

## *b) Hip replacement*

A hip replacement can either be done in totality or partially depending on the degeneration of or damage to, the joint (Lee *et al.* 2013). A total hip replacement (THR) consists of removing the femoral head and acetabulum and replacing these two components with artificial components. During a hip replacement, an incision is made through different muscles depending on the approach used, and these muscles then have to be re-attached after surgery (Jerosch, Theising and Fadel 2006). The different incisions with their effects are discussed below. A partial hip replacement entails the replacement of one of the articular components, either the femoral or the acetabular component. The type of replacement performed by the orthopaedic surgeon will depend on the type of degeneration of, or damage to, the joint as well as the surgical approach to be adopted (Lee *et al.* 2013).

## *c) Surgical approaches and their influences*

Kurtz *et al.* (2007, p. 781) stated that the occurrence of THR will increase from 209 000 procedures to 572 000 procedures per year in the USA, a total increase of 174% between 2005 and 2030. This rise in THR rates may be ascribed to the developing demand for a replacement due to the increased success and improved outcome after a THR. A possible cause for the additional need for THR may be the increased body mass index (BMI) of the population, according to Sturm (2007, p. 492), where one in four Americans are overweight. Similar results are seen in South Africa where obesity is increasing dramatically according to Stats SA (2003) and the HSRC (2013). No literature was available indicating the rate of THR in South Africa. The anterolateral and posterior approaches are commonly used in THR. During the posterior approach, the posterior capsule is severed as well as the short external rotator muscles while maintaining the abductor muscles. During the anterolateral and lateral approaches the anterior capsule is exposed by cutting through a portion of the m. gluteus medius and minimus to perform the replacement (Ross and Brown 2010, p. 44).

After completing a Cochrane review, Jolles and Bogoch (2006) failed to prove a superior surgical approach when performing a hip replacement. This was also stated by Ibrahim *et al.* (2013, p. 6). During a prospective study conducted by Smith *et al.* (2012, p. 360) the researchers found that patients reported better outcomes after a posterior approach when compared to the anterolateral approach. Although not discussed by the authors, the activities and age of the patients as well as the rehabilitation of the patients in each of the three studies may have varied, thus resulting in improved end results by patients who underwent more rehabilitation. Unfortunately the studies did not state how much more rehabilitation the patients received.

Minimal invasive surgery (MIS) implies that a smaller incision (less than 10cm) causing less damage to the skin, muscles and bone respectively (Ibrahim *et al.* 2013, p. 6 and Jerosch, Theising and Fadel 2006, p. 164). The same approaches discussed previously can be applied during MIS. During the anterior approach no muscles are cut and minimal damage is caused, but with the lateral approach, an incision is made through the m.gluteus medius muscle which is split and therefore the only muscle damaged (Ilchmann *et al.* 2013, p. 136). The preservation of the soft tissue shows a positive relationship with the rate of dislocations (Jerosch, Theising and Fadel 2006, p. 171) as dislocation forces can be counteracted more effectively by the muscles which thus decreases the dislocation rate. Minimal invasive surgery may have a resultant effect of improved functional ability after the replacement when compared to the standard techniques (Jerosch, Theising and Fadel 2006, p. 170). Madsen *et al.* (2004, p. 44) showed that 85% of patients have a limp after the standard surgery technique which may lead to compensation and adaptive movement patterns, with resultant injuries in the areas of the spine, knee and ankle. Although MIS shows good results initially, the long-term effect may be impeded due to poor visibility during the procedure, resulting in poor placement of the prosthesis (Zhang *et al.* 2014, p. 69).

The fixation of the prosthesis can be cemented, uncemented or hybrid fixated (Smith *et al.* 2012, p. 358). Despite a lack of evidence proving the superiority of cementless fixation, surgeons increasingly prefer this method instead of cemented and hybrid fixation (Chechik *et al.* 2013, p. 1599); however, the researchers did not state the reason for the preference.

#### *d) Rehabilitation after replacement*

Ross and Brown (2010, p. 48) suggested that physiotherapy treatment and rehabilitation post-operatively may significantly benefit the patient who intends to return to sport. Sports that are recommended to increase mobility and strength after a hip replacement by Dubs, Gschwend and Munzinger (1983, p. 165) includes swimming, cycling, rowing and walking.

Rehabilitation of the patient after a hip replacement may be performed in a group or individually, depending on the physiotherapist and hospital the patient is referred to.

Guidelines directing the therapy needed are scarce (Artz *et al.* 2013) and physiotherapy rehabilitation after a hip replacement includes strengthening of muscles surrounding the hip joint as well as any other muscles that are found to be weak during the assessment of the patient, applicable muscle stretches, limitations in functional activities and cardiovascular exercises (Artz *et al.* 2013). Physiotherapy rehabilitation is generally individualised due to the different impairments and activity limitations that the patient presents with. The three day rehabilitation process followed by Umpierres *et al.* (2014) for in-hospital treatment included education of the patient (regarding movements that should be avoided and limb positioning) as well as strengthening exercises targeting the gluteal and thigh muscles (three sets and 12 repetitions) and sitting in a chair on day one, followed by gait retraining on day two which was then continued on day three until discharge. Patients were also encouraged to continue with the physiotherapy exercises upon discharge as instructed.

Improving the hip abductor strength during physiotherapy treatment and rehabilitation may improve the patient's ability to return to sport as this will prevent a limp and decrease the force transmission through the hip (Ross and Brown, 2010, p. 48). However, the reasons for including exercises to improve the muscle bulk/strength, co-ordination, balance and reflexes in the rehabilitation before the patient returns to sport was not provided by Yun (2006, p. 362). A possible reason for the exercises could be to prevent further injuries and instability in the newly implanted joint. The increase in muscle bulk will improve the stability of the joint by creating a physical barrier that will prevent dislocation and subluxations. Improving co-ordination and balance will result in a decreased chance for injuries to occur. The use of ambulatory assistive devices for a prolonged period of time, may also improve the functional outcomes of the patient (Ross and Brown 2010, p. 48). Berger *et al.* (2004) found that crutches are discontinued six days after the surgery although this research was only conducted

on MIS replacements. Ross and Brown (2010, p. 49) suggested that patients who participate in sport activities after a hip or knee replacement should have radiographs taken yearly to enable the surgeons to detect early adverse effects and to address the adverse effects accordingly (these adverse effects are discussed in the sections that follow).

### *e) Symptoms after a hip replacement*

Beaulieu, Lamontagne and Beaulé (2010) described the changes in the gait pattern after a hip replacement, finding that patients retain the same antalgic gait pattern as shown pre-operatively. Patients typically walk with a smaller hip range of motion on the side of the surgery with smaller stride lengths and seem to prefer the adducted position, while hip extension and abduction are neglected. The study also found an associated weakness of the hip abduction and extension muscles, partly due to the surgical incision (especially with the lateral approach) (Beaulieu, Lamontagne and Beaulé 2010, p. 272 and Ross and Brown 2010, p. 44) and pre-surgical muscle atrophy.

Negative effects after a hip or knee joint replacement may include delayed hypersensitivity, osteolysis, instability, wear and tear, aseptic loosening, peri-prosthetic fracture and dislocations, but this will differ from individual to individual (Heisel, Silva and Schmalzdried 2003, p. 1374; Hui *et al.* 2011, p. 624 ; Höll *et al.* 2012, p. 2513). There also seems to be an increased associated risk for cancer with metal-on-metal prosthesis bearings (Heisel, Silva and Schmalzdried 2003, p. 1374). Delayed hypersensitivity experienced after a hip or knee replacement may include symptoms such as unexplained pain associated with aseptic effusions and implant loosening, but it is not clear whether the hypersensitivity causes the aseptic loosening or if the loosening causes the hypersensitive reaction. (Heisel, Silva and Schmalzdried 2003, p. 1375).

Osteolysis is the process of breakdown or reabsorption of bone. It is usually symptom free and weakens the bone due to bone density decrease and forces that normally would not have any effect on normal bone, causing fractures (Heath *et al.* 2009). Detection of osteolysis proves to be difficult and normally occurs too late as osteolysis is detected only when a fracture occurs and investigations such as x-rays or scans show a decrease in bone density

(Ren *et al.* 2011). Osteolysis around the knee is more difficult to detect after a replacement as the proximal tibia and distal femur typically have a lower bone density and the prosthesis further limits the visibility of the fractures and area (Berry 2004). Lübbecke *et al.* (2011, p. 457) investigated the osteolysis rate in cemented hip replacements after 10 years of high impact activities and found the rate to be 20% in good cemented hips in comparison with 50% in poorly cemented hips. They also stated that this rate seems to be decreasing as years pass due to improved technology

Smith *et al.* (2012, p. 359) found that a number of patients still experience pain, functional limitations and dissatisfaction after a hip replacement. These findings were supported by Cowie *et al.* (2013, p. 698) who reported that 6.5% of patients still experienced hip pain, 5.8% experienced decreased range of movement and 8.4% experienced stiffness. Jerosch, Theising and Fadel (2006, p. 165) suggested that the cause of hip pain might be due to the trochanteric bursa that is excised during surgery, while Beaulieu, Lamontagne and Beaulé (2010, p. 269) concluded after their research that muscle weakness may be the cause of pain. The reason for these differences in opinion might be that Beaulieu, Lamontagne and Beaulé (2010) chose their participants more carefully and followed their patient's progress up to 15 months, while Jerosch, Theising and Fadel (2006) only included one surgeon's patients and followed the participants' progress up to 12 months.

Auffarth and Reschet (2011 cited in Chechik *et al.* 2013, p. 1597) indicated that higher levels of pain after surgery were found during the anterior approach hip replacement. Even though hip pain after a hip replacement was found in 9% of patients, knee pain with a knee replacement was found to be as high as 16% in patients (Huch *et al.* 2005, p. 1720). Huch *et al.* (2005) suggested that the reason for this might be that typically hip replacement patients maintain a higher level of activity and participation in sports than knee replacement patients.

Numbness laterally and caudally to the incision may occur due to palsy of the lateral femoral cutaneous nerve which may occur during a hip replacement utilising the anterior approach (Ilchmann *et al.* 2013, p. 136). The incidence of lateral femoral cutaneous nerve palsy is increased to 70% during the anterior approach (Chechik *et al.* 2013, p. 1597), and lateral femoral cutaneous nerve palsy may lead to a loss of sensation in the lateral aspect of the thigh and weakness of hip flexion and extension (Kargel *et al.* 2006, p. 240).

Palsy of the sciatic nerve can occur during the posterior approach, resulting in a loss of sensation and motor function in the posterior aspect of the lower limb (Jerosch, Theising and Fadel 2006, p. 170), weakness or paralysis of hip flexion, extension and all ankle movements (Moore and Dalley 2006, p. 623). Hip abductor and extensor muscles are commonly found to be weak after a hip replacement, as stated by Mikkelsen, Mikkelsen and Christensen (2012, p. 224) and Fouilleron *et al.* (2012, p. 5), but the authors did not state the reason for the weakness. A possible reason could be the incision, pain inhibiting the muscle or fear of exercise. The incidence of sciatic nerve palsy in hip replacements is 0.17% to 7.6% and is associated with neuropathic pain syndromes (Wolf *et al.* 2014, p. 1). Neuropathic pain is classified as pain that is instigated by any lesion or dysfunction in the nervous system (Bouhassira *et al.* 2005, p. 30) and symptoms include paroxysmal or persistent pain that is not associated with a stimulus (Woolf and Mannion 1999, p. 1960).

Results from a study performed by Jerosch, Theising and Fadel (2006, p. 170) indicated that the rate for hip dislocation is increased during the posterior approach when compared to the anterolateral and lateral approach. During the anterolateral approach, the abductors are excised and the strength of the muscles may be decreased, causing the patient to limp. (Jerosch, Theising and Fadel 2006, p. 170).

## *2 Knee*

### *a) Knee anatomy*

The knee is a synovial joint with primary movements of flexion/extension. The knee joint consists of three joints namely the patellofemoral, the tibiofemoral and the tibio-fibular joint (Moore and Dalley 2006, p. 684). Although the biomechanics of the entire body have an influence on the knee joint due to the lower limb being viewed as a closed kinetic chain, the focus will mainly be on the knee biomechanics. The reason for this is that movement in one joint of the lower limb results in movement of other joints of the lower limb.

Although the articulation and congruency themselves do not provide for a stable joint, the stability of the knee joint is provided by several structures including the ligaments, the muscles, capsule and the meniscus (Bowman and Sekiya 2010 and Shoemaker and Markolf 1986). According to Shoemaker and Markolf (1986) the meniscus plays an important role in the stability of the knee and was proven by examining the stability in cadaveric knees with the meniscus intact, partially removed and totally removed. The capsule, along with ligaments surrounding the knee joint, limits accessory movement of the knee as described by Bowman and Sekiya (2010).

Ligaments of the knee include the cruciate ligaments, the patellar ligaments, the medial collateral ligament complex, the lateral collateral ligament complex, the posterolateral ligament complex and the oblique popliteal ligament complex. Please refer to Table 2 for a summary of the structures and function of the knee joint.

**Table 2 : A summary of the ligament structures and function**

<b>Structure</b>	<b>Function</b>	<b>Author or reference</b>
Anterior and posterior cruciate ligaments	Prevent anterior and posterior translation in the knee joint respectively.	Veltri <i>et al.</i> 1995
Posterolateral ligament complex	Limits posterior translation, varus movements, external rotation and external rotation.	Veltri <i>et al.</i> 1996
Popliteal complex	Resists posterior translation, varus movements and external rotation.	Veltri <i>et al.</i> 1996
Medial collateral ligaments	Prevent valgus of the knee and limit anterior translation of the tibia.	Robinson <i>et al.</i> 2006
Posteromedial capsule	Limits valgus movements, internal rotation and posterior translation of the tibia with knee extension.	Robinson <i>et al.</i> 2006
Lateral collateral ligaments	Limit varus movements, anterior translation and external rotation.	Wroble <i>et al.</i> 1993

The femoral component of the knee is a convex surface area and the tibial plateau a more concave area. The tibial plateau has a ridge more or less in the middle, dividing the plateau into a medial and lateral area and therefore increasing the surface area. The notch between the two femoral condyles fits the medial and lateral eminences of the tibial plateau thus improving stability (Schneppendahl *et al.* 2012, p. 2091). Volz *et al.* (1988) found that a knee replacement closely matches the anatomy of the knee. When looking at the knee models which have mock tibial eminences, it was found to be more stable than those without the ridge.

Table 3 below provides a summary of the muscle structures and function of the knee joint, while Figure 2 visually illustrates the anatomy of the knee and the structures discussed in this section.

**Table 3 : A summary of the muscle structures and their stabilising function**

<b>Muscle structure</b>	<b>Function</b>
Tensor fascia lata and m. gluteus maximus	Inhibits the adduction force on the knee and reinforces the capsule.
Iliotibial band	Provides varus stability in knee extension, especially while running.
M. Semimembranosus	Decreases anterior subluxation of the knee and tenses the knee's stabilising ligaments.
M. Gastrocnemius	Reinforces the capsule and improves knee stability.
Hamstring	Prevent posterior translation of the femoral condyles on the tibia and prevents hyperextension.
M. Quadriceps	Prevents posterior subluxation and anterior translation.
M. Popliteus	Primary local stabiliser.

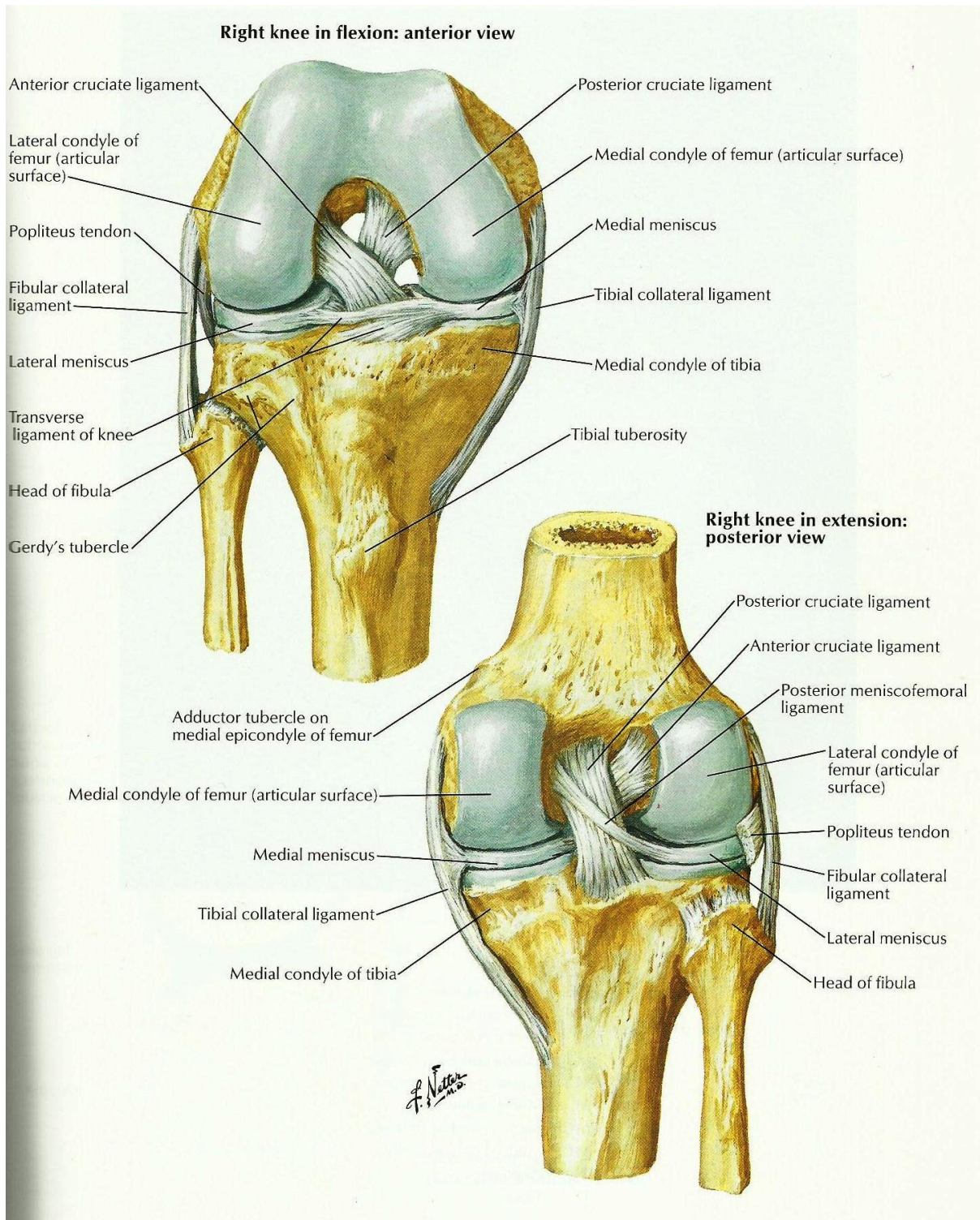


Figure 2 : The knee anatomy (Netter 2006, p. 509)

## *b) Knee replacement*

A total knee replacement (TKR) entails the removal of the femoral condyles and tibial plateau and replacing these with artificial components. A partial knee replacement entails the replacement of one component of the knee with an artificial component, usually either the tibia or femur. With a uni-compartmental knee replacement, only one component of the tibia or femur is replaced, either the lateral or medial condyle. It is expected that the rate of total knee replacements will grow by 673% between 2005 and 2030 because patients typically have a higher BMI, are more active and live longer (Crowninshield, Rosenberg and Sporer 2006 cited in Wylde *et al.* 2008, p. 920). No statistics for the prevalence of knee replacements in South Africa could be found.

## *c) Surgical approaches and their influence*

With a knee replacement, three approaches can be utilised to perform the surgery, namely the standard medial para-patellar, mid-vastus and sub-vastus approach (Ibrahim *et al.* 2013, p. 5).

Although the standard medial para-patellar approach is the most common due to good exposure of the knee joint, the blood supply and extensor mechanisms are compromised and rehabilitation can be adversely affected (Alcelik *et al.* 2012, p.230). The mid-vastus approach results in lower pain levels post-surgery and improved range of motion and muscle strength, but the knee is not adequately exposed and this may compromise the success of the joint replacement. The sub-vastus approach shows good results regarding pain post-surgery and muscle strength, but in the long-term, this procedure shows no differences to any of the other approaches (Ibrahim *et al.* 2013, p. 5).

Minimal invasive surgery in the knee means a smaller incision with less scarring at the incision site and Lüring *et al.* (2008, p. 933) showed that MIS has good short term effects in comparison with the standard technique, but the differences even out a year after the replacement. Siramanakul and Sriphirom (2012, p. 54) and Costa *et al.* (2013, p. 44) found that MIS has better functional outcomes when compared to the standard approach, but the long term functional outcome still needs to be determined and investigated. Although studies

indicate the results of MIS to be superior, there are associated challenges and risks to this approach, (Zhang *et al.* 2014, p. 65 and Lüring *et al.* 2008, p. 928) one of which is limited visibility during surgery. Fortunately this challenge can be addressed by computer-assisted knee replacement in combination with the MIS technique (Zhang *et al.* 2014, p. 66). The use of computer assistance is not a standard technique and this is only utilised by surgeons with a great deal of experience (Zhang *et al.* 2014, p. 70). Garrett and Walters (2010, p. 60) found that only 15% of surgeons regularly use computer assistance in South Africa during the performance of a knee replacement.

#### *d) Rehabilitation after replacement*

Bloomfield and Hozack (2014, p. 89) reported that a few athletes return to high impact sport after a hip and knee replacement, but their ability to compete in a high demand athletic sport may be limited due to pain, restricted functional outcome or activity limitations that were imposed by the surgeon. When the patient's strength, mobility, and coordination have improved sufficiently after a TKR, the patient is then allowed to return to high impact sport such as tennis, cross-country skiing, jogging, hiking, and mountaineering (Bradbury *et al.* 1998, p. 534).

The importance of a good rehabilitation programme is apparent throughout research due to the link made with muscle weakness and the development of symptoms (Beaulieu, Lamontagne and Beaulé 2010, p. 272 and Mizner and Snyder-Mackler 2005, p. 1083). Protocols directing the rehabilitation after a knee replacement are scarce, but general guidelines are available. Rahmann, Brauer and Nitz (2009) described the benefits of an inpatient aquatic physiotherapy programme as part of the rehabilitation process. They compared physiotherapy intervention in hospital, aquatic therapy and water therapy. The researchers described the aquatic therapy programme as specifically designed to improve function and muscle strength in the early post-operative phases, whereas the water exercises were general exercises in the hydrotherapy pool. The aquatic therapy proved to be superior with increasing hip abduction strength, although all therapies proved equal when measuring the gait speed and functional abilities. The exact programme followed for all three interventions is outlined in detail in the study of Rahmann, Brauer and Nitz (2009).

Naylor *et al.* (2006) described all therapeutic interventions provided by physiotherapists after a knee replacement by performing a survey in four hospitals providing physiotherapy rehabilitation after a knee replacement in Australia. They found that the most commonly used interventions include exercises (strengthening, aerobic, flexibility and functional exercises), functional activities (walking, stairs and sit-to-stand), manual therapy, stretches, management of pain or swelling and education in that order.

### *e) Symptoms after a knee replacement*

Mizner and Snyder-Mackler (2005, p. 1083) found that after a knee replacement, patients typically walked with shortened stride lengths and continued with their habitual gait after the knee replacement. M. Quadriceps strength was proven to be weakened and the asymmetry between the affected and unaffected leg was proven to be a significant contributor to the altered gait and functional movements. No studies are currently available describing the biomechanics of running after a knee replacement.

Running biomechanics is similar to the biomechanics discussed under hip replacement, though knee forces for the knee will be highlighted. Movements that typically occur at the knee are knee flexion and extension and a degree of tension is placed in an adduction and abduction force which is counteracted by the collateral ligaments. Knee flexion varies from 20° to 90° in the running cycle and therefore running should only be attempted once these ranges are obtained. Muscles surrounding the knee that are primarily used during running include the m. gastrocnemius, m. quadriceps and m. hamstring. The strength of these muscles needs to be addressed during rehabilitation to ensure sufficient strength for running.

After a knee replacement, pain, swelling and stiffness of the knee are common complications (Garrett and Walters 2010, p. 59), with the prevalence of knee pain and stiffness after a knee replacement varying from 1.1% to 10.8% according to Garrett and Walters (2010, p. 60).

Yercan *et al.* (2006, p. 114) found that the prevalence of stiffness can vary from three percent to 60% after a knee replacement and in South Africa, Garrett and Walters (2010) observed that 99% of patients experienced pain after the surgery, while 100% of the patients presented with swelling after the replacement. The possible causes for pain and stiffness after a knee

replacement are portrayed in Table 4, but the most common causes for pain include retained haematoma, infection, psychological, mechanical, hyper-immunity and allergy (Garrett and Walters 2010, p. 63).

**Table 4: Possible causes of pain and stiffness after a knee replacement (Garrett and Walters 2010, p. 65, Table II)**

<b>Common articular causes of pain</b>	<b>Causes of stiffness</b>
Infection	Pre-operative stiffness
Prosthetic loosening	History of previous surgery
Instability	Excessive pain
Component failure	Poor patient motivation
Patello-femoral disorders	Reflex sympathetic dystrophy
Peri-prosthetic osteolysis	Heterotopic ossification
<b>Common non-articular causes of pain</b>	
Hip disease	Posterior cruciate ligament tightness
Spine disease	Instability
Vascular disease	Peripheral obesity
Complex regional pain syndrome	Technical error
Psychological illness	Anteriorly shaped femoral cuts
Tendonitis/bursitis	Improper component position
	Oversized components
<b>Less common causes of pain</b>	
Patella clunk syndrome	Patello-femoral dysfunction
Lateral patella facet syndrome	Patella baja
Soft-tissue impingement syndromes	Joint line mismatch
Fabellar impingement	Overstuffing
Popliteus tendon dysfunction	Osteophytes
Tibial component overhang	
Heterotopic ossification	
Recurrent haemarthrosis	
Particulate-induced synovitis	
Cutaneous neuroma	

### *3 Biomechanics during running*

The subject of running biomechanics without a joint replacement was discussed and analysed in detail by Novacheck (1998). Running occurs in phases similar to walking. These phases include initial contact, stance phase, toe off and swing phase. During running various movements occur in the sagittal, coronal and transverse planes during each phase. The pelvis remains relatively stable, although slight movement does occur which influences the position of the hip joint. The hip generally goes into flexion, extension, abduction, adduction and rotation during running. Hip flexion varies from 20° to 80° during running and effective activation of the m. gluteus, m. hip flexors, m. hamstrings and m. quadriceps is needed. M. gluteus activation will prevent a trendelenburg gait and assist in hip extension along with m. hamstring which will also cause knee flexion. Hip flexor muscles will cause hip flexion assisted by m. quadriceps which also influences knee extension (Moore and Dalley 2006). During the stance phase, hip adduction occurs as a mechanism to absorb the impact forces, while during the swing phase the hip goes into slight abduction. The abduction during running leads to a change in joint loading and may decrease the risk for injury, according to Snyder *et al* (2009). For all of the movements to occur optimally, a stable hip joint, and pain free movement as well as optimal muscle and ligament function are all needed. It can therefore be concluded that running biomechanics remain similar after a hip replacement due to the anatomy of the muscles remaining unchanged and the implanted prosthesis mimics the original joint with improved gliding and decreased pain.

Before the patient returns to running, his/her pain, muscle strength (especially gluteal, hip flexor, hamstrings muscles and M. quadriceps) and the hip range of motion all need to be addressed, to prevent any dislocations or injuries that could have been prevented.

Beaulieu, Lamontagne and Beaulé (2010) performed an experimental study by comparing 20 THR patients' lower limb biomechanics with the biomechanics of 20 healthy control participants. The researchers found that weakness of the hip abductors and hip extensors predisposed the patient to a higher injury rate and increased stresses on the joint (Beaulieu, Lamontagne and Beaulé 2010, p. 269).

Konyves and Bannister (2005, p. 156) found that up to 27% of hip replacement patients may have leg length discrepancies. The authors associated leg length discrepancies with lower back pain, sciatica, dissatisfaction and dislocations. The importance of leg length should thus be considered along with muscle strength and balance and these controllable factors could have a serious short- and long-term effect on the body's functioning and the symptoms experienced.

Decreased stride length may be attributed to a decrease in leg length on the surgery side or a lack of required hip ranges as discussed above. This will lead to a shortened swing and stance phase on the surgery side, while the normal side still remains within the normal movement patterns. The shortened stride phases will lead to decreased running speed and will increase the energy output of the individual which in return will increase the chances of earlier fatigue. When fatigue occurs the runner may make use of an abnormal running pattern, and may decrease the stance and swing phase of running as a compensatory mechanism and adversely affect the muscle control and thus the joint stability. The abnormal running pattern will then result in increased strain on the hip and other areas of the body. Although the abnormal running pattern occurs in all fatigued runners, it may prove problematic after surgery if rehabilitation was not completed, thus compromising joint stability and resulting in injuries.

## *4 Conditions leading to a joint replacement*

Conditions that could lead to a joint replacement are osteoarthritis, rheumatoid arthritis, septic arthritis, fractures or other conditions. They are discussed below

### *a) Osteoarthritis*

Osteoarthritis (OA) is defined as degeneration of the articular cartilage of a joint (Dabiri and Li 2013, p. 1) and can be classified as primary or secondary OA. Primary OA is due to age and genetics, whereas secondary OA is due to any form of joint injury or trauma (Cymet and Sinkov 2006, p. 342). OA is a debilitating condition that adversely affects all people who suffer from it. The role of articular cartilage is to line bone endings to ensure smooth frictionless movements of the joint. In OA, the articular cartilage softens and loses elasticity first and then cartilage starts to flake, leading to the progressive thinning of the cartilage layer resulting in a decrease of the joint space. The flakes caused by the erosion act as an irritant for the synovial membrane and cause inflammation in the joint. Erosion of the cartilage continues until the underlying bone is exposed and pain will be experienced by the individual during movement. OA may also cause laxity in the ligaments and changes in the neuromuscular apparatus, suggesting that it is not only the cartilage that is affected (Levy *et al.* 2013, p.271; Takacs *et al.* 2013, p.93).

According to Shrier (2004, p. 534) and Conaghan (2002, p. 330), risk factors for the development of OA include general / systemic factors (obesity, genetics, age - due to weakening of the muscles) or biomechanical factors (climbing more than 15 flights of stairs, previous injuries, lifting more than 10 kg ten times a week), trauma and joint alignment. During the study conducted by Ross and Brown (2010, p. 42) it was found that OA can be predisposed by genetics and the race of an individual.

A general symptom due to OA includes morning stiffness lasting for less than an hour. The symptoms that patients typically experience when suffering from hip OA are longstanding groin pain that progressively worsens (Ross and Brown 2010, p. 43). They might also struggle with lateral leg pain or pain in the area of the greater trochanter, medial knee, lower lumbar or

gluteal area. Patients suffering from knee OA generally experience pain and stiffness in the knee joint and they move with difficulty (American Academy of Orthopaedic Surgeons Board of Directors 2013).

Patients suffering from OA of the hip or knee may present with an altered gait pattern due to the pain (Ross and Brown 2010, p. 43) and may adjust their functional level to be able to cope with their symptoms. Indications for a knee or hip replacement include pain that is unresponsive to medical management as well as radiographical changes in the joint caused by OA (Bradbury *et al.* 1998, p. 532).

As previously stated OA can be disabling and negatively affect a patient's life, in such cases by a hip or knee replacement will be performed to improve the patient's quality of life (De Tejada *et al.* 2010, p. 453 and Bruyère *et al.* 2012, p. 1584). Quality of life (QOL) is usually determined by measuring six domains: physical function, physical independence, pain, emotional state, psychological support and an overall score (Poitras, Beaulé and Dervin 2012, p. 1604). Although surgery imposes a short-term negative influence on QOL (Poitras, Beaulé and Dervin 2012, p. 1604), long term improvements in pain and physical function is observed after a joint replacement (Bruyère *et al.* 2012, p. 1583). Interestingly, no significant changes in the stiffness experienced by patients are observed after the replacement when being compared to before the replacement (Bruyère *et al.* 2012, p. 1583). Salaffi *et al.* (2005) proved that the QOL of patients who suffer from knee or hip OA is adversely affected when being compared with healthy individuals with no knee or hip OA. The largest fallouts of QOL were found with physical functioning as well as pain and according to Rat *et al.* (2009) five to 10% of cases after a knee replacement and 10 to 15% of cases after a hip replacement delivered less than satisfactory QOL and functionality levels.

Radiographical evidence of OA can be observed in the hip when individuals run excessive long distances, though the literature does not state what entails excessive distances (Cymet and Sinkov 2006, p. 343). A debate regarding the pathology of OA in runners exists in the current literature. Schueller-Weidekamm *et al.* (2006, p. 2179) found that running a marathon causes meniscal lesions and joint effusion in some runners, but no damage to the articular cartilage was observed. Krampla *et al.* (2001, p. 72) confirmed these results by performing

MRI scans on runners before and after a marathon. The researchers found that no damage was caused to either the bone or cartilage, but unfortunately both studies only assessed a single event and did not assess the influence of multiple events on the joints. Hohmann, Wörtler and Imhoff (2004, p. 55) proved that no changes in runners' hip and knee MRIs could be observed when comparing marrow oedema, periosteal stress reactions or joint effusions before and after running.

It was found by Shrier (2004, p. 533) that degeneration was not due to wear-and-tear of running or impact forces, but that OA was due to muscle dysfunction causing poor absorption of forces and impact. This leads to microtrabecular damage, which in turn causes sclerosis. This in turn could lead to changes in the stresses and strains across the articular cartilage with the resultant narrowing of the joint space. It can therefore be suggested that running long distances (more than 97 km per week) will lead to fatigue of the muscles, leading to a higher risk of OA. A single marathon run with sufficient rest after the marathon will not fatigue the muscles in trained runners and therefore will not lead to an increased risk of OA. No changes would be visible in the articular cartilage due to the changes occurring mostly in the bone where the force and impact are absorbed. The impact forces measured during running range from 1.5 to 5.5 times the body weight and the impact lasts for only a short period of time (Hreljac 2004, p. 846 and Abe *et al.* 2013, p. 131). Derrick, Dereu and McLean (2002, p. 998) also conducted similar research but results indicated that the impact force reached during running is approximately 1.5 to 2.5 times the body weight. This rate increases, however, when the runner experiences fatigue during running.

Numerous authors have found that OA is more prevalent in runners especially long distance runners and that radiographical changes may be an early predictor of OA (Spector *et al.* 1996, p. 993 and Tveit *et al.* 2012, p. 531 and Conaghan 2002, p. 331).

Although the pathology of OA of joints is disputed, treatment for OA is well established. OA of a joint can be treated by exercise, weight loss, physiotherapy treatment, anti-inflammatory medication, pain medication, arthroscopy or a joint replacement (American Academy of Orthopaedic Surgeons Board of Directors 2013). Newer developments in the treatment of OA include platelet-rich plasma (PRP) and hyaluronic acid intra-articular injections. PRP intra-

articular injections represent a relatively low cost treatment modality with little to no adverse effects (Gobbi *et al.* 2012 and Filardo *et al.* 2011) and can provide pain relief and an improvement in functional abilities (Gobbi *et al.* 2012 and Filardo *et al.* 2011). PRP treatments are shown to stimulate collagen formation and have been shown to improve patients sporting abilities (Gobbi *et al.* 2012) and although the effects of PRP are only short-term, cyclical injections can also be considered (Filardo *et al.* 2011). The World Anti-Doping Agency and the US Anti-Doping Agency have removed PRP from their banned substances list in 2011 (Gobbi *et al.* 2012, p. 170).

Even though newly developed treatment modalities (such as PRP) could prove another effective treatment for OA, joint replacement is still utilised as a last resort treatment option.

### *b) Rheumatoid arthritis*

Rheumatoid arthritis (RA) is an auto-immune disease in which synovial joints are damaged (Aletaha *et al.* 2010). Conservative treatment of RA is aimed at decreasing the inflammation associated with RA (Smolen *et al.* 2010, p. 632). The erosion that occurs within synovial joints in individuals living with RA may create a need for a joint replacement (McQueen *et al.* 2007) and, although the incidences of joint replacements for RA patients have decreased, there is still a place for joint replacements in the treatment of RA (Sokka, Kautiainen and Hannonen, 2008).

### *c) Septic arthritis*

Septic arthritis entails infection that is spread into a synovial joint and it causes rapid destruction of the articular cartilage (Margaretten *et al.* 2007, pp. 1479). If the destruction of the articular cartilage is severe and the initial infection is resolved, a hip replacement may be considered as treatment.

#### *d) Fracture*

There are various fractures that occur, but only the relevant fractures likely to create a need for a hip or knee replacement will be discussed. When surgical management for an acetabular fracture fails, an arthrodesis or total hip replacement may be considered as management (Bellabarba *et al.* 2001, pp. 869). The failure could be due to poor vascularity and healing after an acetabular fracture, the development of post-traumatic OA after surgical interventions, if initial treatment fails and need to be re-addressed although the degree of fracture also determines the treatment modality to be used initially.

A neck of femur fracture may be managed by internal fixation, hemiarthroplasty or a total hip replacement. The management will be determined by the type of fracture and the degree of displacement, although the ideal type of management is still debated (Blomfeldt *et al.* 2006, pp. 160 and Tidermark *et al.* 2003, p. 380).

#### *e) Other*

Various trauma and conditions can be managed with a joint replacement as considered per the circumstances of each individual by the orthopaedic surgeon.

## 5 Athlete running parameters

### a) *Fitt VP*

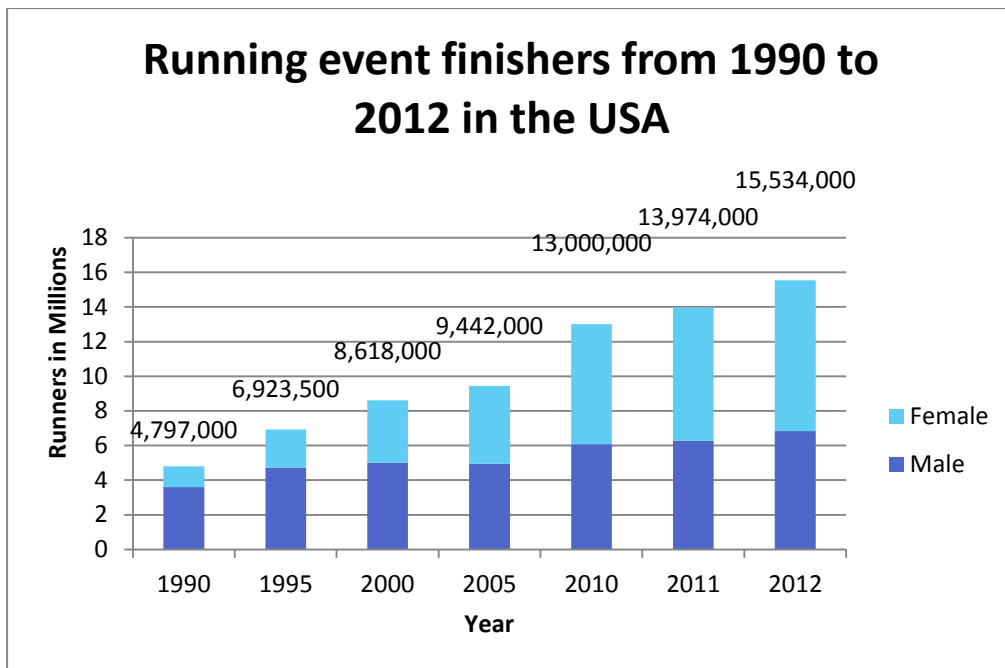
There is no guideline or method found in the available literature to describe the quality of running experienced by runners after a hip or knee replacement. Therefore the researcher's conceptualisation of the quality of running is based on the FITT-VP principles as provided in Table 5. The FITT-VP principles entail frequency, intensity, time, type, volume and progression (ACSM 2014, p. 162).

**Table 5 : Terminology and the definition of the FITT-VP principle**

<b>Terminology</b>	<b>Operational definition</b>
Frequency	How often an incidence or event occurs, e.g. how often someone runs. The frequency of running and training was thus measured during this research study.
Intensity	Refers to the running speed of the participant.
Time	Duration of the exercise session or race.
Type	Road running.
Volume	Refers to the distance the runner is running.
Progression	The progression of symptoms and running.

### b) *Running*

With the increased interest in, and focus on, fitness and a healthy lifestyle, participation in running events has increased. The participation in road running events in the USA rose by six percent from 2007 to 2008 (Running USA 2012). This increased participation in road running can be seen in Graph 1, with the data from 1990 until 2012 summarised. Currently there are approximately 100 000 road runners in South Africa according to race results (excluding five km runners) (M Chamberlain 2016, personal communication 5 July).



Graph 1 : Running event finishers from 1990 to 2012 in the USA (Running USA 2012)

Some of the positive effects as a result of running are higher life expectancy, decreased anxiety and depression as well as improved cardiovascular health, weight loss, an increase in bone density and improved muscle contraction (Conaghan 2002, p. 332). Running has also been proven to decrease blood pressure and improve the participant's general health (Buchan *et al.* 2013, p. 2).

Like any other sport, running unfortunately also entails risks. The biggest risk for running is sustaining an injury. The injury rate of marathon runners has been found, in research, to be 37% to 56% (Derrick, Dereu and McLean 2002, p. 998) and even as high as 90% (Fredericson and Misra 2007, p. 437). The most common site of injury in runners is the knee area according to Fredericson and Misra (2007, p. 438).

Cymet and Sinkov (2006, p. 342) provided evidence of the existence of a relationship between injuring a joint and degeneration of the same joint. This relationship was confirmed by Conaghan in 2002 when determining the relationship between OA and exercise. This led to the conclusion that degeneration of the injured joints (hip or knee) due to trauma is a high risk for marathon runners. It can thus be hypothesised that runners (in particular marathon runners) are exposed to a high risk for degeneration of a joint, and an increased risk for joint

replacements. This is confirmed by Cymet and Sinkov (2006, p. 343) who suggested that it could be injuries to the joint that result in the degeneration and not the impact of running.

Runners have different styles of running and make use of different types of shoes. The basic running styles are heel, midfoot and forefoot strike (Bonacci *et al.* 2012, p. 387). Although the superior running style with the least impact and injuries is still under debate, it is believed that toe running is associated with decreased hip and knee injuries and increased ankle impact injuries, during this running style (Goss and Gross 2012, p. 62).

### *c) Running shoes*

Patients can run with conventional running shoes (tekkies), minimalistic shoes, racers, or barefoot. Although barefoot running has been proven to require less expenditure of energy (Bonacci *et al.* 2012), the support and cushioning provided by the shoe seem to counteract all the negative aspects (such as the weight of the shoe) (Tung, Franz and Kram 2014, pp. 328).

### *d) BMI*

Jassim, Douglas and Haddad (2014, p. 923) found that pre-operative activity, patient age and body mass index (BMI) all influence the rate of return to running. A high BMI seems to be related to the patient's rate of returning to sport after a joint replacement (Cowie *et al.* 2013, p. 699) as higher BMI increases force and weight on the joints of the lower limb, thus predisposing patients to a higher risk of injuries (Taunton *et al.* 2003, p. 243). The average ranges of BMIs are provided in Table 6 (Mahan, Escott-Stump and Raymond 2012, p. 166 and WHO guidelines (2004).

**Table 6: BMI ranges**

<b>BMI ranges</b>	<b>Description</b>
Below 18.5	Underweight
18.5 to 24.9	Normal weight
25 to 29.9	Overweight
30 or higher	Obese

Ground reaction force (GRF) is the force generated between the runner and the ground as initial contact occurs during the running cycle (Novacheck 1998). This force increases as the BMI increases. As the GRF rises, the force on the joints will also escalate, thus increasing the risk of injury on the joints and, in the case of a replacement, also on the replaced joint.

## *6 Return to running after a joint replacement*

In this section the results from the available literature regarding return to running after a joint replacement will be discussed.

Some patients return to high impact sport after a hip or knee replacement, according to Bloomfield and Hozack (2014, p.89), though hip replacement patients have a higher rate of return to sport when compared to the number of knee replacement patients (Ross and Brown 2010, p. 47). Wylde *et al.* (2008) found that the rate of return to running for hip and knee replacement patients was similar and it was suggested by the authors that this might be due to the fact that better pain relief was obtained after a hip replacement when compared to pain relief after a knee replacement (Ross and Brown 2010, p. 47).

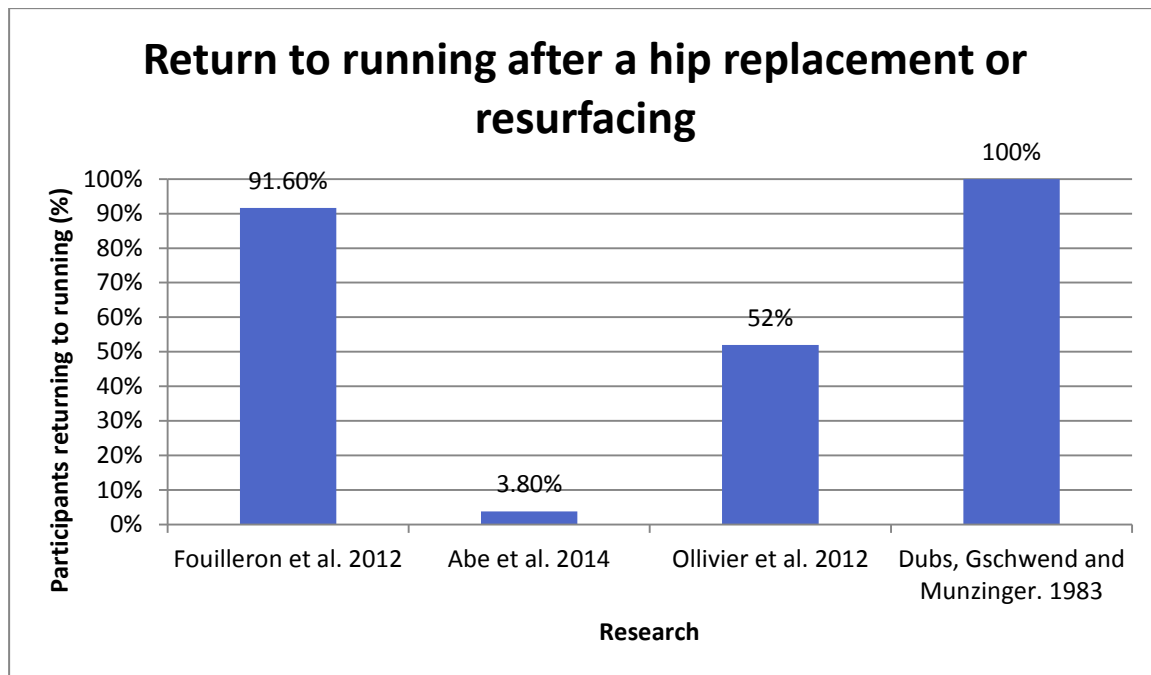
Bradbury *et al.* (1998) conducted a retrospective study to determine the rate of return to sport after a TKR. This study was performed on 160 patients who underwent surgery from the senior author. During the study the results indicated that 65% of patients who had previously participated in sport returned to their sport (unspecified if it was low or high impact sport) and the percentage of return could rise to 77% if the patients had no co-morbidities such as cardiac, arterial, polyarthritis and systemic diseases. The researcher recommended that it was advisable for patients to return to low impact sport rather than high impact sport and contact sport.

Table 7 provides an outline of the classification of sports according to the impact. The low-impact category of sport allows everyone to participate; the intermediate-impact category is recommended only for patients who had already performed the sport prior to the joint replacement, are skilled and experienced in the sport and the high-impact category was off limits to all. Running was classified under the high impact category and was thus not recommended due to the high risk involved of dislocating the hip. Although there are variations in the literature regarding the classification of sport, the most recent classification is depicted below (Vogel *et al.* 2011).

**Table 7 : Classification of sport according to it's impact (Ross and Brown 2010, p. 48, Table 2)**

<b>Low impact</b>	<b>Potentially low impact</b>	<b>Intermediate impact</b>	<b>High impact</b>
Stationary cycling	Bowling	Free weights	Baseball, softball
Calisthenics	Fencing	Hiking	Basketball
Golf	Rowing	Horseback riding	Volleyball
Stationary skiing	Isokinetic weights	Ice skating	American football
Swimming	Sailing	Rock climbing	Racquetball, handball
Walking	Speed walking	Low-impact aerobics	Jogging, running
Ballroom dancing	Cross-country skiing	Tennis	Lacrosse
Water aerobics	Table tennis	In-line skating	Soccer
	Jazz and ballet	Downhill skiing	Water-skiing
	Cycling		Karate

Schmidutz *et al.* (2012, p. 430) found that 33% of patients still competed in high impact activities after their hip replacement and returned to sport five to six months after their surgery. Graph 2 indicates the rate of return to running as found in the literature. All of the studies were performed after hip resurfacing or THR and no literature could be found regarding TKR.



Graph 2 : Return to running after a hip replacement or resurfacing

When looking at the research it seems as if Abe *et al.* (2014) had an extremely low return to running rate though their reported 3.8% were calculated of their total study population. When looking at their results 33 participants were runners before their replacement and 23 of these returned to running (69.7%) which is closer to the results of other studies. It is thus clear that patients return to high impact sport after a joint replacement and though the values for return to running after a joint replacement vary, there are runners running with a replaced hip or knee. Wylde *et al.* (2008, p. 922) found that hip resurfacing did not improve the results regarding participants returning to sport compared to those with a total hip replacement. Therefore literature, and results from the hip resurfacing participants and total hip replacement participants will be grouped together, seeing that the available literature found the results of the two surgeries to be similar.

Ross and Brown (2010) questioned surgeons regarding the time needed to return to sport post-operatively, and the results indicated that 32% of the surgeons suggested that the participants were allowed to return to athletic activity in one to three months while 59% suggested three to six months (Ross and Brown 2010, p. 48). A retrospective study performed by Cowie *et al.* (2013) found that patients returned to their sport on average 18.8 weeks after surgery which is within the time period suggested by the surgeons in the study by Ross and Brown (2010).

The reason why some runners do not return to running after a hip or knee replacement varies according to the literature, though similarities are observed. Jassim, Douglas and Haddad (2014) performed a systematic review to determine whether patients are able to return to athletic activities or not following a lower limb athroplasty. The researchers did not mention the type of athletic activity their participants engaged in, but found during their research that pre-operative activity, age, BMI and the type of replacement (to a lesser extent) influenced the rate of return to sport.

Similar results were found during a study by Cowie *et al.* (2013, p. 699) during which they found that a high BMI seems to be related to the patient's rate of returning to sport after a joint replacement. The patients with a higher BMI typically took longer to return to work and sport, although the researchers did not substantiate the reason for this statement. The results of Cowie *et al.* (2013) are indicative of the fact that BMI would therefore influence the data of this study and therefore the weight and height of the participants were included in the questionnaire to evaluate the influence of BMI during this study.

Figure 3 visually portrays the relationship between age and participation in sports activities before hip or knee replacements. This clearly shows that patients of all ages participated in sports before the replacement and that the rate of participation was still fairly high (above 40%) up to the age of 70 years, after which a slight decrease in participation could be observed. At the age of 80 years a considerable decrease in participation was observed where participation decreased by 10%. These results substantiate the results from Ollivier *et al.* (2012, p. 3062) and Wylde *et al.* (2008, p. 921) proving that more active patients are undergoing hip or knee replacement than were initially thought to have been the case.

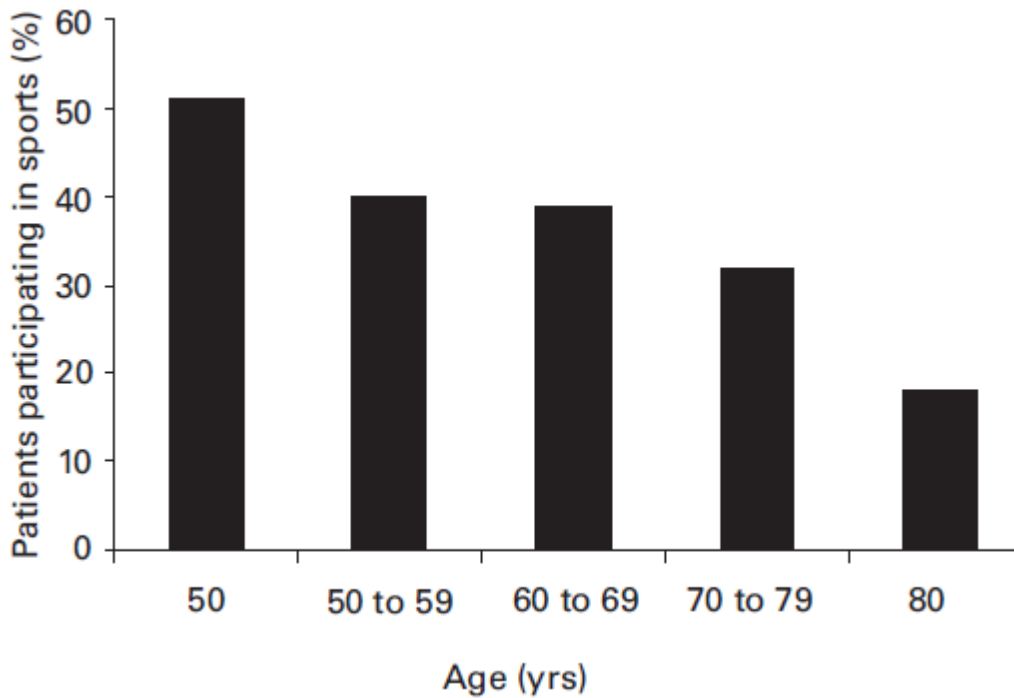


Figure 3 : Age distribution of sports participants with joint replacement (Wylde *et al.* 2008, p. 922, Figure 2).

Wylde *et al.* (2008, p. 922) found that an increase in age will lead to a lowered rate of return to sport after a joint replacement in the knee or hip, while Huch *et al.* (2005) similarly found that the participants' age, participants' concerns regarding the hip or knee replacement, and the advice of the surgeon, influenced the return to sport.

Similar results were found during a retrospective study by Wylde *et al.* (2008) during which they included all patients with a knee or hip replacement or resurfacing surgery from 2004 to 2006. The data was collected utilising questionnaires. During the study the researchers established that the reasons why participants did not return to sport after a joint replacement was due to medical advice (12% of participants), pain (27% of participants), an inability to perform the required movements (26% of participants) a fear of damaging the joint (10% of participants) and participants had a lack of confidence (seven percent).

Though some patients choose not to return to sport after their replacement, some participants do return to running. The quality of running was also described in the literature when participants took part in running after a hip or knee replacement. Jassim, Douglas and Haddad

(2014) found that the total time spent on an activity remained unchanged, although the intensity decreased in knee and hip replacements according to their review. Fouilleron *et al.* (2012, p. 4) also found that there was no change in the time spent running, though during their study the distance decreased in patients over 50 years, whereas it remained unchanged for patients under 50 years of age. The study only assessed the short-term effects of running with a mean follow-up of 33 months after surgery.

Ross and Brown (2010) also determined the level of participation in a variety of athletics activities (except cycling) and found that all patients had a decreased level of participation after a hip replacement. Most of the participants returned to their sport after the hip replacement, but at a lower intensity (Jassim, Douglas and Haddad 2014).

The running parameters for participants running with a replaced hip was described by Abe *et al.* (2013, p. 133) which indicated that patients jogged on average four times per week, 3.6 km per session at about 7.7 km/h. Patients with a hip resurfacing typically had a higher frequency and duration of exercise after the replacement when compared to before the replacement (Banerjee *et al.* 2010, p. 1234 and Naal *et al.* 2007, p. 709). This is contradictory to the results from other literature, but it should be noted that this study is much older than the previously discussed studies.

Runners had a decreased level of participation according to Ross and Brown (2010) and the aspects influencing the quality of running should be taken into account. A literature review on the return of patients to athletic activities after a knee or hip replacement was performed by Bloomfield and Hozack (2014). The researchers reported that a few athletes return to high impact sport, as their ability to compete in high demand athletic sport might be limited due to pain, restricted functional outcomes or these activity restrictions that has been imposed by the surgeon. The duration of the symptoms pre-operatively, the satisfaction of the patients post-operatively, pre-operative function and the motivation of the patient also seem to have a direct influence on the level of participation in sports (Ollivier *et al.* 2014, p. 1041).

The benefits of running are obvious from the literature discussion above, though the possible adverse effects should be considered when looking at running with a hip or knee replacement. However Jassim, Douglas and Haddad (2014) stated that little evidence is available indicating that high levels of activity lead to early knee or hip implant failure. Similarly Huch *et al.* (2005) found that active patients (patients who participated in sport) had a lower revision rate when compared to less active patients after a hip or knee replacement. Ollivier *et al.* (2012) found during their retrospective study that high impact sport poses an increased risk for a hip replacement to fail.

During the study of Ollivier *et al.* (2012), the researchers observed no difference between the dislocation rates when comparing athletes competing in low impact sport with athletes competing in high impact sport. It was, however, found that the survival of the replaced joints was lower for the high-impact sport participants and that the wear rates were higher. Figure 4 shows the relationship between the lifespan of a hip replacement for patients participating in high-impact sport and patients participating in low-impact sport after 15 years of sport participation. Results from the research also indicated that high-impact sport participants had less pain, less symptoms, better activities of daily living and sports performance.

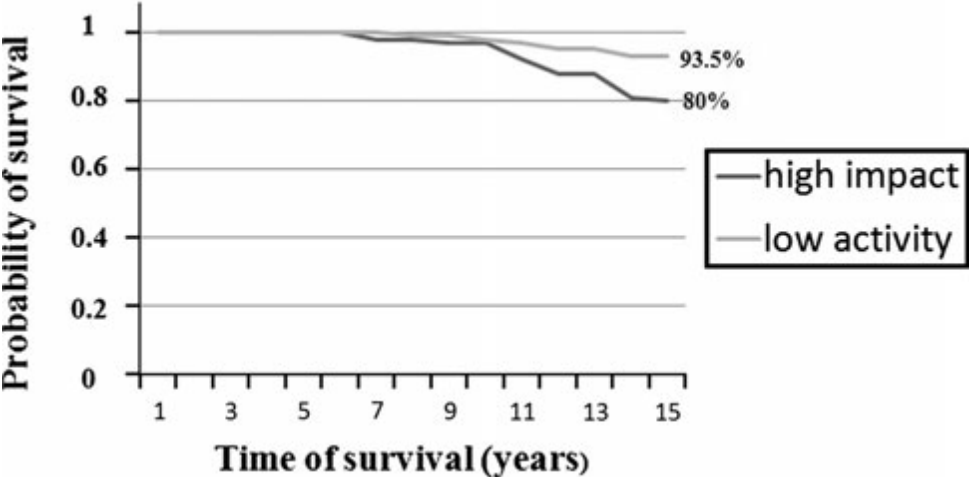


Figure 4 : The survival rate of replaced joints when participating in high impact sports versus low impact sports (Ollivier *et al.* 2012, p. 3064, Figure 2).

Different surface options for young patients during a hip replacement were discussed by Heisel, Silva and Schmalzdried (2003). They indicated that a higher level of activity predisposes the joint to increased forces on the replaced joint (Heisel, Silva and Schmalzdried 2003, p. 1366). This implies that the prosthesis needs to be stronger and more durable. Three types of material combinations which may be used during a replacement were developed to meet these needs. Each type of combination has their own benefits and risks, and the correct prosthesis will vary according to the patient's needs and lifestyle. The benefits and risks for each type of combination option are set out in Table 8.

**Table 8 : Benefits and risks of prosthesis options (Heisel, Silva and Schmalzdried 2003, p. 1366, Table I)**

<b>Bearing materials</b>	<b>Benefits</b>	<b>Risks</b>
<b>Cross-linked polyethylene</b>	High wear resistance, no toxicity, relatively cheap, multiple liner options	Gross material failure, increased bioactivity of wear particles
<b>Metal-on-metal</b>	Higher wear resistance, favours larger diameters, lot of research available	Lots of ion release, delayed type hypersensitivity, carcinogenic
<b>Ceramic-on-ceramic</b>	Highest wear resistance, no toxicity, improved lubrication	Position sensitivity, liner chipping, fracture risk, osteolysis observed in some patients

Ceramic-on-ceramic was proven to have the least erosion followed by metal on metal, followed by metal on ceramic, while metal on polyethylene has the highest rate of wear and tear (Heisel, Silva and Schmalzdried 2003, p. 1372). The researchers also stated that the durability of the implanted prosthesis was improved by introducing cementless fixation of the prosthesis (Heisel, Silva and Schmalzdried 2003, p. 1366). Huch *et al.* (2005, p. 1719) stated (in concurrence with Yun 2006, p. 363 and Chechik *et al.* 2013, p. 1598) that cementless fixation of the hip prosthesis during a hip replacement and cemented prosthesis for knee replacement are advisable for more active patients.

Smith and Nephew developed a new prosthesis range for hip and knee replacements that is more durable, has increased hardness, lowered friction and lower wear rates. The manufacturers combined the strength of metal with the wear resistance and smooth surface of ceramics. This new development is known as the oxinium range. With this new and improved prosthesis a higher level of function can be achieved by individuals (Tsukamoto *et al.* 2006, p. 510).

Laskin (2003) found that a higher level of function could be obtained when using Oxidised zirconium surfaces, while, Bal *et al.* (2007) found that the damage of the Oxidised zirconium surfaces was less than that of cobalt-chromium polyethylene surfaces under abrasive wear conditions. Innocenti *et al.* (2009) found that no clinical or radiological evidence of adverse effects was present at a five year follow-up period in knee replacements using Oxidised zirconium surfaces.

The Tables below summarises all the findings from the literature review considering that the results found are diverse. Table 9 outlines all the items that may influence patient's rate of return to sport or athletic activities. Table 10 outlines all the effects that running and sport may have on the participant and Tables 11 and 12 outlines the return to running with the possible influences according to the literature.

**Table 9 : Influences on sports and athletics**

Components tested to influence sports and activity	Jassim, Douglas and Haddad (2014) (return to sport)	Ollivier <i>et al.</i> (2012) (level of participation)	Wylde <i>et al.</i> (2008) (return to sport)	Bradbury <i>et al.</i> (1998) (return to sport)	Bloomfield and Hozack (2014) (high impact sport participation)	Cowie <i>et al.</i> (2013) (return to sport)	Huch <i>et al.</i> (2005) (return to sport)
Pre-operative activity	√						
Patient's age	√	√	√				√
BMI	√					√	
Duration of symptoms pre-operatively		√					
Satisfaction post-operatively		√					
Pre-operative function		√					
Motivation		√					
Type of replacement (hip/knee)	√ (although less significant than other factors)		√ (hip more than knee)				
Pain			√	√	√		
Post-operative function			√		√		
Activity restriction by surgeons			√		√		√

**Table 10 : Symptoms and signs after a hip or knee replacement**

<b>Author</b>	<b>Side effects</b>	<b>Symptoms</b>	<b>Pain</b>	<b>Replacement loosening</b>	<b>Replacement failure</b>	<b>Wear and tear</b>
Abe <i>et al.</i> (2013)	None at five years					
Jassim, Douglas and Haddad (2014)	Little evidence available					
Ollivier <i>et al.</i> (2012)		Decreased	Decreased		Increased THR failure with high impact	
Dubs, Gschwend and Munzinger (1983)				(Hip) decreased in active patients		
Ross and Brown (2010)				14.3% of prosthetic loosening in sedentary patients, 1.6% in patients who participated in sport	Impact durability THR	Four times higher with athletes vs non-athletes
Hui <i>et al.</i> (2011)						Decreased with oxidised zirconium surfaces

**Table 11 : Running parameters after a knee or hip replacement**

<b>Author</b>	<b>Quality of running</b>	<b>Intensity</b>	<b>Sport performance</b>	<b>Running time</b>	<b>Distance</b>	<b>Running recommended</b>
Banerjee <i>et al.</i> (2010) and Naal <i>et al.</i> (2007, p. 709)	THR increased frequency and duration of running after hip resurfacing					
Jassim, Douglas and Haddad (2014)	Activity unchanged, intensity decreased					
Ross and Brown (2010)		Lower				
Ollivier <i>et al.</i> (2012)			Improved			
Fouilleron <i>et al.</i> (2012)				Hip resurfacing no change	Age >50 decreased, age <50 unchanged	
Vogel <i>et al.</i> (2011)						No
Bradbury <i>et al.</i> (1998)						No

**Table 12 : Personal factors after a replacement influencing return to running**

<b>Author</b>	<b>Lack of knowledge</b>	<b>Activities of daily living</b>	<b>QOL</b>	<b>Physical function</b>
Ollivier <i>et al.</i> (2012)	√	Improved	Improved	
Wylde <i>et al.</i> (2008)	√			
Huch <i>et al.</i> (2005)	√			
Tsukamoto <i>et al.</i> (2006)				Higher level with oxinium
Hui <i>et al.</i> (2011)				Higher level with oxinium

**In summary:**

Previous studies have indicated that the intensity of running, mileage and level of participation decreased after a hip or knee replacement, however, the frequency and duration of training increased after the replacement.

The literature also indicate that the quality of running is affected by pain, restricted function, patient satisfaction, motivation, pre-operative symptoms and function. The results regarding the effects of running suggest that running has little to no adverse effect after a hip or knee replacement.

The process followed during this research study will be described in the following chapter.

## Chapter 3 : Methodology

During this chapter the method and process followed during this research study will be described in detail.

### *1 Research design*

An explorative retrospective descriptive study design was followed.

### *2 Study sample*

#### *a) Study population*

It is very difficult to estimate the population size of runners who have had hip or knee replacements in South Africa within the time frame of this study due to the lack of literature regarding the number of hip and knee replacement in runners in South Africa. South Africa currently has about 100 000 active runners who participate in distances greater than 5 km. Only a small proportion of these would have had hip or knee replacements, although assessing even that proportion is difficult due to a lack of literature.

This study's population consisted of all road runners who had undergone a hip or knee replacement and returned to running in South Africa. Patients who attempted to run, but stopped running after a hip or knee replacement were also included.

Assuming that one percent of runners might undergo hip or knee replacements, that would indicate a population of 1000. The sample of ten used in this study would (using a 95% confidence level) give a margin of error of 31%. As a simple example, while this study indicated that 60% of the hip and knee replacement patients who returned to running were

male, the true proportion in the population could be (with 95% certainty) anything from 30% to 90%.

### *b) Study sample*

A sample of convenience was utilised in that all road runners who had undergone a hip or knee replacement and returned to running in South Africa were included in the sampling frame and were included if they agreed to participate. Snow-ball sampling was also used in that certain participants identified other runners who qualified for the study and approached them to become involved in the research study by providing their contact details, with their permission to the researcher.

### *c) Inclusion criteria*

All individuals returning to running after a hip or knee replacement, irrespective of the date on which the patient had the replacement and returned to running. The participants had to give informed consent. Participants had to be able to understand and read English or Afrikaans.

### *d) Exclusion criteria*

Foreigners and participants who did not run after their joint replacement were excluded. Foreigners were excluded because all registered athletes in South Africa associated with a club are South African citizens and clubs were contacted to gain participants. There was no way known to the researcher to contact foreign runners to complete the study. Trail runners were not included in the study due to the differences in biomechanics, training and running surfaces, which might have influenced the symptoms experienced.

### *3 Measuring instruments*

The questionnaire used in the research study was designed by the researcher based on previous research conducted as well as identified limitations from previous research conducted. After a preliminary questionnaire had been developed, experts further guided the design of the questionnaire (a panel that consisted of physiotherapists, biokineticists, biostatistician, sports physician and surgeon). This was done by discussing the research study with a panel which consisted of a sports physician, biokineticists, biostatistician and physiotherapists. Questions regarding the FITT-VP, BMI, training gear, diagnosis and rehabilitation were included in the questionnaire to ensure an insightful understanding of the circumstances leading up to the replacement and the rehabilitation after the replacement.

The first section of the questionnaire gathered demographic information and the medical history of the participant. The second section included questions to determine the symptoms runners experience and their quality of running. Information regarding the surgical procedure and rehabilitation was also obtained during the completion of the questionnaire.

Questions included in the questionnaire were based on the Womac questionnaire where symptoms are rated on a four-point scale where zero is none and four is extreme symptoms. The Womac questionnaire was chosen due to its relevancy to the study as the questionnaire is designed to gather data from patients living with knee or hip pain and limited function or diagnosed with osteoarthritis. The Womac questionnaire was chosen to show clearly the difference in the intensity of symptoms experienced by the participants. By using a four-point scale, comparison of results was made easier with the expectation of a small study sample, whereas a 10 point scale such as the VAS scale would have delivered a wide variety of results that would have been difficult to compare with other participants and studies. The Womac questionnaire is a validated instrument designed to determine the symptoms of patients who live with lower limb OA (Kersten, White and Tennant 2010, p. 9). The validation of the Womac questionnaire was performed by Kersten et al 2010 on participants with hip or knee pain while awaiting a knee or hip replacement utilising factor analysis and Rasch analysis methods.

Two qualified physiotherapists proficient in English and Afrikaans were asked to perform forward translation of the questionnaire while two different individuals performed backwards translation. The translated questionnaires were compared by the researcher and consensus was achieved during a meeting held with the translators, whereupon the questionnaire was finalised (Degroot, Danneburg and Vanhell 1994).

The questionnaires (both Afrikaans and English versions) were provided to an orthopaedic surgeon and a qualified physiotherapist who read through the questionnaire. The purpose was to determine whether the questionnaire tested what was intended to be tested as well as to ensure the questionnaire is comprehensive and thorough (See Appendix A for the English questionnaire). The orthopaedic surgeon and physiotherapist found the face validity of the newly developed questionnaire used in the research to be acceptable for the purpose of this study. The physiotherapist was able to provide insight into the rehabilitation and measurements of symptoms and the orthopaedic surgeon were able to provide insight as to what symptoms patients typically complain of to him to ensure all possible symptoms and adverse effects could be explored during this study.

#### *4 Ethical clearance*

Ethical clearance had been obtained from the Ethics Committee of the University of the Free State on 10/03/2015 (Ethical clearance number: ECUFS 16/2015). See Appendix B for the ethical clearance certificate.

Informed consent was obtained from participants after they were requested to read the information letter explaining the aim as well as the procedure of the study. No remuneration was offered to participants.

The hard copies of the signed informed consent letter along with the completed questionnaires are kept in a locked cabinet and only the researcher has access to the key of the cabinet. The electronic versions of the signed informed consent form and the completed

questionnaires are kept on the researcher's computer which is protected by a password. Only the researcher knows the password and no one other than the researcher will access the computer. All the data collected was be saved on two separate and safe places to ensure data is not lost during unforeseen events.

Numbers was allocated to each participant and the number was added to the questionnaires. Patients who experienced symptoms was referred to a medical practitioner for assessment. This was done by contacting the participant with their preferred way of communication (e-mail, post, sms or telephonically).

## *5 Pilot study*

A pilot study was conducted on one participant. The hard copy of the questionnaire was provided to the participant who then completed it in Afrikaans (according to the participant's preference). The participant was asked if he understood the questions and if the questionnaire was appropriate (did not make him feel uncomfortable). The participant's responses were monitored to determine if the questions were accurate in obtaining the information intended to achieve the aims of the study. The time needed to complete the questionnaire was also determined during the pilot study to inform other participants accurately. The pilot study was performed in Afrikaans (the participant's preference). No difficulties were identified and no changes were made to the questionnaire, therefore the data was included in the results of the main study. The English questionnaire was not piloted because no participant was known to the researcher who prefers English before the study was initiated.

## *6 Method*

A letter explaining the purpose and significance of the study, as well as the methodology of the intended study was sent electronically to all chairpersons of running clubs in South Africa on 07/04/2015 (a list of all road running clubs in South Africa's contact details are available to the researcher and is available on <http://www.runnersguide.co.za/Clubs/>). The chairperson was asked to distribute the information regarding the study to all club members and the researcher's contact details were provided to ensure that possible identified participants could phone, sms or e-mail the researcher or alternatively the chairperson could then provide the researcher with the possible participant's contact details for her to be able to contact the participant directly. The participants were then provided with the information leaflet (Appendix C), informed consent (Appendix D) together with the questionnaire (Appendix A) (in the participant's language choice) electronically (via e-mail) or by means of a hard copy (by post). The clubs also sent out questionnaires, information letters and informed consent forms to members they identified, although the majority sent the contact details of the members they identified to the researcher who contacted the participants directly and, if they were interested, the questionnaire, information letter and informed consent forms were attached to the e-mail. Those who had no access to e-mail were contacted telephonically to obtain their address, and the questionnaire as well as the informed consent and information letter was then sent via post. An envelope with a stamp was also provided in an attempt to ensure the participant returned the completed documents without any cost implications.

Data/questionnaires were collected from 07/04/2015 to 25/11/2015 and participants could take as much time as needed on completing the questionnaires as no time limit was imposed on them. Three reminders were sent to all the clubs and identified candidates along with another copy of the questionnaires and information leaflets.

The participants were asked to sign and complete the documents and send it to the researcher via e-mail or post (whichever method they preferred).

## *7 Data capturing and analysis*

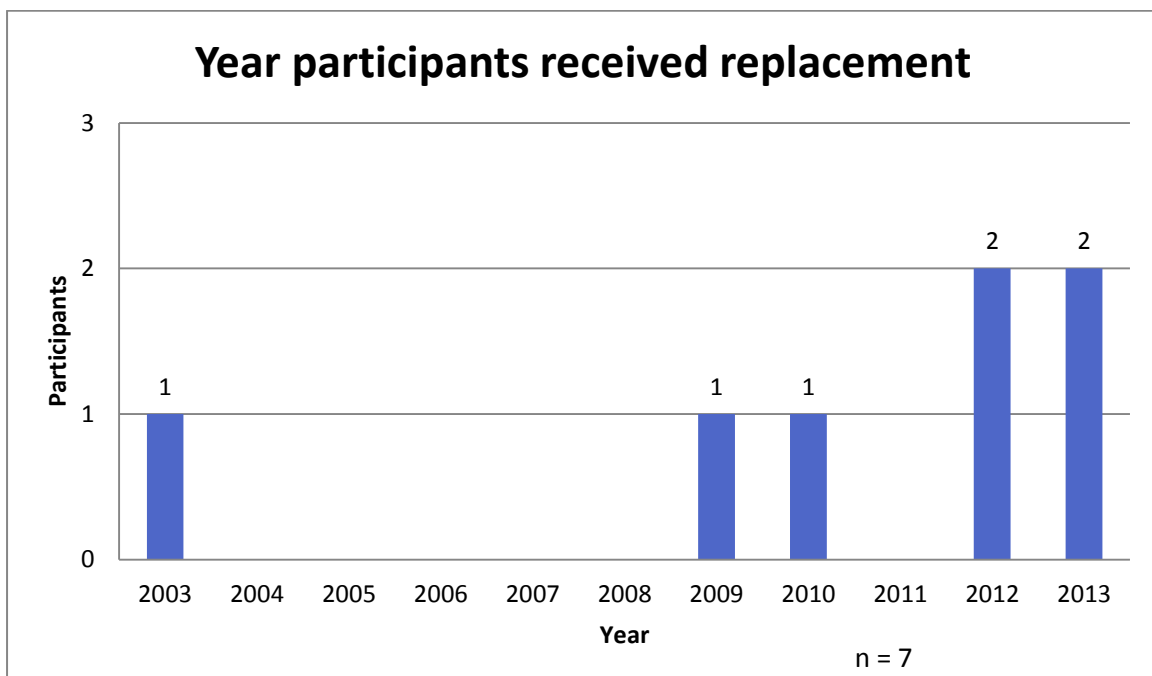
Completed questionnaires were printed by the researcher and the data collected was captured on an Excel spread sheet. The Excel sheet was coded according to the responses to ensure that one language and format of capturing was utilised. The codes used were according to the guidance and preferences of the biostatistician responsible for data analysis. A qualified physiotherapist was asked to verify the captured data. This captured data was sent to a biostatistician at a Tertiary Institution and he analysed the data.

Results were divided into categories according to the type of surgery received (hip or knee replacement), the BMI and the rehabilitation participants received. Since the data is mostly descriptive, results were presented by means of frequencies and percentages for categorical data, and medians and means for continuous data. Results are outlined in Chapter 4.

## Chapter 4 : Results

The results found during this research process are presented in this chapter. Results discussed are grouped according to relevancy and to improve the understanding of the study.

Ten participants gave informed consent and were included in the study. Four participants were female and six were male. All participants' surgeries took place between 2003 and 2013 of whom five had their surgery after 2010 (three participants did not indicate the date of surgery). The figure below (Graph 3) represents the surgeries and correlating years.



Graph 3 : Year participants received replacement

Four of the participants underwent a hip replacement, while the remaining six had a knee replacement. Nine of the participants underwent a replacement due to pain and one participant experienced limitations with daily activities. Seven of the participants' diagnosis was osteoarthritis, two had a fracture and one was unsure of his / her diagnosis (one participant reported he / she had had hip dysplasia since birth).

All participants indicated that they ran with conventional type of shoes (tekkies). Six participants indicated that they always ran with a specific brand of running shoe whereas four participants indicated that they ran with whatever was available when they purchased running shoes. All of the participants used well known quality and brand running shoes. All participants except one received a home exercise programme after the replacement although it was not clear who provided the home programme. One of the participants used pain medication (the type was not specified) daily, while another used pain medication every consecutive day during data collection due to knee pain (both these participants had had a knee replacement). The first participant had been running for three years after the replacement while the second participant had the replacement in 2012.

In each instance the data was not normally distributed, thus the median value will be given.

The median age of participants was 63 years (range 40 to 69 years), although the reason of the participant aged 40 years for the replacement also differed from the most frequent reason. This participant had sustained a fracture and therefore needed the replacement. The participants had a median of 49 months that had passed after their replacement (range 36 months to 157 months). Complications participants experienced during and after the surgery were not explored, though patients could have provided feedback regarding this at the end of the questionnaire where participants were given the opportunity to give feedback on any other information they thought relevant.

The median time it took participants to return to running after their replacement was three months (range one to seven months). Participants were running a median of 16 months with their replacements, with ranges varying from one month to 48 months at the time of the data collection.

Table 13 summarises the information regarding the surgery site and symptoms. Eight of the ten participants thus were still experiencing symptoms at the time of data collection. Sixty percent of the participants were still experiencing pain at the time of data collection while 60% of participants experienced stiffness.

**Table 13 : Symptoms experienced according to surgery site**

<b>Type of surgery performed</b>	<b>Area of incision</b>	<b>Number of participants</b>	<b>Time elapsed after replacement</b>	<b>Symptoms experienced</b>
Right hip replacement	Anterior incision	One	5 years	Stiffness in right thigh and knee anteriorly (n=1)
Right hip replacement	Lateral incision	Two	6 and 5 years	Experienced pain and stiffness in right hip and thigh anteriorly; laterally as well as buttock (n=1)
Left hip replacement	Lateral incision	One		Experienced pain on the left thigh anteriorly and laterally with stiffness on the left thigh posteriorly (n=1)
Right knee replacement	Anterior incision	Three	7 and 4 years	Experienced right knee pain anteriorly (n=2), lateral right knee pain with stiffness anteriorly and laterally (n=1)
Left knee replacement	Anterior incision	One	4 years	None
Knee replacement	Unspecified	Two	13 years	Right knee pain anteriorly and posteriorly (n=1), experienced stiffness in the right knee anteriorly, posteriorly and laterally (n=1)

Of the ten participants, seven were still running, whereas three had stopped running, though the period that they were running after the replacement were not stated. The reasons for not continuing to run varied with one participant indicating that running was difficult, but that he/she would still want to run if possible. Another participant indicated that he / she had been advised not to run due to “brittle bones” though he / she did not specify who had advised her (diagnosis was unspecified). The last participant indicated sustaining an achilles tear as being the reason for not running currently, but will be returning to running again after the injury is fully healed. The table below provides information regarding the participants’ background information and their running details (Table 14).

All participants’ furthest running distance decreased compared to that achieved before the replacement with a median decrease of 69.5km (range three to 387km). Six participants trained for races while three only trained for pleasure. The other participant did not answer the question.

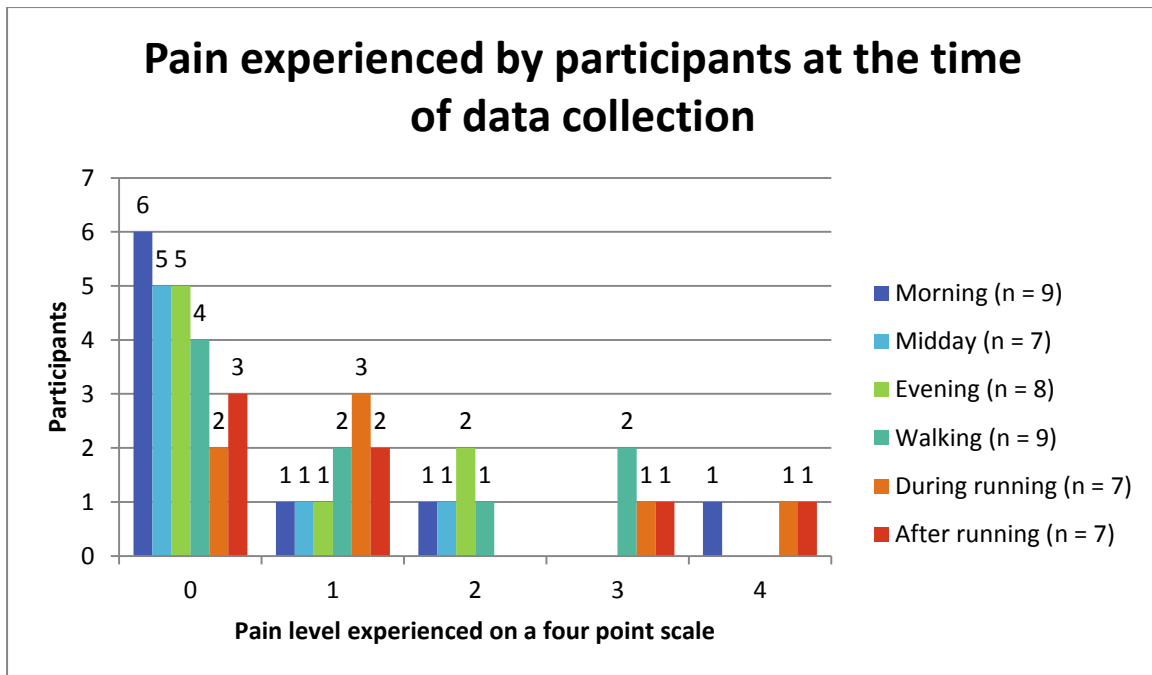
**Table 14 : The demographics and running information for each participant**

<b>Gender</b>	<b>Age in years</b>	<b>Type of replacement</b>	<b>Months after replacement</b>	<b>BMI</b>	<b>Diagnosis</b>	<b>Rehabilitation provided by</b>	<b>Medication</b>	<b>Number of rehabilitation sessions</b>	<b>Home programme received</b>
Male	69	Knee	118 months	26.1	Osteoarthritis	None	No	0	Yes
Male	60	Hip	Not stated	25.7	Osteoarthritis	Biokineticist	No	30	Yes
Male	40	Knee	Not stated	29.4	Fracture	None	No	0	Yes
Male	Not stated	Knee	Not stated	23.9	Osteoarthritis	Physiotherapist	Yes	6	No
Female	56	Hip	30 months	21.1	Osteoarthritis	Physiotherapist and Biokineticist	No	10	Yes
Male	66	Knee	73 month	23.0	Osteoarthritis	Physiotherapist	No	2	Yes
Male	63	Knee	154 months	29.4	Osteoarthritis	Physiotherapist	No	12	Yes
Female	63	Hip	71 months	21.8	Unsure	Physiotherapist	No	1	Yes
Female	57	Knee	42 months	19	Fracture	Physiotherapist	Yes	5	Yes
Female	67	Hip	37 month	20.9	Osteoarthritis	Physiotherapist	No	5	Yes

Table 15 depicts the running parameters of the participants. The median frequency at which participants ran per week was five times, though two participants indicated their frequency of training varied with their programme, whereas one participant stated the frequency varied with circumstances. Participants ran a median of 40 km per week, with distances varying from 20 to more than 60 kilometres and had a median decrease of 1.5 min/km (range of zero to five min/km) in their running pace.

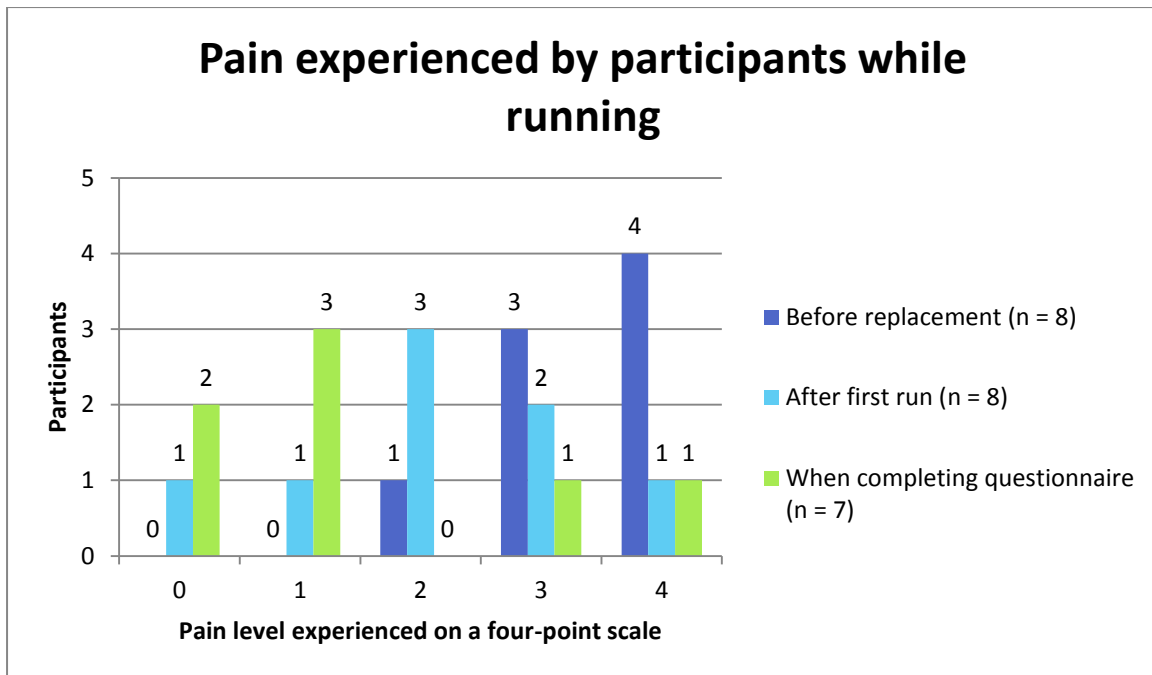
**Table 15 : Running parameters for each participant**

<b>Running currently</b>	<b>Time of return after replacement</b>	<b>Time running with replacement</b>	<b>Frequency of running per week</b>	<b>Average distance ran per week</b>	<b>Decrease in running pace</b>	<b>Decrease in furthest distance</b>
Yes	Two months	Three years	Twice but varies with circumstances	25 km	2.85 min/km	62 km
Yes	One month	17 months	Six times	55 km	1 min/km	387 km
Yes	Six months	Three months	Twice (varies with training programme)	39 km	Incorrectly answered	3 km
No	Two months	Three years	Six times	60 <sup>+</sup> km	2 min/km	75 km
Yes	Six months	15 months	Five times	45 km	0.6 min/km	69 km
Yes	One month	Four years	Three times	40 km	1.5 min/km	0 km
No	Not indicated	Not indicated	Varies with training programme	20 km	2 min/km	69 km
No	Three months	One month	Five times	Not indicated	5 min/km	70 km
Yes	Seven months	16 months	Five times	30 km	1.5 min/km	80 km
Yes	Five months	11 months	Five times	40 km	0 min/km	75 km

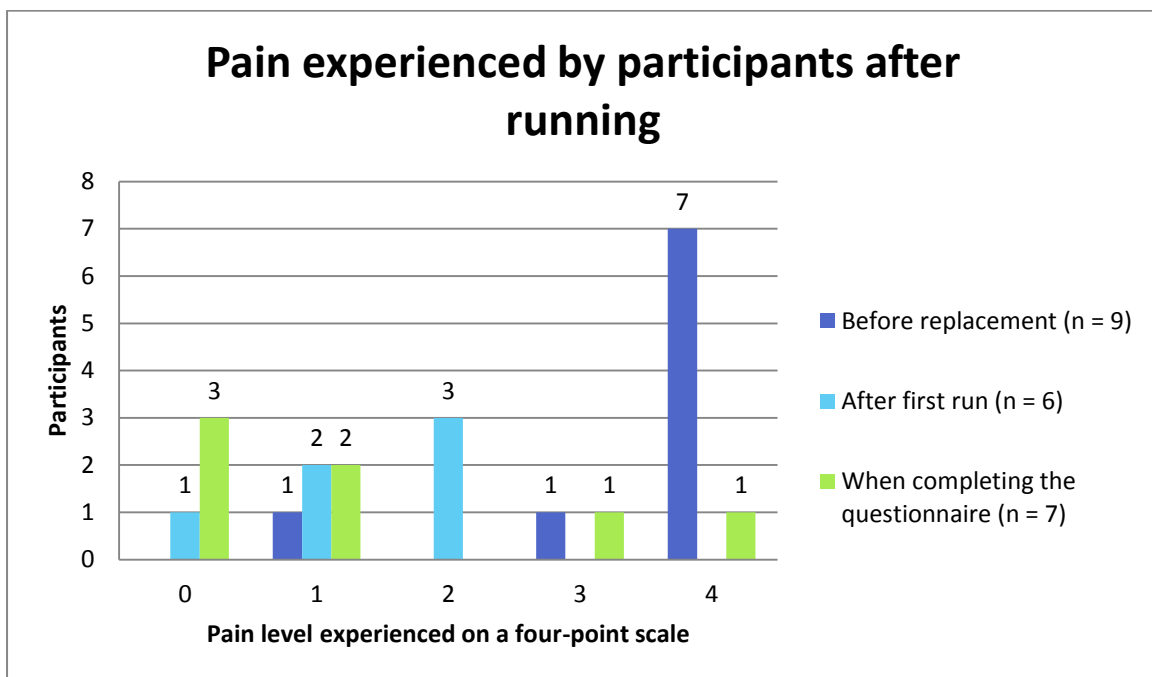


Graph 4 : Pain experienced by participants at the time of data collection

Participants were asked to rate their pain on a four-point scale (as used in the Womac scale), where zero represented no pain and four the highest intensity of pain. The data is presented in Graph 4. Most participants typically had no pain, although a higher level of pain was experienced during running. The median morning pain participants indicated was zero (range zero to four) with the median midday pain zero (range zero to two) and the median evening pain at zero (range zero to two) on the scale. The median pain when walking was one (range zero to three); pain during running was one (range zero to four), while pain after running was one (range zero to four). Participants typically had low levels of pain at the time of data collection with pain increasing during running and walking.



Graph 5 : Pain experienced by participants while running

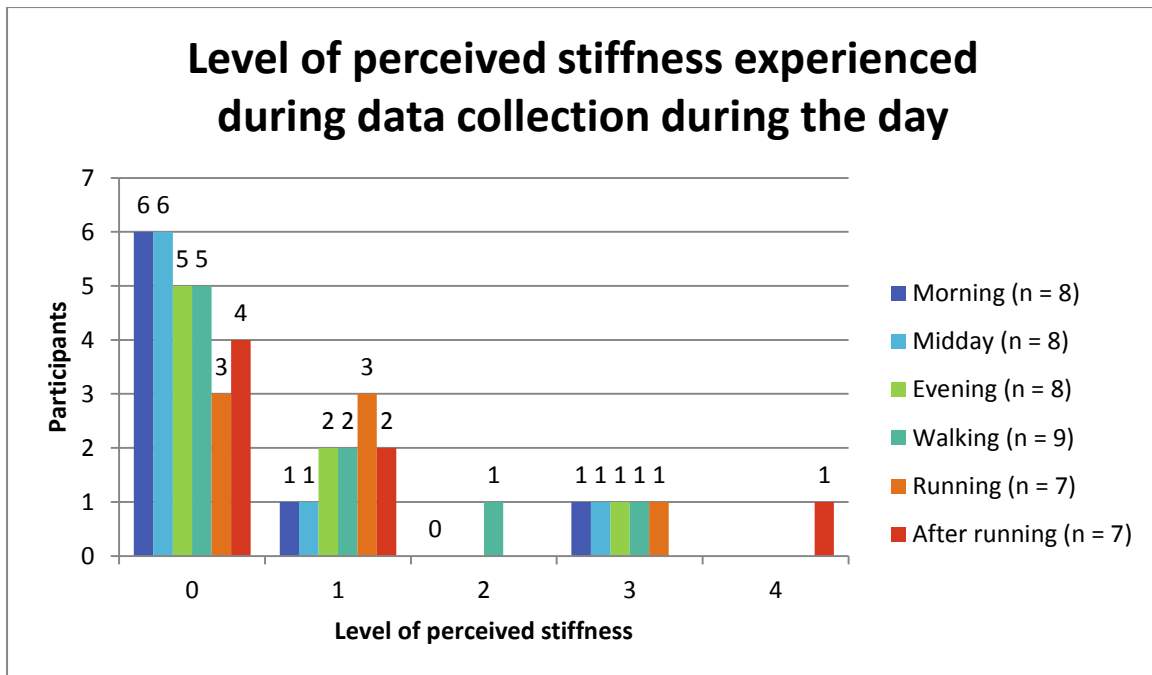


Graph 6 : Pain experienced by participants after running

Graph 5 represents the pain levels out of four experienced by participants while running, while Graph 6 represents the pain intensity after running. A zero depicts no pain where a four is the worst pain experienced. Two participants rated their current pain levels (after a period of running) as no pain experienced. Three participants reported a one out of four intensity of pain, whereas two participants each rated their pain as a three and four out of four respectively.

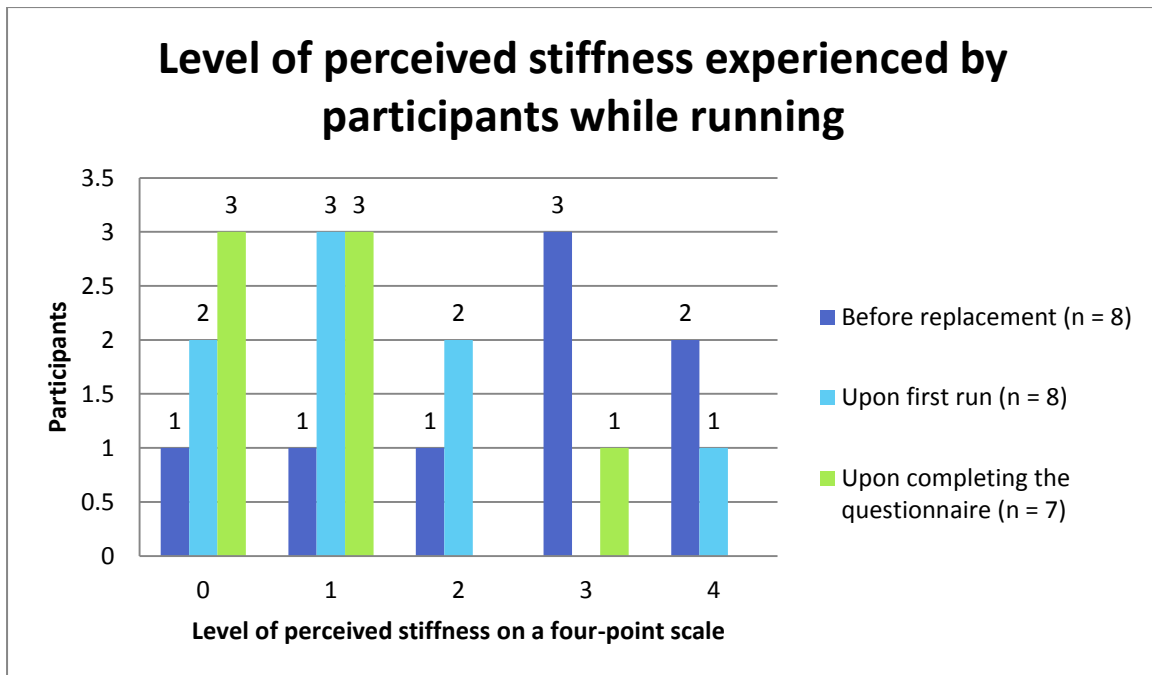
Pain levels during running were very high before the replacement with seven participants rating their pain as severe. The pain decreased after the replacement and with the participants' first run, five participants classified their pain as mild or moderate while one participant experienced no pain, one slight pain and one severe pain. The median pain experienced before the replacement while participants were running was 3.5 (range two till four) as measured on a four-point scale. The average pain experienced by participants decreased to two (range zero to four) after the replacement upon the participants' first run, and during data collection a further decrease in pain intensity was found when the median of the pain intensity was one (range zero to four) during running. Most participants had no pain or a low intensity of pain, though 71% of participants still had pain during data collection.

Participants typically experienced severe pain after running before the replacement and the median pain after running before the replacement was four (range one to four). The intensity of pain experienced after running decreased after the replacement as the median pain during the first run was 1.5 (range zero to two) and the median pain score during data collection was one (range zero to four). At the time of completing the questionnaire it seems as if 29% of participants experienced higher levels of pain after running though 43% had no pain after running and 29% had a low intensity of pain. Most participants thus still experienced pain during data collection, though the intensity of the pain was at a lower level when compared to the pain experienced before the replacement.

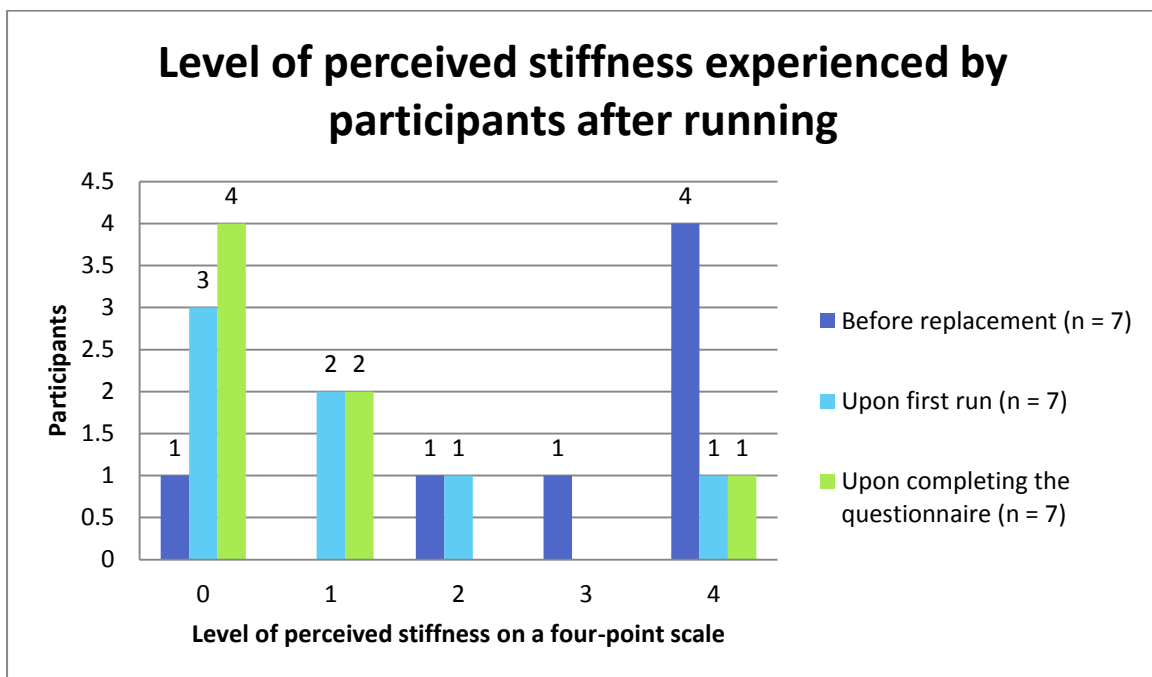


Graph 7 : Level of perceived stiffness experienced during data collection during the day

Participants were asked to rate their stiffness on a four-point scale where a zero represents no stiffness whereas a four represents the highest level of stiffness experienced. The data is presented in Graph 7. Most participants experienced little to no stiffness although a few experienced moderate to severe stiffness. The median morning and midday stiffness was zero (range zero to four). The median evening stiffness as well as stiffness while walking was zero (range zero to four). The median stiffness while running was one (range zero to three) and the median after running was zero (range zero to four).



Graph 8 : Level of perceived stiffness experienced by participants while running

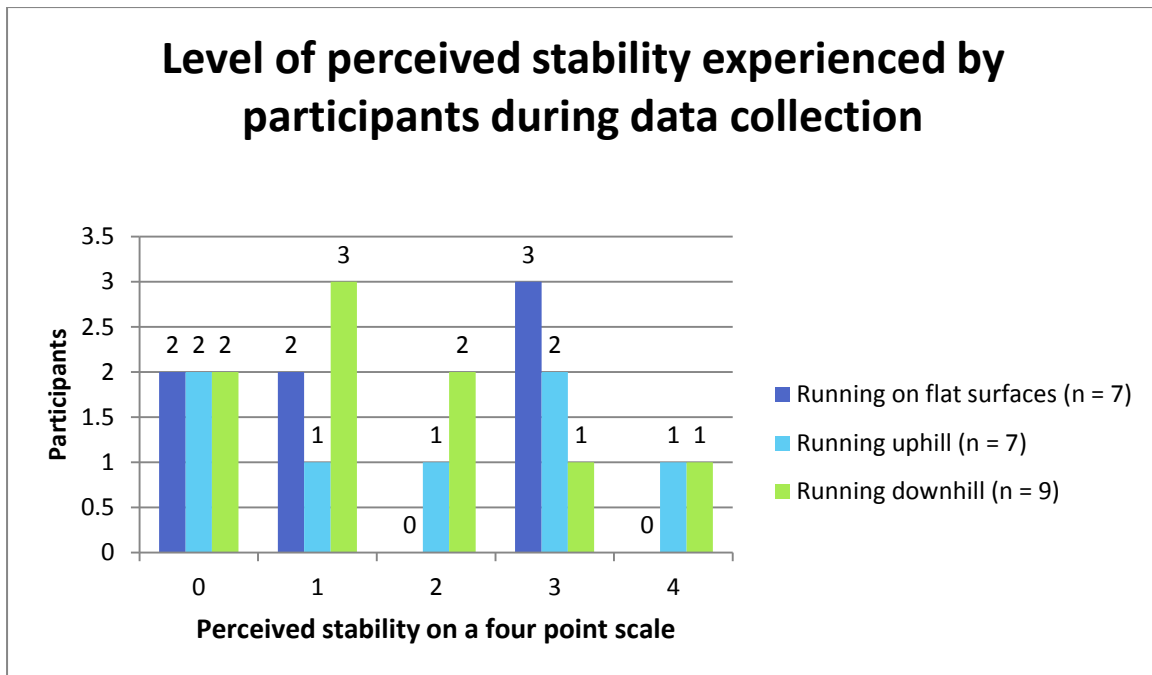


Graph 9: Level of perceived stiffness experienced by participants after running

In Graph 8 it is clear that stiffness while running decreased significantly after the replacement, where most participants felt none to some stiffness while running, with one participant experiencing moderate stiffness during data collection while running. Graph 9 depicts the stiffness experienced by participants after running. Before the replacement a high level of stiffness was experienced, while some stiffness after running still persisted after the replacement, though to a lesser extent.

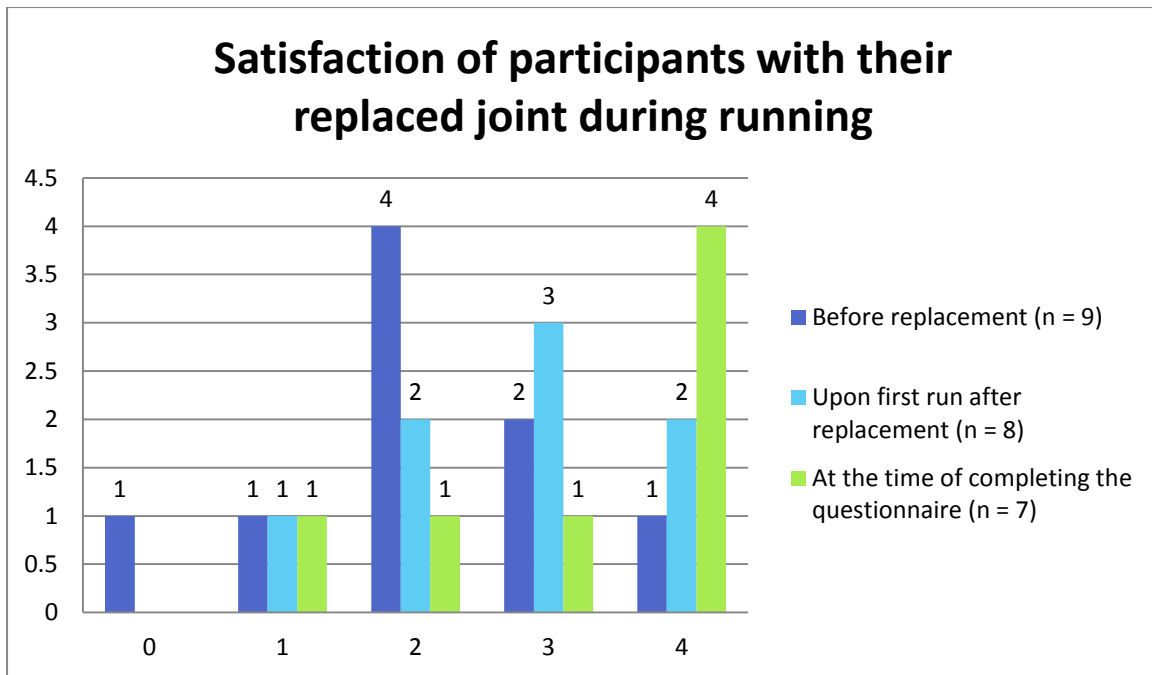
Most of the participants (87.5%) experienced stiffness before the replacement during running, while 71.4% of those participants experienced extreme stiffness. Upon their first run after the replacement 75% of participants had stiffness during running with 16.7% of those participants experiencing extreme stiffness. The perceived stiffness further decreased when participants had been running with their replaced joint for some time. During data collection 57.1% of participants experienced stiffness while running with 25% of those participants experiencing extreme stiffness. The median score for stiffness while running before the replacement was three (range zero to four) on a four-point scale and this score decreased after the replacement with a median of one (range zero to four) upon participants' first run and one (range zero to three) during data collection.

The majority of the participants (85.7%) of participants experienced stiffness after running with 83.3% of those participants having experienced extreme stiffness before the replacement. Upon participants' first run after the replacement 57.1% of participants experienced stiffness after running with 25% of those participants experiencing extreme stiffness. After running with their replacement for a while, 42.9% of participants experienced stiffness after running with 33.3% of those participants experiencing extreme stiffness after running. The median score for stiffness after running was four (range zero to four) before the replacement on a four-point scale and one (range zero to four) upon participants' first run and zero (range zero to four) during data collection.



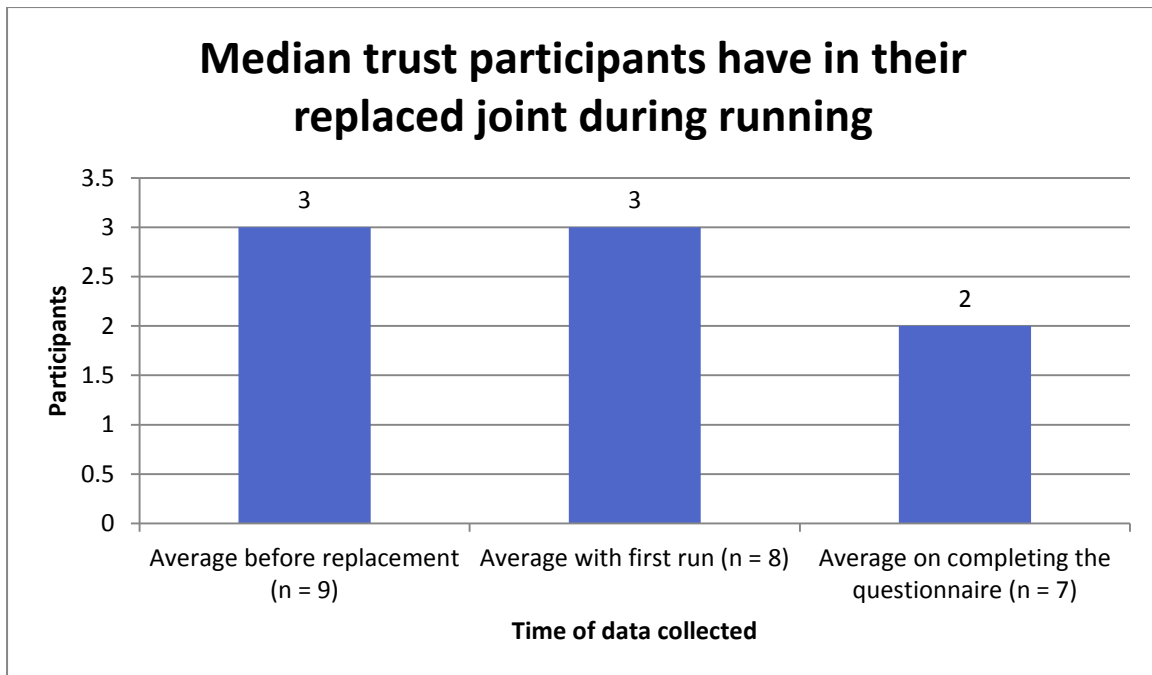
Graph 10 : Level of perceived stability experienced by participants during data collection

Graph 10 represents the level of perceived stability while running. The median perceived stability of the joint before the replacement while running on a flat surface was three (range two to four). The median for running uphill before the replacement was three (range one to four) and running downhill was three (range zero to four). The median perceived stability of the replaced joint during data collection while running on a flat surface was one (range zero to four). The median score for running uphill was two (range zero to four) and while running downhill was two (range two to four) during data collection.



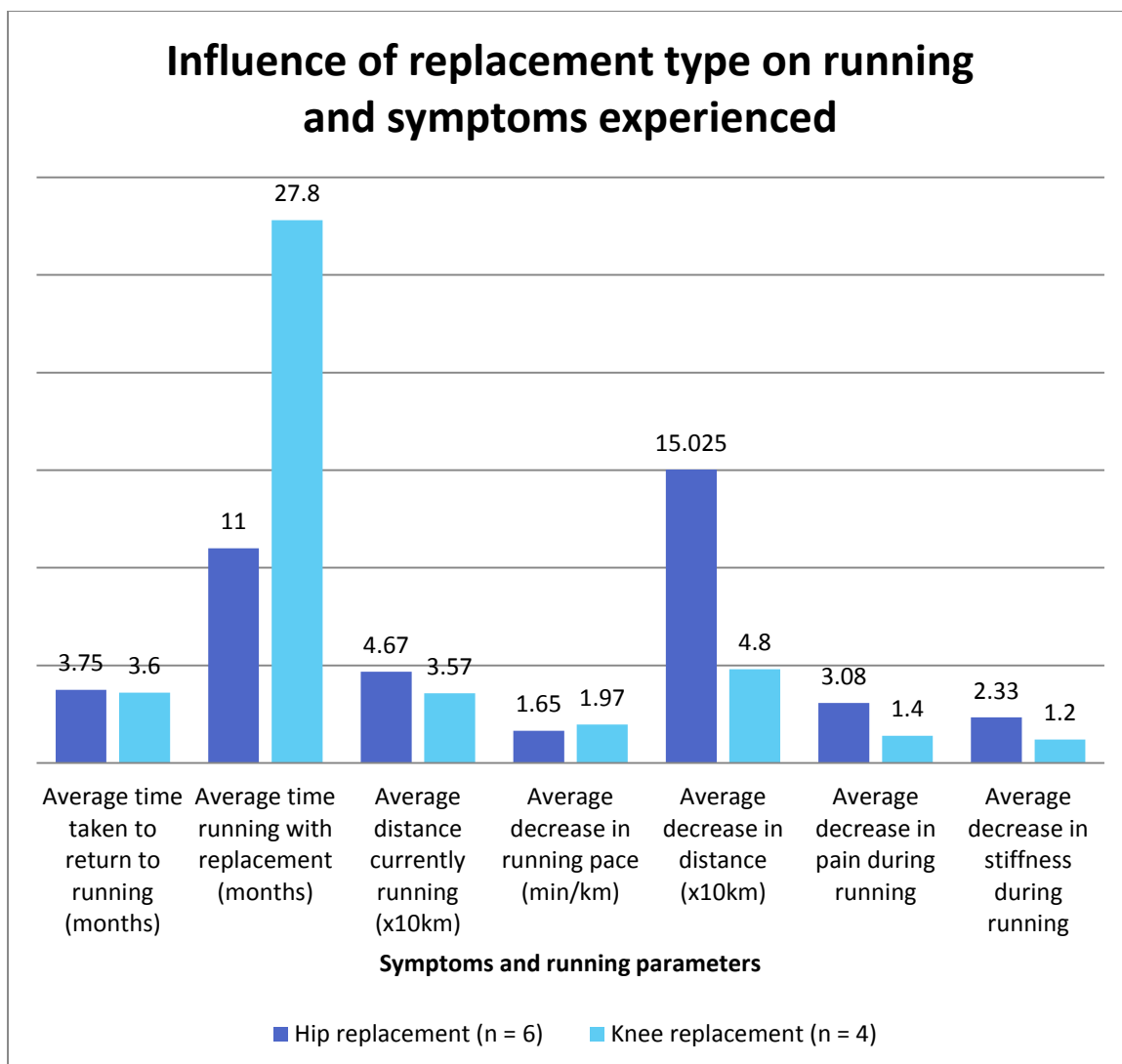
Graph 11 : Satisfaction of participants with their replaced joint during running

Two participants were unsure during data collection of their level of satisfaction, while one participant was unsure of the level of satisfaction during the first run. The median satisfaction participants experienced before the replacement was two (range zero to four), while the average during participants' first run after the replacement was three (range one to four). This further improved at data collection to an average of four (range one to four). The satisfaction participants experienced with their replaced joint during running is displayed in Graph 11.



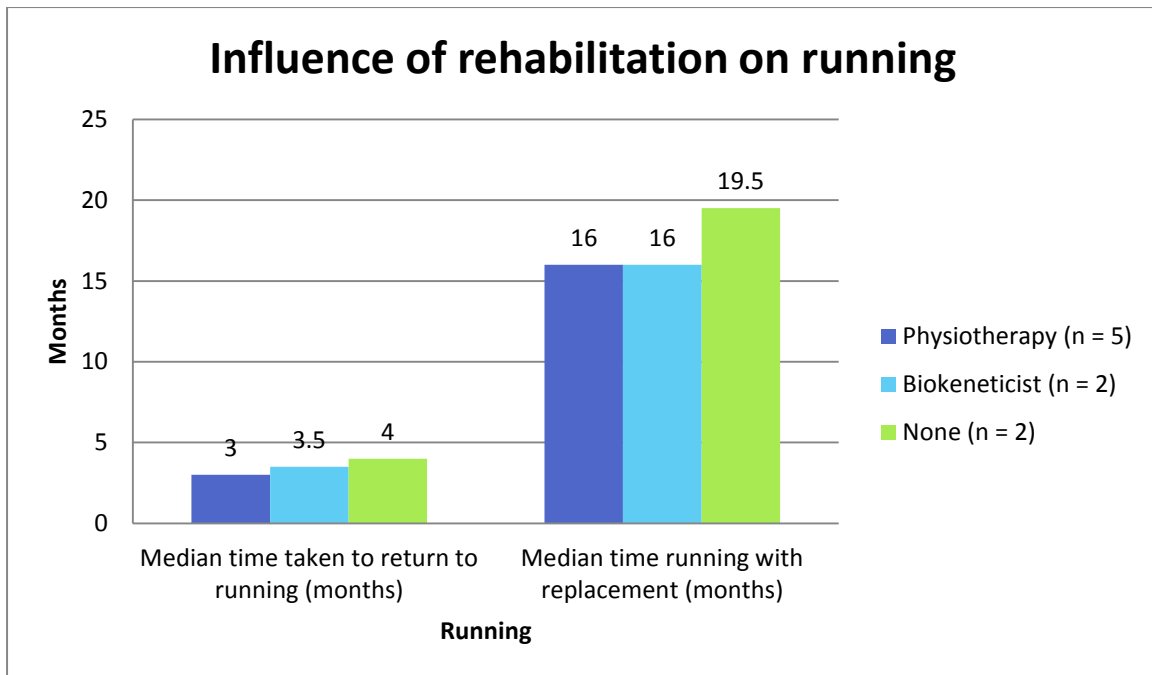
Graph 12 : Median trust participants have in their replaced joint during running

Graph 12 visually portrays the changes in perceived levels of trust participants had in their replaced joint while running on a flat surface. Before the replacement a median score of three (range two till four) was measured. During the first run after the replacement the score was three (range zero to four) and during data collection two (range zero to four).

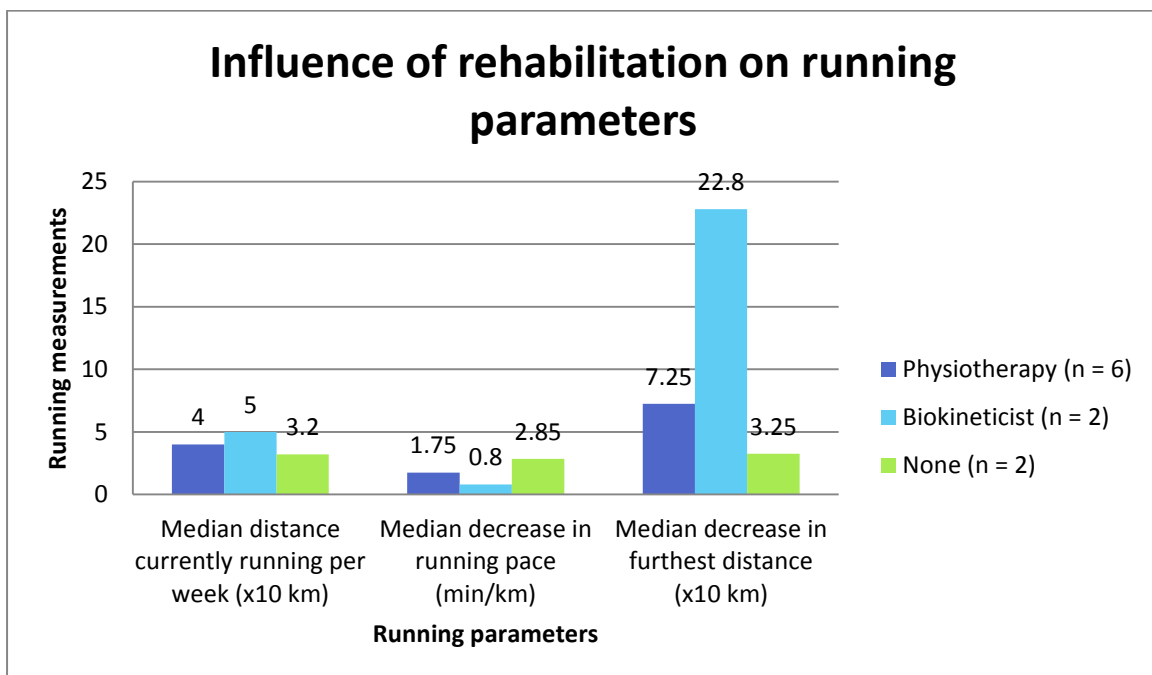


Graph 13 : Influence of replacement type on running and symptoms experienced

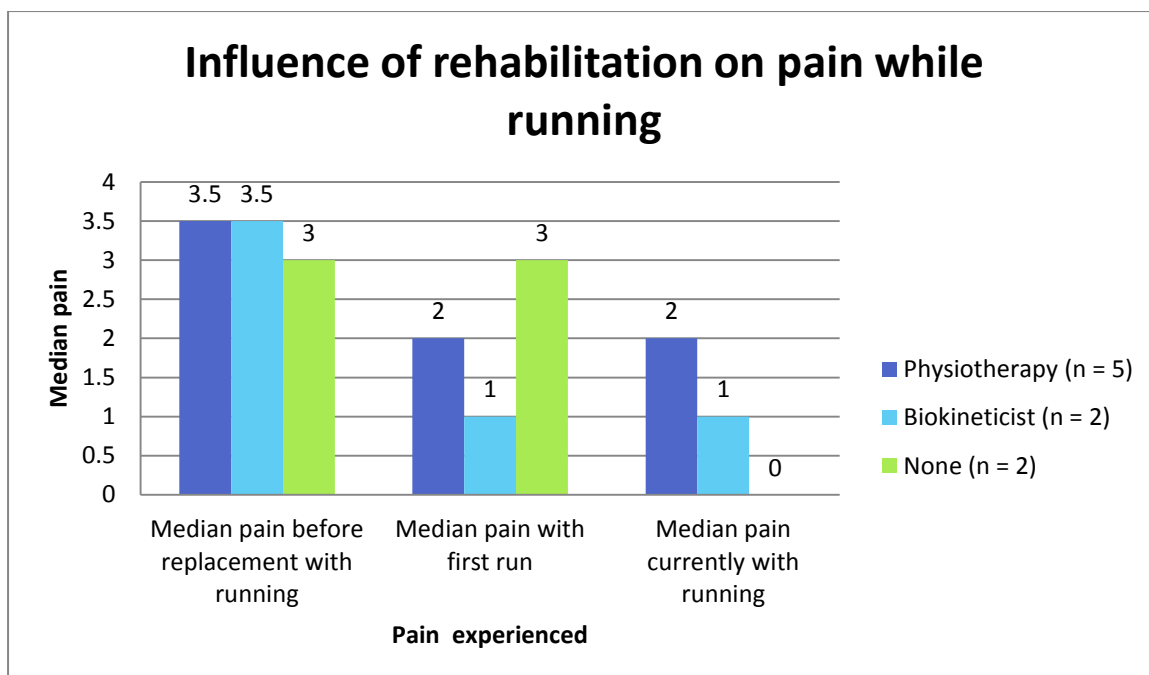
Graph 13 shows the influence of replacement type on running and symptoms. The running pace of knee replacement participants decreased by 1.2 min/km more than that of hip replacement participants. Hip and knee replacement participants had a median decrease in running distance of 72 km. Hip replacement participants were running further when using the median compared to knee replacement participants (an average of 10.5 km more per week). The median of the hip and knee replacement participants' furthest distance before the replacement was 90 km. One of the knee replacement candidates had no change in distance (the participant was able to run 90 km again) although this specific participant's running pace did decrease with 1.5 min/km. In total, it seems that knee replacement participants experienced a smaller decrease in symptom intensity and their median running pace did decrease somewhat more than that of the hip replacement participants.



Graph 14 : Influence of rehabilitation on running



Graph 15 : Influence of rehabilitation on running parameters



Graph 16 : Influence of rehabilitation on pain while running

The influence of the rehabilitation provided by physiotherapists and biokineticists against that of no rehabilitation is compared in Graph 14, 15 and 16. Two patients received rehabilitation from a biokineticist (the light blue graphs), two patients received no rehabilitation (the green graphs) and six patients received rehabilitation from a physiotherapist (the dark blue graphs). Physiotherapy rehabilitation lasted a median time of 3.5 weeks whereas biokineticist rehabilitation lasted a median time of 5.9 months.

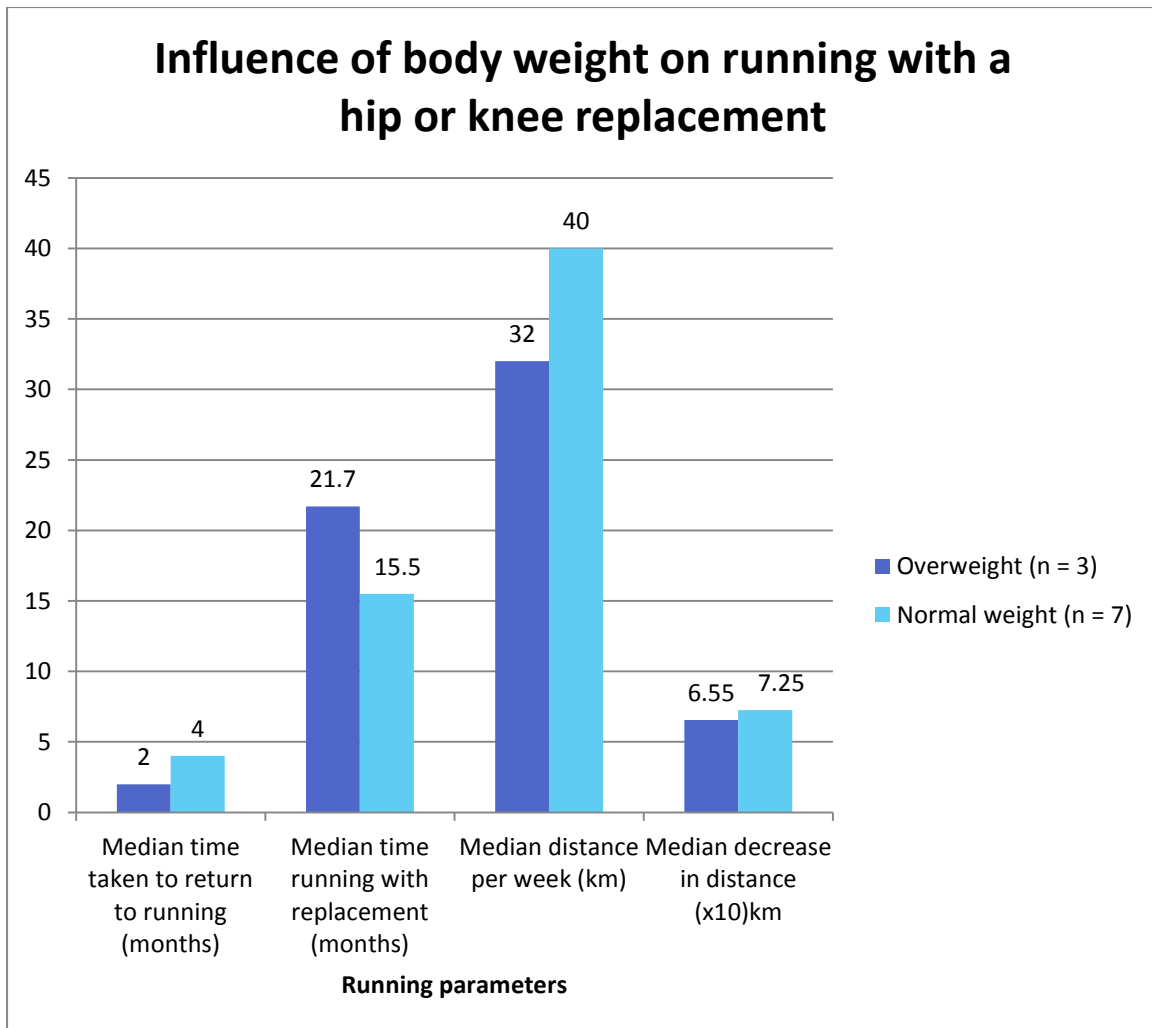
All the participants who received no rehabilitation had had knee replacements whereas all participants who received biokineticist rehabilitation had undergone a hip replacement. Thirty three point three percent of the participants who received physiotherapy rehabilitation had had a hip replacement. Nine out of ten participants received a home programme and all of the participants who received a home programme reported their programme included strengthening exercises and stretches. All the participants from the biokineticist and the no treatment group are currently running (two participants in each group respectively), whereas only three of the six participants from the physiotherapy rehabilitation group are currently running.

The biokineticist's rehabilitation lasted on median of 20 sessions in total for the participants whereas physiotherapist's sessions were five. The median time it took participants who received physiotherapy to return to running was three months, participants who received rehabilitation from a biokineticist returned after 3.5 months and participants who did not receive any rehabilitation returned after four months (Graph 14).

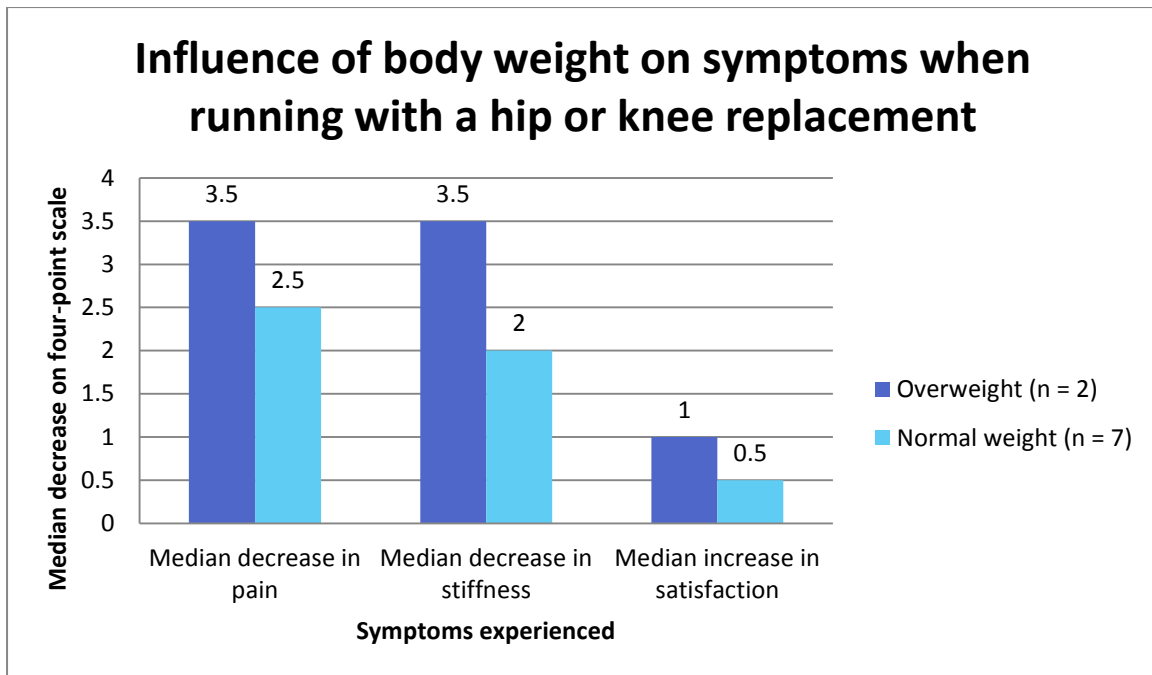
In Graph 15 the physiotherapy and no rehabilitation groups were similar in decreasing their median distance per week with 40 km and 32 km respectively, whereas the biokineticist group decreased their median distance per week by 50 km. The biggest decrease in running pace was in the group who received no rehabilitation (2.85 min/km). The physiotherapy rehabilitation group followed with a decrease of 1.75 min/km and the biokineticist group decreased by only 0.8 min/km. The biokineticist rehabilitation group experienced the largest decrease in the total distance they ran with this being 228 km, followed by physiotherapy group with a distance of 72.5 km and lastly the group who received no rehabilitation with 32.5 km.

Although the pain levels experienced by the participants were similar before the replacement, patients who received biokineticist rehabilitation experienced the greatest decrease in pain during their first run (2.5) after which their pain levels remained unchanged (depicted in Graph 16). Physiotherapy rehabilitation provided a decrease of 1.5 average intensity out of four for pain experienced during their first run which remained unchanged up till the time of completing the questionnaire. The pain levels of the group who received no rehabilitation pain levels remained unchanged when comparing their score before the replacement and during their first run. After this their average pain level during data collection decreased with three leaving this group with no pain.

While analysing the data it was observed that body weight also influenced the results, and therefore the data regarding body weight will be discussed below. Graph 17 below indicates the running parameters and Graph 18 shows the influence of body weight on symptoms after the replacement during data collection. Four of the participants were overweight, whereas six of the participants were within the normal and healthy body weight ranges.

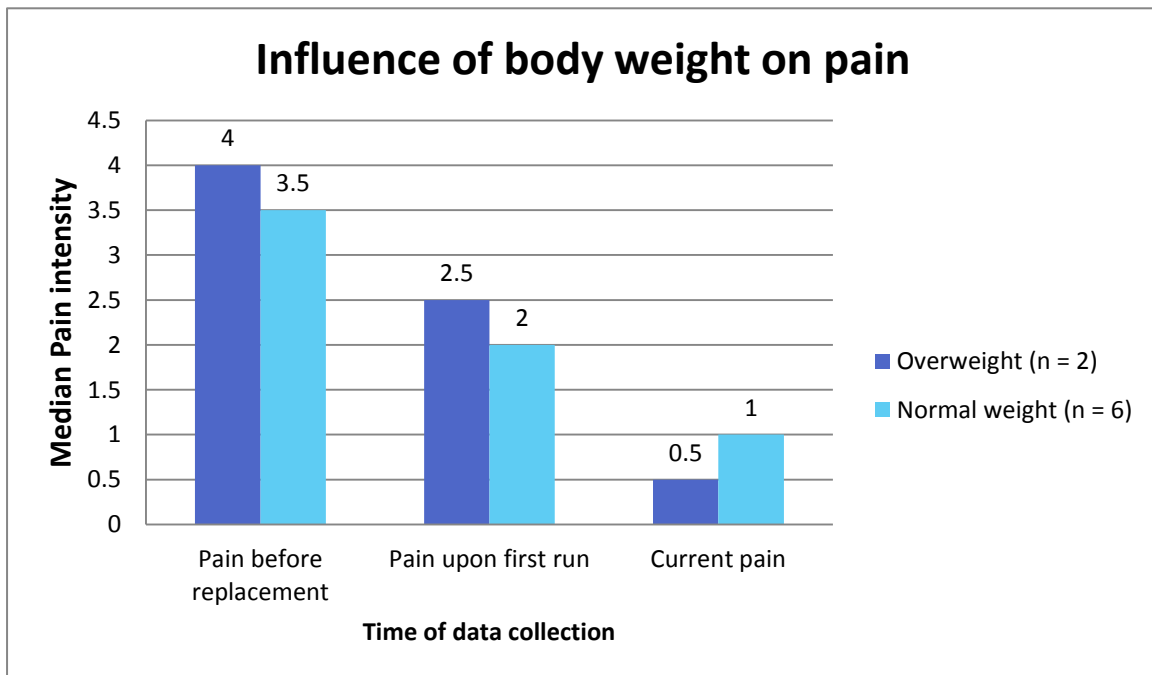


Graph 17 : Influence of body weight on running with a hip or knee replacement



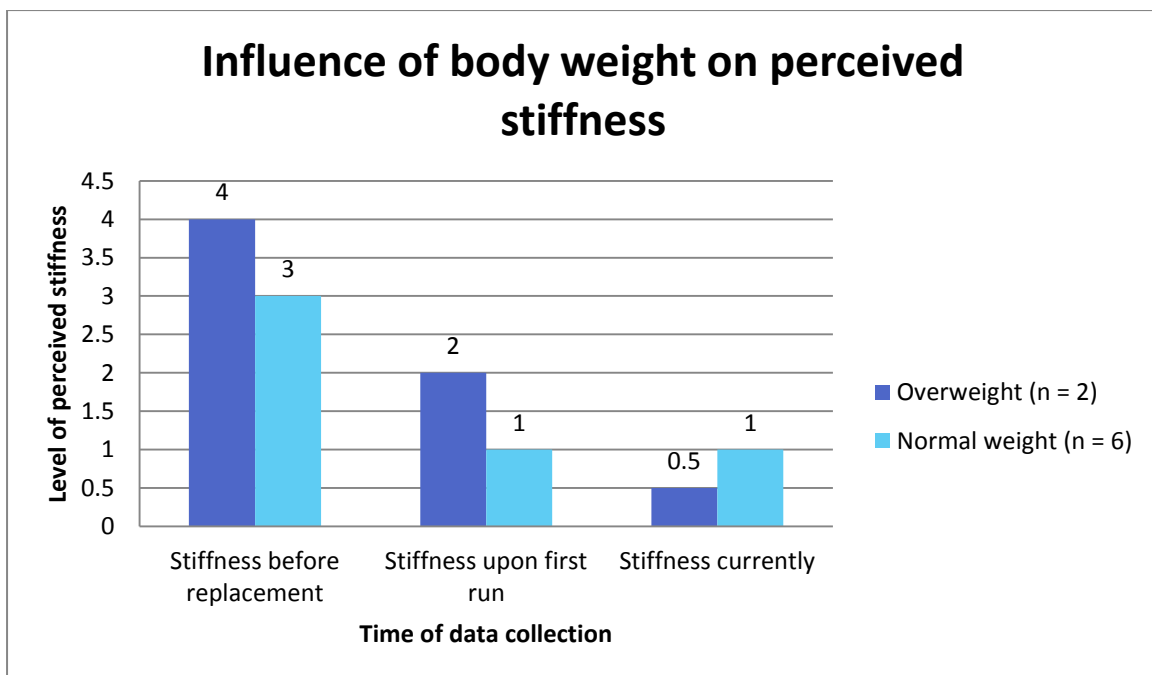
Graph 18 : Influence of body weight on symptoms when running with a hip or knee replacement

Fifty percent of participants from the normal body weight group had undergone knee replacements where 75% of participants from the overweight group had had a knee replacement. The median time participants ran with their replaced joints was 21.7 months for the overweight group and 15.5 months for the normal body weight group. The median decrease in distance was 72.5 km for the overweight group and 65.5 km for the normal body weight group. The overweight group had a decrease of 3.5 in pain scores (on a four-point scale), stiffness decreased with 3.5 and participants' satisfaction with their replaced joint improved with one. The normal body weight group had a decrease of 2.5 in pain and two in stiffness with satisfaction with their replaced joint improving with 0.5.



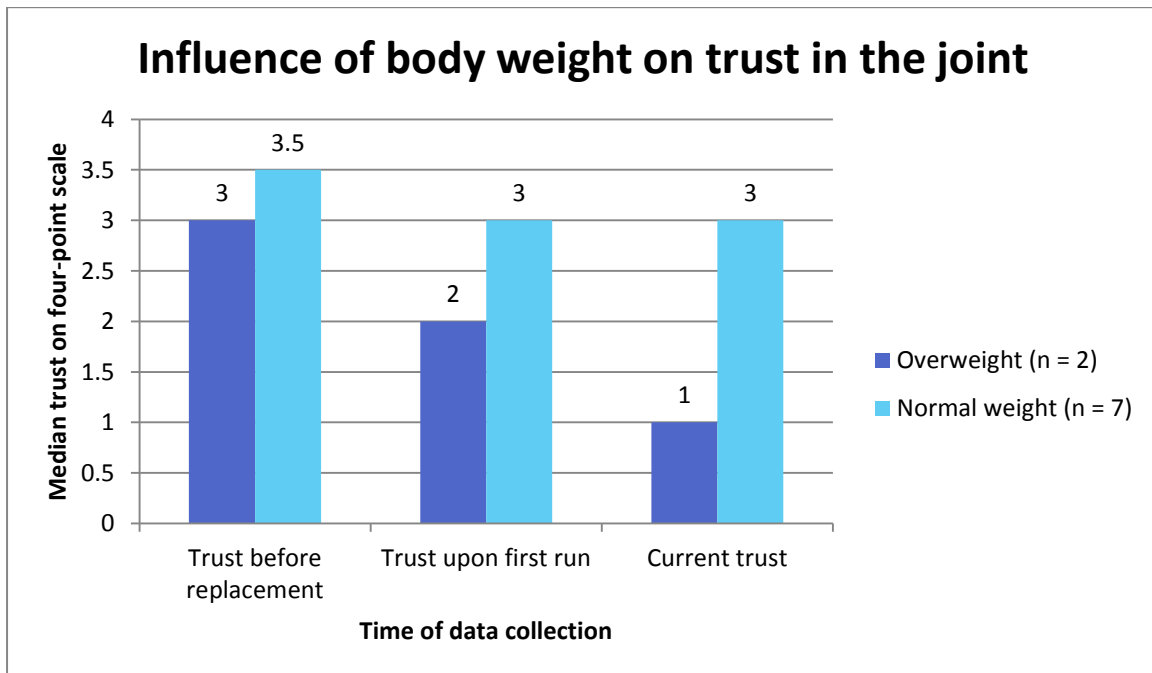
Graph 19 : Influence of body weight on pain

Graph 19 depicts median pain levels of the two body weight groups before the replacement, during participants' first run and during data collection.



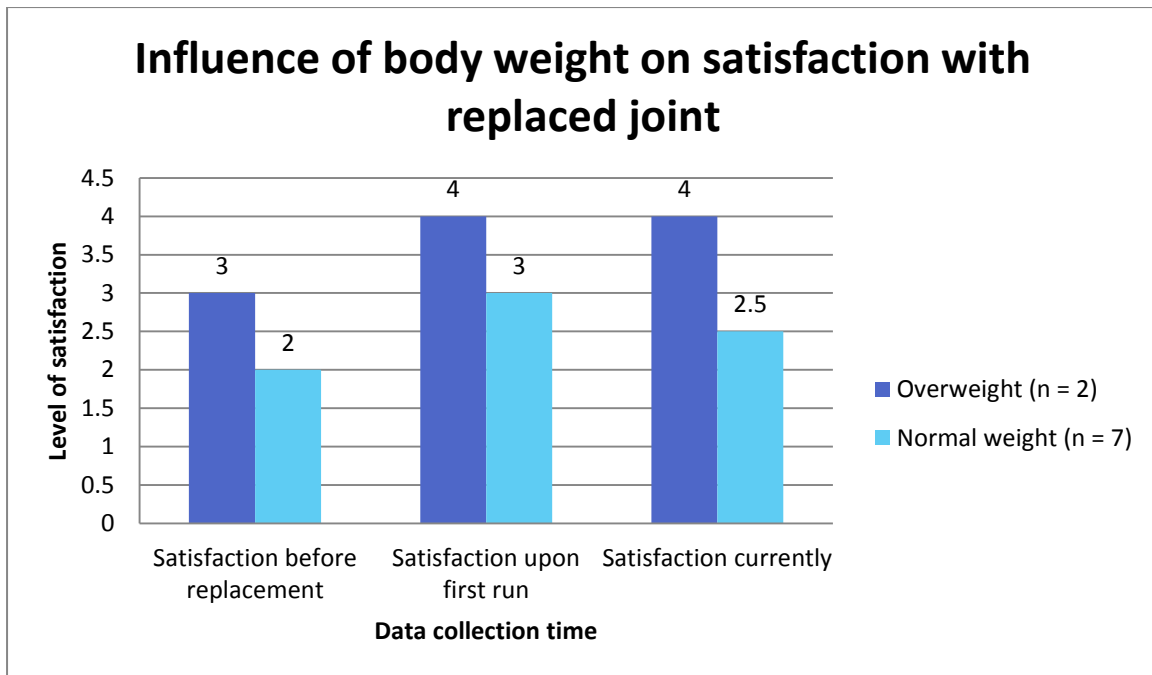
Graph 20 : Influence of body weight on perceived stiffness

Graph 20 depicts the two body weight group’s mean perceived stiffness levels before the replacement, during participants’ first run and during data collection.



Graph 21 : Influence of body weight on trust in the joint

Graph 21 depicts the trust the participant had in the joint before the replacement, during the first run and during data collection. The normal body weight group’s trust in the replaced joint’s scores increased with 0.5 from before the replacement to the time of data collection. The overweight group’s scores decreased with two on a four-point scale from before the replacement to the time of data collection. According to the data, the trust in the joint for the normal weight group remained fairly unchanged, whereas the trust overweight participants had in their replaced joint improved after the joint replacement.



Graph 22 : Influence of body weight on satisfaction with replaced joint

Graph 22 depicts the satisfaction score of individuals with their joint replacement for the two body weight groups. The normal body weight group had a median increase of 0.5, whereas the overweight group’s score increased with one. Both groups therefore had an improvement in satisfaction with their replaced joints.

Participants were given the opportunity to add any comments at the end of the questionnaire and these remarks are depicted in Table 16.

**Table 16 : Comments made by participants**

Comments made by participants	“Started to exercise too soon after the replacement” (the participant returned to running two months after the replacement).
	“The quality of my running, walking, mobility and flexibility - since the hip replacement has improved immeasurably. I have been attending weekly Biokinetics post-surgery sessions, from 3 months – to present

	(21 months). I last ran 90 kms in 2000 (a long time ago!), and I ran 32 kms in December 2012 (7 months before the hip replacement)”.
	Completed nine Comrades Marathons before the replacement and completed his / her 10 <sup>th</sup> Comrades after the replacement with ease. He / she then experienced knee pain again and decreased his / her running to postpone the second replacement. The replacement failed four years after his / her initial replacement, and the tibial portion had to be removed and replaced with a longer stemmed prosthesis in 2014. **The feedback the participant provided in the questionnaire was with regards to the first replacement.
	Had no pain but has difficulty in running though walking is not as satisfying as running.
	Not running any more, only walking.
	Was going to change sport due to the knee pain experienced.

**In summary :**

In this chapter it can be seen that weight, rehabilitation and type of replacement all influence symptoms. Participants still experienced pain and stiffness while running with a replaced joint though trust in the replaced joint while running improved. In the chapter to follow the results observed during the study will be discussed.

## Chapter 5 : Discussion

In this chapter the results obtained during the study will be discussed and compared to the available literature.

Participants typically had higher averages of pain when running than at rest. This suggests that running increases the pain more than walking increases the pain in the case of this study's participants. This might be due to the high impact of running and the inability of the prostheses to cope with the impact (1.5 – 5.5 times the body weight according to Hreljac (2004, p. 846) and Abe *et al.* (2013, p. 131) or it might be due to adverse effects after the replacement as discussed in the previous chapter. It is also possible that the rehabilitation they received might not have been sufficient to enable good biomechanics (as previously discussed) during a high impact sport such as running, thus predisposing them to injuries. Jasani, Richards and Wynn-Jones (2002, p. 992) found that psoas muscle impingement typically occurs after a hip replacement and is exacerbated by activities with hip flexion and external rotation, typically associated with running. Therefore, the influence of different types of rehabilitation was investigated in the study and will be discussed later in the chapter.

Participants' median pain after running was a four before the replacement which decreased to a 1.5 during data collection. This decrease in pain experienced by participants in this study might be due to the original diagnosis and cause of the pain being resolved. The cause of the pain after the replacement was not assessed in the participants during this research study, though Beswick *et al.* (2012) found during a literature review that 10% to 34% of patients suffer from chronic pain after the hip or knee replacement and seven percent to 23% after a hip replacement. The pain that still persisted could be due to the change in gait pattern resulting in strain on structures or due to loosening, retained haematoma, infection, psychological, hyper-immunity, allergy, trochanteric bursa that is excised during surgery, muscle weakness or psoas muscle impingement that is exacerbated by the running and persists after running (Heisel, Silva and Schmalzdried 2003, p. 1374; Hui *et al.* 2011, p. 624 ; Höll *et al.* 2012, p. 2513; Garrett and Walters 2010, p. 63; Jerosch, Theising and Fadel 2006, p. 165; Beaulieu, Lamontagne and Beaulé 2010, p. 269).

During their first run after the replacement more participants rated their pain as lower whereas high intensity pain was not as prevalent. As time passed after the replacement, a larger decrease in pain levels could be observed in participants. This could have been due to improved function or rehabilitation after the surgery and the initial joint (eg. OA, fracture) being resolved after the surgery as the incision initially causes some pain though with healing, the pain decreases.

Three participants indicated they were unsure of the perceived level of stability of their replaced joint during their first run and two participants during data collecting. It might be that the participants wrongfully interpreted a score of five as the highest score of stability. During data collection the participants surely would have known their perceived level of stability and the score of unsure which they indicated was therefore surprising. It might also be that they were not running at that time, therefore indicating that they were unsure of their perceived stability of the replaced joint.

The scores for stiffness were overall lower for all participants than their pain scores although one participant experienced severe stiffness during running and after running. Five participants experienced stiffness during the day and pain and stiffness persisted during walking. Participants typically had a higher average stiffness during and after running when compared to stiffness experienced during the day. Stiffness increased during walking, but also increased more during running when compared to stiffness during the day.

Garrett and Walters (2010, p. 60) found that the incidence of stiffness varied from 1.1 – 10.8% after questioning surgeons regarding the symptoms patients had post-operatively. The results found during the present study were higher with 50% of participants reporting stiffness. The participants in the Garrett and Walters (2010) study were non-runners, thus it seems that runners experienced more stiffness than non-runners.

The persistent stiffness was not assessed, and could have been attributed to the higher activity levels that participants engaged in that caused stiffness or due to the impact, poor muscle strength, altered gait/running pattern that could have been present in the participants.

Due to the surgery and rehabilitation time, participants did not train for running for an average of three months, during which time they might have lost some of their fitness and muscle strength. The loss of muscle strength could be due to the surgical incision as well as the initial protection stage where rehabilitation typically entails protection, maintenance of range of motion and basic strengthening as described by Physiopedia (2016).

Fouilleron *et al.* (2012, p. 3) found that five percent of participants in their study still experienced stiffness that hindered them after a hip resurfacing. The results of the present study differ in that 50% of all participants still experienced stiffness, with 25% of knee replacement participants still having high levels of stiffness, while no one from the hip replacement group experienced high levels of stiffness. The reason for the high levels of stiffness in knee replacement patients was not evaluated, though it may be due to the anatomy of the knee. The knee is less stable when compared to the hip as seen when previously discussing its anatomy. Hip replacement participants received rehabilitation from a biokineticist while knee replacement participants received rehabilitation from a physiotherapist only. This might have influenced the symptoms resulting in the higher pain levels the participant experienced, though the reason for this should be evaluated in more detail.

During the study by Fouilleron *et al.* (2012) their participants' average age was 50.7 years, 12.3 years less than the present study's mean age. Nilsson and Lohmander (2001) found that younger patients had better outcome postoperatively when compared to older patients (over 75 years). As Fouilleron *et al.* (2012) proved that the running distance decreased for participants over the age of 50, it might be an indication that results from this study might not be accurate to young patients, only patients in the age range similar to this study.

The study of Fouilleron *et al.* (2012) shows that the mean return to running after the replacement was after 16.4 weeks (about four months), one month later than the mean of this study. Their study also only included hip replacement participants, while knee replacement participants were included in the present study and this might have influenced the results of the study.

Participants' stiffness while running decreased from a median of three before the replacement to a one during data collection. Participants' average stiffness after running was a four before the replacement which decreased to a zero during data collection. The decrease in stiffness was not assessed in participants, and therefore the causes for the decrease are unknown though it could be hypothesised that the decrease in stiffness could be due to the resolution of the initial diagnosis (70% of participants had a diagnosis of OA which is known to cause stiffness) (American Academy of Orthopaedic Surgeons Board of Directors 2013).

When analysing the results of the study it appears as if stiffness and pain decrease while running and after running with a joint replacement. The reason for this decrease is unclear and should be investigated further, though it may be because exercise decreases stiffness experienced as seen with activities during the day.

The perceived stability of the replaced joint was measured utilising a four-point scale while running on flat surfaces, uphill and downhill. Most participants were satisfied with their replaced joint on flat surfaces. Similar results were found when participants ran downhill, though half of the participants were not satisfied with their replaced joint when running uphill. The reason for this could be due to the increased percentage of lower limb muscle activation required to propel the runner forward when running uphill when compared to running downhill or on flat surfaces which are more effortless (Sloniger *et al.* 1997). Running uphill may thus result in earlier muscle fatigue which adversely influences the stability of the replaced joint perceived by the participants.

Participants were mostly not satisfied with their joint before the replacement as would be expected due to the pain, stiffness and symptoms experienced by the runner before the replacement. This improved and most participants were satisfied with their joint after the surgery during their first run and during data collection. The reason for this may be due to a decrease in pain and stiffness and improved stability of their joint as perceived by the participants.

Participants' median trust in their replaced joint with running was three before the replacement on a four-point scale. The median for participants during their first run was three. The median for trust in their joint during data collection improved to two. The trust in their joints did not show big changes (only improved with one), this could be due to persisting pain and stiffness.

Overall hip replacement participants fared better than knee replacement patients, as expected when taking previous studies into account (such as that of Ross and Brown 2010), although the hip replacement participants had not been running with their replacement as long as knee replacement participants. This influenced the data because of more wear possibly experienced by the knee replacement participants over time. Knee replacement participants had been running an average of 23 months longer with their replacements when compared to the hip replacement participants. The data in this study was not separated according to the type of replacement while analysing the data (for example while analysing the influence of weight or rehabilitation) due to the small size of the study sample. During future studies, different types of replacements should be taken into account.

Knee replacements was proven to experience more pain and symptoms after the surgery according to Ross and Brown (2010, p. 47) possibly due to a longer history of pain before the replacement when compared to hip replacement patients, though the researchers did not explore this. The same results were observed during this study where hip replacement participants experienced a decrease in their pain and perceived stiffness of one / 0,5 more than knee replacement participants.

The higher intensity of symptoms knee replacement participants experienced may be due to the longer running distance per week and one participant running the Comrades (though this participant's scores for the symptoms was within the average range when compared to that of the other participants). One knee replacement participant did experience higher levels of symptoms compared to the other knee replacement participants, but this participant did have an Achilles tear and repair which possibly influenced the symptoms the participant experienced. This influenced the average intensity of the symptoms experienced though for this reason the median was used instead of the average to eliminate skewness of data. Similar results were found by Huch *et al.* (2005) where patients of the hip replacement group had a lower pain score when compared to knee replacement participants. As discussed in the anatomy of the hip and knee, the stability of the knee joint depends mostly on the ligaments and muscles of the knee whereas the stability of the hip joint is due to the muscles and also the bony structures of the acetabulum and the labrum. Due to the hip joint's better stability compared to that of the knee joint, it is possible that slight instability of the knee joint may persist after a knee replacement, leading to more pain experienced by the knee replacement participants. It may also be due to the subjectivity of pain intensity when rating according to a scale. It is easy to indicate if pain is present or not, though the level of pain may be subjective depending on whether participants have a high or low tolerance to pain. This may mean that some patients may experience the same level of pain though one participant describes the pain as mild while another participant might indicate it as severe pain as pain is very subjective (Williamson 2005, p. 799).

Eight of the ten participants still experienced symptoms after the joint replacement. Most of the participants had persisting pain and stiffness. Participants with hip replacements with an anterior approach experienced stiffness, while those with a lateral approach experienced pain and stiffness. Auffarth and Reschet (2011 cited in Chechik *et al.* 2013, p. 1597) found that participants with an anterior approach had higher levels of pain. The reason for the difference between their results and this study's results might be due to the population used, because Auffarth and Reschet (2011) included elderly people with fractures, whereas the population in the present study was younger participants who were running. All but one participant who had undergone a knee replacement had symptoms, one had only knee pain, while the other two had knee pain and stiffness. It should be noted that environmental and personal factors

were not further assessed such as camber of road, dominance of leg, running style, injuries, etc. and these factors could have influenced the results of the study.

Huch *et al.* (2005, p. 1719) found that 72% of sports participants in their study who received a hip replacement had severe to moderate pain before their replacement whereas 100% of their participants had mild to no pain five years after their replacement. A large number of participants who underwent a knee replacement (93%) had severe to moderate pain before the replacement and 98% of their participants had mild to no pain five years after their replacement. The study was done on sports participants, and thus results from low and high impact sports participants were included in the study. During this study it was found that 100% of participants with a hip replacement had mild to no pain after the replacement and 50% of knee replacement participants had mild to no pain after the replacement while running. During the study performed by Huch *et al.* (2005) only a small percentage of their participants were runners, while most of the other participants competed in other sports (such as swimming, cycling, dancing, etc.) and in fact some of the participants did not compete in any sports activities. This might have positively influenced their results while during this study, only the results of runners are presented.

When comparing biokineticist, physiotherapy and no rehabilitation, the results from biokineticist and no rehabilitation indicated a larger decrease in symptoms (pain and stiffness). The time taken to return to running and average time running with the replacement was fairly equal for biokineticist, physiotherapist and no rehabilitation. Though various factors such as motivation, goal setting and socio-economic situation influences rehabilitation, these factors were not assessed during this study. Physiotherapy rehabilitation was found to be effective in decreasing pain, improving range of motion and function after a knee replacement by Artz *et al.* (2015) when compared to no rehabilitation.

The median distance of the biokineticists' patients that they were running per week remained fairly high (50 km/week) while the physiotherapy and the no rehabilitation group's median weekly distance was 40 and 32 km/week respectively. The biokineticist rehabilitation group's pace only decreased by 0.8 min/km whereas the physiotherapy rehabilitation group's pace decreased with 1.75 min/km. The decrease in distance was significantly higher in the

biokineticist rehabilitation group with a decrease of 228 km and the physiotherapy rehabilitation group decreased with 72.5 km while the no rehabilitation's group decreased with 32.5 km. The biokineticist group's pain (as measured on a four-point scale) decreased with 2.5 and physiotherapy group's pain decreased by only 1.5.

When assessing the reason for the excessively large decrease in the longest distance for the biokineticist group it was found that one participant's furthest distance before the replacement was 403 km and after the replacement he was only able to run 16 km. The distance of 403 km was an excessive spike in data with all the other participants' furthest distance averaging at 82 km when the 403 km was excluded. It could thus be reasoned that this participant's results for distance should be excluded due to the excessive deviation from the norm. The biokineticist group's median would then be 69 km which is closer to the other group's values of 61.3 km and 32.5 km. The no rehabilitation group also contained the only participant whose furthest distance was only 15 km before the replacement, thus also deviating from the longest distance of the other participants of at least 90 km. This also influenced the no rehabilitation group's results as the participant's decrease in furthest distance was only three kilometres where all other participants' decrease in furthest distance was 62.5 km. If this participant's results were excluded from the calculations for decrease in furthest distance, the decrease for the no rehabilitation group would be 62 km. This indicates that the average decrease in distance was fairly similar for all three groups with the physiotherapy group at a decrease of 72.5 km and that of the biokineticist group at 69 km. One participant from the physiotherapy group experienced no decrease in longest running distance as he / she was able to run 90 km again after the replacement. It should also be noted that the biokineticist group included one male and one female participant, the physiotherapy group included three males and three female participants and the group that received no rehabilitation included only two male participants. This could have influenced the data as comparing males with females is not ideal due to the difference in anatomy, function and muscle strength (Malinzak *et al.* 2001, p. 443). Due to the limited number of participants in this study, the results of males and females could not be separated.

When closely analysing the reason for the larger decrease in pain levels for the no rehabilitation group, it can be observed that they took longer to return to running after the replacement. Their average running pace decreased the most, resulting in an average running pace after the replacement of 10.1 min/km with the biokineticist group's at 6.55 min/km and that of the physiotherapy group at 6.75 min/km. It can thus be reasoned that it is possible that taking longer to return to running after a replacement and running at a slower pace will result in decreased pain levels. This might be due to a slower running pace resulting in less impact on the replaced joint or due to kinematic differences during different speeds of running (Everett, O'Connor and DeWitt 2009), while a longer time taken to return to running might have resulted in improved muscle strength and the normal healing process being allowed.

It can thus be reasoned that rehabilitation from a professional is needed after a replacement. The reason for biokineticist's rehabilitation efficacy in this study might have been due to their average total sessions of 20 whereas physiotherapy's was only five. The reason for this difference in average sessions could be due to physiotherapy's scope of practice with physiotherapists being more involved with the acute phase of rehabilitation and treatment and the biokineticist being more involved with final stage rehabilitation. Physiotherapy sessions start in hospital and are aimed at improving functional outcome after the surgery and to decrease length of stay in hospital (Munin *et al.* 1998) and at this time the patient may not declare his or her intent to return to running. Rehabilitation was thus focused on symptom reduction (oedema and pain), strengthening, stretching and improving function (initial rehabilitation) while participants receiving rehabilitation at the biokineticist engage in final stage rehabilitation aimed at a return to sport. It is thus possible that biokineticists prepares patients to return to running whereas physiotherapy rehabilitation is not necessarily aimed at return to sport with joint replacements. Thus end results from the two rehabilitation groups can therefore not be effectively / statisticly compared as the aims of treatment of the two groups could have differed. Unfortunately no research were found that compared rehabilitation groups to investigate the influenc of this on the symptoms and quality of running experienced by runners when they return to running after a hip or knee replacement.

Two participants still had a high intensity of pain during and after running (a score of three or more out of four). Most participants experienced no pain during running, although some

participants experienced a low intensity of pain during the day. Eighty three point three percent of participants who underwent a knee replacement still experienced pain.

When analysing results according to weight, four participants were overweight (A BMI of  $\geq 25$  according to Mahan, Escott-Stump and Raymond (2012, p. 166)) and six participants' weight was in a normal range (BMI between 18.5 and 24.9 according to Mahan, Escott-Stump and Raymond (2012, p. 166)). The median pain as rated on a four-point scale before the replacement was similar (overweight group at four and normal weight group at 3.5 average). The pain experienced during their first run after the replacement decreased for the overweight and normal weight group by 1.5 on the median scores. The normal weight group's pain further decreased with one when considering pain during data collection, while the overweight group experienced a further decrease of two. The overweight group experienced a larger decrease in pain overall when running compared to that of the normal body weight group, with most of the pain decrease for the normal weight group occurring shortly after the replacement whereas the overweight group had the largest decrease in pain after running with the replacement for a while. It may be that the overweight group lost weight when they started running again, thus resulting in a decrease in pain as their body weight decreased because the impact of running decreases with a decrease in body weight. The normal body weight group experienced a decrease in pain as soon as the cause of pain was resolved (the osteoarthritis, fracture, etc.). Unfortunately there was no studies found that evaluated the influence of weight on the runners' symptoms or quality of running.

The stiffness experienced by the overweight and normal weight group before the replacement was four and three respectively. A significant decrease in stiffness was observed in the overweight and normal weight group during their first run after the replacement (a decrease of two on the median score). The overweight group then had a decrease in stiffness of 1.5 whereas the normal weight group's average score for stiffness remained unchanged during data collection. No evidence could be found in the available literature regarding the influence of body weight on stiffness.

The trust in the joint for the normal weight group's participants remained fairly unchanged whereas the overweight group's trust in their joint improved significantly. Both groups' satisfaction with their replaced joints improved.

To understand the difference in data, further analysis was done between the two groups. The median time taken to return to running after the replacement was two months for the overweight group and four months for the normal weight group. Both groups were running with their replacement for a few months, with the overweight group running 1.5 months more with their replacement than the normal weight group.

The differences between the two groups are seen when taking distances into account. The normal weight group's participants ran a median of 40 km per week, eight kilometres more than the overweight group per week. The median decrease in longest distance was 72.5 km for the normal weight group, whereas the overweight group's distance decreased with 65.5 km. A participant from the normal weight group managed to complete a 90 km race again, resulting in him being the only participant with no change in furthest distance.

A difference is also noted taking the participants' running speed into account during data collection. The median running pace of the overweight group was eight min/km whereas the normal weight group's average pace was 6.55 min/km at the time of data collection. This is a significant difference and could suggest that the normal weight group's pace is faster, but that more symptoms are experienced by the group. One of the normal weight group's participants had undergone an Achilles repair which might have influenced his symptoms. The scores did increase significantly during data collection for the participant, resulting in out of the ordinary high score for pain and stiffness while running with the replacement. This might have been due to the Achilles repair though it did not influence the data considering that the median value was used.

It is also important to note that the weight and height scores were provided by the participant self and inaccuracy might arise due to a lack of knowledge, accurate measuring devices or subjectivity of the participants. BMI measurements can also be influenced by the muscle mass of the participant though for endurance runners this is not as probable as for sprinters.

Busato *et al.* (2008) found during their study that BMI adversely affects the function and mobility of overweight patients in comparison with normal weight patients. The decrease in pain post-operatively was relatively similar in both groups according to McLaughlin and Lee

(2000 cited in Busato *et al.* 2008). Similar results are seen in this study. It is possible that the pain levels were equal for both groups, though the difference in running parameters had an impact on the symptoms experienced. Because the median running distance was more for the normal weight group as well as a faster running pace, the impact of the running was greater for the normal weight group resulting in increased pain experienced by the normal weight group while running. When considering all variables, the normal weight group ran further distances at a faster pace though their symptom relief was not as much as that of the overweight group. Thus the normal body weight group had better functional outcomes when compared to the overweight group.

Of all the participants participating in the study five had negative consequences regarding their replacement. One participant had a need for revision of his knee replacement after only four years. According to Rodriguez, Bhende and Ranawat (2001) the average time for a revision was 11.4 years after the total knee replacement in participants who did not compete in sports. The participant that had the failure completed his / her tenth Comrades after the first replacement. This might indicate the extent of adverse effects when running long distances after a replacement. Two of the participants could not run again and one stated that he / she wanted to run but was unable to do so, while one participant considered changing his sport due to pain experienced.

### **In summary :**

Knee replacement candidates experienced a smaller decrease in symptom intensity when compared to hip replacement participants and the knee replacement participants' average running pace decreased somewhat more than the hip replacement candidates, although the decrease for average distance per week was less for knee replacement participants when compared to that of hip replacement participants.

The median time to return to running after a replacement was three months. Pain and stiffness were found to increase with running when compared to pain experienced through the day. After the replacement the participants' running pace decreased as well as their furthest distance they were able to run.

Although the results show that running is possible, participants' feedback clearly indicates that return to running with a replacement was not satisfactory and had negative results (pain and revision) in the long run.

The research aim was to describe the symptoms and quality of running of road runners experienced after a hip or knee replacement. Participants still experienced pain and stiffness after their replacement. Their quality of running decreased when compared to running before the replacement.

## Chapter 6 : Limitations and Recommendations

Some limitations were observed while performing this study and they will be highlighted during this chapter. This is to ensure follow-up studies can use these recommendations to improve their studies and ensure results of statistical value.

The English questionnaire was not piloted, only the Afrikaans questionnaire. This might have influenced results and in future studies this limitation should be addressed to identify possible difficulties participants might have with the questionnaire. Due to the small sample size, statistical significant changes could not be observed during the study. Therefore, the study should be seen as an exploratory study and a similar study with a larger population should be performed before recommendations can be made regarding return to running after a knee or hip replacement. Furthermore, a long term follow-up study should be performed when considering that the results of this study were only after an average of 20 months pre-operatively. A prospective study should also be considered to account for possible recall of information by participants.

To ensure the answers reported truly reflect the response of the participants, a structured interview with a physical examination is recommended as some of the participants could have interpreted the scoring differently than initially intended by the researcher, especially the grading system of their symptoms on the four-point scale. Participants also had limited knowledge regarding their rehabilitation and during this study the rehabilitation was explored in an open question and very little information was gained. In future studies closed ended questions should be used to explore therehabilitation and input from the participants' physiotherapists or biokineticist should be included in similar studies. Environmental and personal factors should be included such as camber of road, dominance of leg, running style, injuries, etc.

Future studies should consider including an option for participants to indicate that they are unsure of the degree of symptoms that they are experiencing and the VAS scale might be of help. More research is needed to determine the influence of BMI on return to running and the

symptoms experienced because so little research is available on the influence of BMI. The decrease in pain and stiffness experienced by participants should be assessed by a researcher in future studies to determine the cause for the pain and stiffness and the influence of rehabilitation on symptoms during and after running. A dietician's involvement might be useful with anthropometric measurements to ensure more accurate readings regarding the participants' weight status. Environmental and personal factors (such as camber of road, dominance of leg, running style, injuries, etc) should also be assessed during future studies to evaluate their influence on results. The difference in symptoms experienced by males and females should also be investigated as it is clear from the available literature that the sex of an individual may also play a role in the symptoms experienced during running.

By keeping these limitations and recommendations in mind follow-up studies can avoid these limitation during their research.

## Chapter 7 : Conclusion

The aim of the study was to describe the symptoms and quality of running of road runners experienced after a hip or knee replacement. This aim was met and the symptoms and quality of running will be summarised below.

Pain and stiffness increased during activities such as walking and more so with running in participants after a hip or knee replacement. Participants' satisfaction while running on a flat surface and downhill improved after the replacement though half of the participants were not satisfied with their replaced joint while running uphill. Hip replacement participants had less symptoms when compared to knee replacement participants though 80% of all participants still had symptoms with running after their replacement.

Rehabilitation from a professional resulted in decreased symptoms and biokineticist rehabilitation reduced symptoms while running more than physio or no rehabilitation. Overweight participants had lower pain levels when compared to normal body weight participants though this higher level of pain of the normal body weight group could be attributed to the faster running speed and further distance reported that is found in the normal weight group. The stiffness in the normal and overweight group is similar at the time of data collection but trust in the replaced joint improved in the overweight group.

One participant had a revision of the replaced joint after running with it and five participants had negative feedback regarding running with a replaced joint. When taking the results into account it seems as if symptoms increase with running and the survival of the replaced joint might be adversely affected by running.

Although the sample in the present study was small there are clear indications that running with a replacement is possible but symptoms such as pain and stiffness are experienced by participants during running and after running. Running pace decreased when compared to running before the replacement and the quality of running might be affected with longer distances.

Final judgement regarding return to running as well as quality of running after a joint replacement can only be done once further research is conducted on a larger population and differentiation is made between knee and hip replacements and male and female participants, as well as other factors such as BMI, training load etc.

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# Appendices

## 1 Appendix A : English Questionnaire

### Return to Running questionnaire

#### Symptoms and quality of running experienced by road runners after a hip or knee replacement

Complete the following questionnaire as honestly as possible. Mark your answer with an x in the applicable box.

		<i>For Office use only</i>	
1	Gender	Male <input type="checkbox"/> Female <input type="checkbox"/>	1 - 3 4
2	Age	_____	5 - 6
3	Date of surgery (yyyy/mm/dd)	____ / ____ / ____	7 - 12
4 a)	Weight (kg)	_____	13 - 15
b)	Height (cm)	_____	16 - 18
5	With what type of shoe do you run?	Conventional running shoes (tekkies) <input type="checkbox"/> Minimalistic shoes <input type="checkbox"/> Barefoot <input type="checkbox"/> Cross trainer <input type="checkbox"/> Other _____	19
6	Do you always run with a specific brand of shoe?	Yes <input type="checkbox"/> No, I run with whatever is available when I go to buy <input type="checkbox"/> No, I run with whatever is cheapest when I go to buy <input type="checkbox"/> Other _____	20
7	What brand of shoe are you currently running with?	Adidas <input type="checkbox"/> Asics <input type="checkbox"/> Brooks <input type="checkbox"/> Inov-8 <input type="checkbox"/> K-Swiss <input type="checkbox"/> New Balance <input type="checkbox"/> Newton <input type="checkbox"/> Nike <input type="checkbox"/> Puma <input type="checkbox"/> Reebok <input type="checkbox"/> Saucony <input type="checkbox"/> Other <input type="checkbox"/> Specify: _____	21 - 22 23 - 24
8	Type of surgery	Knee replacement <input type="checkbox"/> Hip replacement <input type="checkbox"/>	25
9	Reason for surgery	Pain <input type="checkbox"/> Daily activities influenced <input type="checkbox"/>	26
10	Diagnosis that lead to the replacement	Osteoarthritis <input type="checkbox"/> Rheumatoid arthritis <input type="checkbox"/> Septic arthritis <input type="checkbox"/> Fracture <input type="checkbox"/> Unsure <input type="checkbox"/> Other <input type="checkbox"/> Specify: _____	27 28 - 29

11 Indicate if you received any treatment by any of the following professionals after your replacement

Physiotherapist

Biokineticist

Other

Specify: \_\_\_\_\_

12 Describe the duration of your treatment at the medical professional that you indicated above:

How long was it: \_\_\_\_\_ Weeks or \_\_\_\_\_ Months

How many sessions per week/month (as specified above): \_\_\_\_\_

How many sessions in total: \_\_\_\_\_

13 Did you receive a home program?

Yes

No

If yes, what did the home program include (e.g., Stretches, exercises, pain management, etc.)?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

14 Are you taking any pain medication?

Yes

No

If yes, how often and why?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

15 Are you currently running?

Yes

No

If no, why not?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

*For Office use only*

<input type="checkbox"/>	30
<input type="checkbox"/>	31 - 32
<input type="checkbox"/>	33 - 34
<input type="checkbox"/>	35
<input type="checkbox"/>	36 - 37
<input type="checkbox"/>	38 - 40
<input type="checkbox"/>	41
<input type="checkbox"/>	42 - 43
<input type="checkbox"/>	44 - 45
<input type="checkbox"/>	46 - 47
<input type="checkbox"/>	48
<input type="checkbox"/>	49 - 50
<input type="checkbox"/>	51 - 52
<input type="checkbox"/>	53 - 54
<input type="checkbox"/>	55
<input type="checkbox"/>	56 - 57
<input type="checkbox"/>	58 - 59
<input type="checkbox"/>	60 - 61

16 How long after the replacement did you return to running?  
 \_\_\_\_\_ Months or \_\_\_\_\_ Years

*For Office use only*


62 - 63  
64

17 How long have you been running with your replaced joint?  
 \_\_\_\_\_ Months or \_\_\_\_\_ Years


65 - 66  
67

18 How often do you run in a typical week?  
 \_\_\_\_\_ Times  
 or

--	--

68 - 69

Unsure   
 Varies with my training programme   
 Varies with my circumstances

--

70

19 What distance do you run on average per session:  
 \_\_\_\_\_ km During the week  
 \_\_\_\_\_ km Over weekends


71 - 72  
73 - 74

20 What is your average total distance for the whole week:  
 \_\_\_\_\_ km

--	--	--

75 - 77

21 What was your average running pace before and after your operation?  
 Before: \_\_\_\_\_ (min/km)  
 Currently: \_\_\_\_\_ (min/km)

	:			
	:			

78 - 81  
82 - 85

22 Do you run races or just for pleasure?  
 Races   
 Pleasure

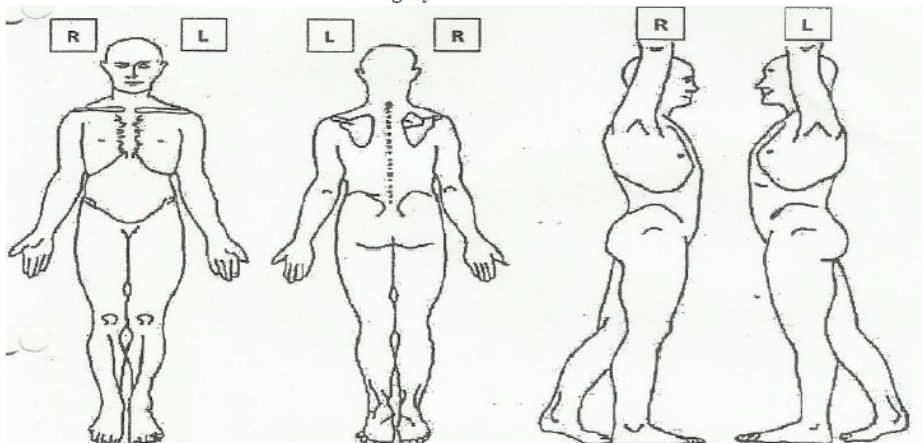
--

86

23 What is the furthest distance you have run before and after the operation?  
 Before: \_\_\_\_\_ km  
 After: \_\_\_\_\_ km


87 - 89  
90 - 92

24 Indicate on the body chart / mannequin where you experience pain with a X,  
 and the area where you experience stiffness with an O (if any).  
 Indicate where the scar of the surgery is with a l




93 - 96  
97 - 100  
101 - 104  
105 - 108

For questions 25 to 29, the following scale is applicable. Please fill in the appropriate number indicating your degree, intensity or severity of the symptom.  
 0=None 1=Slight 2=Moderate 3=Severe 4=Extremely severe 5=Unsure

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25 Indicate the intensity/severity/degree of pain you experienced during every activity for:  
 - the time before your replacement  
 - your first time running after your replacement  
 - and currently:

	Before replacement	Upon first run	Currently		
morning	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	109 - 111
midday	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	112 - 114
evening	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	115 - 117
walking	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	118 - 120
running	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	121 - 123
after running	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	124 - 126

26 Indicate the level of stiffness you experience during each activity for:  
 - the time before your replacement  
 - your first time running after your replacement  
 - and currently:

	Before replacement	Upon first run	Currently		
morning	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	127 - 129
midday	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	130 - 132
evening	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	133 - 135
walking	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	136 - 138
running	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	139 - 141
after running	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	142 - 144

27 Indicate your level of trust in your joint for each activity for:  
 - the time before your replacement  
 - directly after your replacement upon your first time running  
 - and currently:

	Before replacement	Upon first run	Currently		
walking	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	145 - 147
running on flat surfaces	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	148 - 150
running uphill	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	151 - 153
running downhill	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	154 - 156

28 Indicate how stable your replaced joint feels for each activity for:  
 - the time before your replacement  
 - directly after your replacement upon your first time running  
 - and currently:

	Before replacement	Upon first run	Currently		
walking	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	157 - 159
running on flat surfaces	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	160 - 162
running uphill	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	163 - 165
running downhill	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	166 - 168

29 Indicate your satisfaction with your ability to run:

Before replacement	<input type="text"/>	
Upon first run	<input type="text"/>	
Currently	<input type="text"/>	<input type="text"/>

## Return to Running questionnaire

30 Is there anything that you would like to add regarding your symptoms?

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---

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---

---

31 It is possible that myself or another researcher from our university might wish to follow up on this study some time in the future. Would you mind if a researcher were to contact you in the future to ask whether you would consider participating again?

Yes

No

If yes, please provide the contact details where you would prefer to be contacted on:

---

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---

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*Thank you for your participation in this study. Questionnaires can be sent to [ninnette.dutoit@gmail.com](mailto:ninnette.dutoit@gmail.com) or contact the researcher on 071 515 3635 if other arrangements should be made, or to pick up the questionnaire in Pretoria.*

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170 - 172  
173 - 175  
176 - 178  
179 - 181  
182 - 184  
185 - 187

## 2 Appendix B: Ethical clearance certificate



Research Division  
Internal Post Box G40  
☎ (051) 401-7795  
Fax (051) 4444359

E-mail address: EthicsFHS@ufs.ac.za

Ms M Marais

2015-03-10

REC Reference nr 230408-011  
IRB nr 00006240

MS N DU TOIT  
DEPT OF PHYSIOTHERAPY  
FACULTY OF HEALTH SCIENCES  
UFS

Dear Ms du Toit,

ECUFS NR 16/2015

DEPT OF PHYSIOTHERAPY

**PROJECT TITLE: MINI DISSERTATION: SYMPTOMS AND QUALITY OF RUNNING EXPERIENCED BY ROAD RUNNERS AFTER A HIP OR KNEE REPLACEMENT.**

1. You are hereby kindly informed that, at the meeting held on 03 March 2015, the Ethics Committee approved the above project.
2. Committee guidance documents: Declaration of Helsinki, ICH, GCP and MRC Guidelines on Bio Medical Research. Clinical Trial Guidelines 2000 Department of Health RSA; Ethics in Health Research: Principles Structure and Processes Department of Health RSA 2004; Guidelines for Good Practice in the Conduct of Clinical Trials with Human Participants in South Africa, Second Edition (2006); the Constitution of the Ethics Committee of the Faculty of Health Sciences and the Guidelines of the SA Medicines Control Council as well as Laws and Regulations with regard to the Control of Medicines.
3. The Committee must be informed of any serious adverse event and/or termination of the study.
4. Any amendment, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.
5. A progress report should be submitted within one year of approval of long term studies and a final report at completion of both short term and long term studies.
6. Kindly use the ETOVS/ECUFS NR as reference in correspondence to the Ethics Committee Secretariat.

Yours faithfully

  
DR SM LE GRANGE  
CHAIR: ETHICS COMMITTEE

Cc Roline Barnes



### 3 *Appendix C: Information leaflet*

**INFORMATION LEAFLET  
QUESTIONNAIRE STUDY**

University of Free State: *Symptoms and quality of running experienced by road runners after a hip or knee replacement*

Dear Participant

#### Introduction

I, Ninnette du Toit, am currently a student in Physiotherapy at the University of Free State. I am conducting research for my masters degree. I am a road runner and identified that there is runners who returned after a hip or knee replacement, although little information is available.

#### Title of the research project

The title of the study is “*Symptoms and quality of running experienced by road runners after a hip or knee replacement.*”

#### Purpose of the study

I am interested in knowing what symptoms (if any) are experienced by runners when they return to their sport after a hip or knee replacement. I also want to see what the quality of running is, if you are able to run like you used to. By gathering this information, I will be able to write a report that may assist surgeons, other medical professionals and other runners to know what to expect if the runner wishes to return to running after a hip of knee replacement. This research may also be published in medical books or journals which are available worldwide. This study may also lead to further research into this field.

### Selection of participants

All runners who returned to their sport after a hip or knee replacement in South Africa. Runners who started running after their replacement but stopped are also welcome to participate.

### Description of research

All participants will be asked to sign an informed consent form and they will receive a copy of the informed consent and a copy of this information leaflet (electronically or a hard copy). After signing the informed consent form, you are asked to fill in a questionnaire. You can complete the questionnaire in English or Afrikaans, an electronic or hard copy version is available. If you wish to complete a hard copy, please contact me so that I can post a hard copy to you. Inside the envelope will be a stamp and envelope to return the questionnaire to me.

In the questionnaire you will mostly choose the answer that best represents your experience. Few questions will ask you to write an answer. The questionnaire includes personal questions to help me understand your situation so that I don't make incorrect conclusions. If you feel uncomfortable to answer certain questions you are allowed to leave them open. I would like to request you to complete the questions as honestly as possible to help me truly understand how you feel. It will take more or less 9 minutes to answer all the questions.

You are participating in this research voluntarily (of your own free will) and if you wish to, you can stop participating at any moment. No harm will come to you if you participate in this research. Unfortunately no remuneration can be offered to you, but your participation will help the research project to be a success. Nobody will be able to know which form is the information you have given and your identity will be kept a secret at all times.

The results of the study might be published in a journal or book for medical professionals so that they can know what symptoms are experienced and what to expect when a runner wishes to return to his sport. You will also be asked in the questionnaire whether you would allow myself or someone else from the UFS to contact you in a few years to follow up on your running progress.

If you want to ask anything before you start with the questions, or later on, you can phone or sms me, Ninnette du Toit at 071 515 3635 or e-mail me at [ninnette.dutoit@gmail.com](mailto:ninnette.dutoit@gmail.com), or the person supervising me, Ms Roline Barnes at [BarnesRY@ufs.ac.za](mailto:BarnesRY@ufs.ac.za) or 082 740 1069. You may also contact the University of the Free State Ethics Committee (contact number: 051 – 405 2812) if you have any queries/questions or concerns regarding your rights or welfare as a research participant.

Thank you for your participation

A handwritten signature in black ink, appearing to read 'Ninnette du Toit'.

Ninnette du Toit

#### 4 *Appendix D: Informed consent*

Consent to participate in research  
Questionnaire study

University of Free State : *Symptoms experienced by runners upon return to sport after a hip or knee replacement*

I, \_\_\_\_\_, volunteer to participate in a research project conducted by Ninnette du Toit, a student at the University of Free State who is performing a research study to complete her Master's degree in Sport. I understand that the research study is designed to gather information about symptoms and experiences that a runner has when returning to running. With the help of this information, surgeons who perform the surgery and runners who are going for a hip or knee replacement will know what to expect. I will be one of approximately 60 people that complete a questionnaire for this research.

1. My participation in this research is voluntary. I understand that I will not be paid for my participation. I may withdraw and discontinue participation at any time without penalty. If I decline to participate or withdraw from the study, there will be no consequences.
2. If I feel uncomfortable in any way with any of the question from the questionnaire, I have the right to decline to answer the question or to stop the questionnaire.
3. I understand that the researcher will not identify me by name in any reports using information obtained from this questionnaire, and that my confidentiality as a participant in this study will remain secure. Subsequent uses of records and data will be subject to standard data use policies which protect the anonymity of individuals and institutions.
4. I understand that this research study has been reviewed and approved by the Ethical committee from the Faculty of Health Sciences of the University of Free State, which can be contacted any time on 051 – 405 2812 for more information.
5. The study will entail only filling in a questionnaire that is bilingual (Afrikaans and English) and the questionnaire can be completed in any of the two languages. The results from all the questionnaires will be analysed and a conclusion will be drawn up

from all the results. The conclusion and results will be published in a medical journal.  
The results may also be presented at a medical congress.

6. I understand that it is important to fill in the questionnaire as accurately as possible I have the right to take as much time as needed to complete the form accurately.
7. I have read and understand the explanation provided to me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study.
8. I have been given a copy of this consent form.

I understand what is required of me and I have had all my questions answered. I do not feel that I am forced to take part in this study and I am doing so of my own free will. I know that I can withdraw at any time if I so wish and that it will have no consequences for me.

\_\_\_\_\_  
My Signature

\_\_\_\_\_  
Date

\_\_\_\_\_  
My Printed Name

\_\_\_\_\_  
Signature of the Investigator

For further information, feel free to contact the researcher Ninnette du Toit 071 515 3635 or [ninnette.dutoit@gmail.com](mailto:ninnette.dutoit@gmail.com) or the supervisor of the study, Ms Roline Barnes at [BarnesRY@ufs.ac.za](mailto:BarnesRY@ufs.ac.za) or 082 740 1069.