THE ROLE OF A BIOKINETICS REHABILITATION PROGRAMME IN ALLEVIATING ANTERIOR KNEE PAIN IN ADOLESCENTS

By

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For Willem whose love, support and patience made this work possible

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SYNOPSIS

Anterior knee pain is a common condition prevalent within the adolescent population and frequently interferes with sporting and routine activities. The condition is often self-limiting, but can take up to two years to resolve. Surgical intervention is not recommended in this population group, and often there is no demonstrable anatomical abnormality. Conservative treatment should always be the first approach.

A questionnaire designed to determine the incidence of anterior knee pain among adolescents was distributed to various local schools, and was completed under the guidance of either a researcher or the parents. Results from the questionnaires indicate that 27.4% of adolescents who participated in the study had experienced non-traumatic anterior knee pain at some time between the ages of 10 and 17 years. Of this group, 42.9% was male and 57.1% was female.

Subjects in the intervention section of the study followed a Biokinetics rehabilitation programme which aimed at stabilising the knee joint by stretching and strengthening the involved musculature and improving proprioception and dynamic stability of the lower limb. The programme resulted in significantly reduced subjective ratings of pain and disability in the experimental group ($N=18$) compared to the control group ($N=12$). This improvement in condition can be attributed to the increase in strength, flexibility, proprioception and dynamic balance components tested. The decrease in pain as indicated on a Visual Analogue Scale was in the range of 35.3 to 43.0% at the post- and post-post testing in comparison with the initial pain ratings ($p<0.01$). There was also significant improvement in the ability to perform activities indicated by individual subjects on the Patient-Specific Functional Scale ($p<0.01$). All subjects in the experimental group indicated improvement in their condition at the post-test. Most of the group reported that their condition was at least as good or better at the post-post test compared with the post-test.

There was an increase of between 9.0 and 17.5% in muscle strength in both the quadriceps and hamstring muscle groups at the post- and post-post testing of the experimental group ($p<0.01$). There was a small but significant improvement of between 2.2 and 4.4% in quadriceps, hamstring and gastrocnemius flexibility of the experimental group at the post- and post-post testing ($p<0.01$). There was also a large significant improvement in both proprioception and dynamic balance of the experimental group at the post- and post-post testing ($p<0.01$), which is indicative of improved stability of the knee joint complex. Proprioception as measured on a wobbleboard improved by between 49.5 and 50.8%, and dynamic stability scores improved by 37.5 to 53.2% at the post and post-post testing ($p<0.01$).

These variables improved as a consequence of the Biokinetics rehabilitation programme and were maintained or improved further at the one month follow up. In the context of South African health care, a structured Biokinetics rehabilitation programme based on sound clinical and scientific principles has the potential to endear positive outcomes in the treatment of anterior knee pain.

OPSOMMING

Anterior knie pyn is 'n algemene kondisie wat 'n wye verskydenheid pasiënte affekteer. Dit kom algemeen voor in die adolesent populasie en meng dikwels in met sport en roetine aktiwiteite. Die kondisie is gereeld van 'n selfbeperkende aard maar kan tot twee jaar neem voor dit verdwyn. Chirurgie word nie aanbeveel in hierdie populasie groep nie, en daar is dikwels geen demonstreerbare anatomiese abnormaliteit nie. Die kondisie behoort altyd eers op 'n konserwatiewe wyse behandel te word.

Proefpersone in die intervensie deel van die studie het 'n Biokinetiese rehabilitasie program gevolg. Die program se mikpunt was om die kniegewrig te stabiliseer deur die strek en versterking van die omliggende spiere, asook deur die verbetering van propriosepsie en dinamiese stabiliteit van die onderste ledemate. Daar was 'n statisties beduidende vermindering van subjektiewe evaluering van pyn en gestremdheid in die eksperimentele groep (N=18) in vergelyking met die kontole groep (N=12). Hierdie verbetering in die kondisie van proefpersone kan toegeskryf word aan verhoogde krag, soepelheid, propriosepsie en dinamiese balans komponente wat getoets is in die studie. Die pyn wat op 'n *Visual Analogue Scale* aangedui was, was tussen 35.3 en 43.0% minder tydens die post- en post-post toetse in vergelyking met die eerste pyn evalueringe ($p<0.01$). Daar was ook 'n statisties beduidende verbetering in die vermoë om sekere aktiwiteite uit te voer ($p<0.01$). Hierdie aktiwiteite was op die *Patient-Specific Functional Scale* aangedui. Die hele eksperimentele groep het aangedui dat hulle kondisie verbeter het op die post-toets, en meeste van die groep het aangedui dat hulle kondisie dieselfde of beter was tydens die post-post-toets.

Daar was 'n verbetering van tussen 9.0 en 17.5% in die quadriceps en hamstringspiere krag op die post- en post-post-toets ($p<0.01$). Soepelheid van die quadriceps, hamstring en gastrocnemiusspiere het tussen 2.2 en 4.4% verbeter op die post en post-post-toets ($p<0.01$). Daar was ook 'n groot verbetering in propriosepsie en dinamiese stabiliteit van die eksperimentele groep op die post- en post-post-toetse ($p<0.01$). Propriosepsie wat op 'n wobbleboard gemeet was, het tussen 49.5 en 50.8% verbeter, asook dinamiese stabiliteit wat tussen 37.5 en 53.2% verbeter het ($p<0.01$).

Hierdie komponente het verbeter as gevolg van die Biokinetiese rehabilitasie program en het verder verbeter of dieselfde gebly teen die opvolg sessie 'n maand later. In die konteks van Suid Afrikaanse

gesondheidssorg het 'n gestruktureerde Biokinetiese rehabililitasie program, gebaseer op streng kliniese en wetenskaplike beginsels, die potensiaal om positiewe uitkomste te hê vir die behandeling van anterior kniepyn.

CONTENTS

SYNOPSIS......iv
OPSOMMING......vi
LIST OF TABLES......x
LIST OF FIGURES......xii

CHAPTER 1: INTRODUCTION......1
Overview......1
Statement of the problem......2
Research hypothesis......3
Test hypotheses......3
Limitations and delimitations......6
Assessment protocol......6
Study design and data analysis......8

CHAPTER 2: REVIEW OF LITERATURE......9
Structure and function of the knee joint......9
Anterior knee pain......14
Incidence of anterior knee pain......17
Clinical findings......18
Prognosis......19
Conservative treatment......20
Proprioception and dynamic joint stability......22

CHAPTER 3: METHODS AND PROCEDURES......29
Subjects......29
Research groups......29
Assessment protocol......30
Intervention programme......39

CHAPTER 4: RESULTS AND DISCUSSION......40
Section 1: The incidence of anterior knee pain among adolescents......40

Incidence of anterior knee pain....40
Level of activity of respondents....42
Activities exacerbating condition....43

Section 2: The influence of a Biokinetics rehabilitation programme on anterior knee pain in adolescents....44
Subjective ratings of pain and disability....48
Change in condition....52
Structural and functional variables measured....52

CHAPTER 5: CONCLUSION....68

REFERENCES....71

APPENDICES....86

LIST OF TABLES

Table **Page**

1: Number and percentage of subjects per category and per gender.................. 40

2: Level of activity of affected and non-affected respondents as indicated on questionnaire..42

3: Descriptive data of the control and experimental groups.....................................44

4: Mean duration of anterior knee pain as reported by the control and experimental groups..45

5: Injured knees in control and experimental groups...45

6: Q-angles of the control and experimental groups...46

7: Mean activity levels according to the Activity Rating Scale (Marx et al., 2001) of the control and experimental groups.................47

8: Activities most-commonly reported by subjects to cause pain on the Patient-Specific Functional Scale (Chatman et al., 1997)...................47

9: Baseline values of pain as indicated on a Visual Analogue Scale (VAS) for the control and experimental groups..................................48

10: Percentage change and change in scores of mean ratings of worst, least and normal pain as indicated on a VAS at the post- and post-post testing, for the control and experimental groups.......................50

11: Baseline values of disability as indicated on the Patient-Specific Functional Scale..51

12: Baseline values of mean muscle strength and percentage difference of the control and experimental groups...53

13: Percentage gain in mean muscle strength of the control and experimental groups at the post- and post-post testing............................55

14: Baseline mean muscle flexibility values and percentage difference of the control and experimental groups...58

15: Percentage change in mean muscle flexibility of the control and experimental groups at the post- and post-post testing............................62

16: Baseline values of proprioception as measured on the
Willknox Wobbleboard, dynamic balance as measured using
the Bass Test, and static balance as measured with the
Stork Stand of the control and experimental groups and the
percentage difference between the groups..64
17: Percentage change in the performance of activities of
proprioception (wobble board) and dynamic balance (bass test)
at the post- and post-post testing..66

LIST OF FIGURES

Figure **Page**

1: Anterior view of the knee joint....9

2: Posterior view of the knee joint....10

3: The testing of muscle strength....36

4: Testing proprioception on the Willknox wobbleboard....36

5: The Stork stand....37

6: Layout for Bass test for assessing dynamic stability....38

7: The prevalence of anterior knee pain per age group, represented as a percentage of all the respondents, as indicated on the knee pain questionnaire....41

8: The prevalence of anterior knee pain compared with level of activity as indicated on the questionnaire....42

9. Activities reported to exacerbate anterior knee pain as indicated on the questionnaire....43

10: The control group's mean ratings of worst, least and normal pain as indicated on a visual analogue scale at the pre- and post-testing....49

11: The experimental group's mean ratings of worst, least and normal pain as indicated on a visual analogue scale at the pre, post- and post-post testing....49

12: Mean ratings of ability to perform various activities as indicated on the Patient-Specific Functional Scale at the pre, post- and post-post testing of the control and experimental groups....51

13: Mean values of right quadriceps strength of the control and experimental groups at pre-, post- and post-post testing....53

14: Mean values of left quadriceps strength of the control and experimental groups at pre-, post- and post-post testing....54
15: Mean values of right hamstring strength of the control and experimental groups at pre-, post- and post-post testing....54
16: Mean values of left hamstring strength of the control and experimental groups at pre-, post- and post-post testing....55
17: Mean values of right quadriceps flexibility of the control and experimental groups at pre-, post- and post-post testing....59
18: Mean values of left quadriceps flexibility of the control and experimental groups at pre-, post- and post-post testing....60
19: Mean values of right hamstring flexibility of the control and experimental groups at pre-, post- and post-post testing....60
20: Mean values of left hamstring flexibility of the control and experimental groups at pre-, post- and post-post testing....61
21: Mean values of right gastrocnemius flexibility of the control and experimental groups at pre-, post- and post-post testing....61
22: Mean values of left gastrocnemius flexibility of the control and experimental groups at pre-, post- and post-post testing....62
23: Mean wobbleboard scores of the control and experimental groups at pre-, post- and post-post testing, as measured by recording time in seconds unbalanced on the Willknox Wobbleboard....65

24: Mean Bass Test scores of the control and
experimental groups at pre-, post- and post-post
testing as measured by the Bass Test 65

CHAPTER 1: INTRODUCTION

OVERVIEW

The knee joint is the largest and one of the most complex joints in the body (Thompson & Floyd, 1998; Arnheim & Prentice, 2000). The knee joint complex is comprised of a number of articulations between the femur and the tibia, femur and patella, femur and fibula, and tibia and fibula. The ligaments, joint capsule and muscles that surround the joint primarily stabilise the knee joint (Arnheim & Prentice, 2000). Dynamic muscle stabilisation provided by the quadriceps, hamstring and gastrocnemius muscles protects the knee joint, allowing the knee to withstand stresses and strains (Huston & Wojtys, 1996). The major functions of the knee involve weight bearing and locomotion, which place considerable strain on the joint (Thompson & Floyd, 1998).

Anterior knee pain is a common condition that affects a wide age range of patients (Cutbill et al., 1997). It is prevalent within the adolescent population and frequently interferes with sporting and routine activities. As a result, a large number of adolescents may be forced to limit their physical activity or perform sub-optimally in the sporting arena (Galanty et al., 1994). Sport plays a central role in the lives of many adolescents. Cessation of physical activity is detrimental to the developing individual, negatively affecting physical development, general fitness, body composition, the development of motor skills and psychosocial development (DiFiori, 1999; Patel & Nelson, 2000). It may also lead to the adoption of lifelong sedentary lifestyle habits. The condition is often self-limiting, but can take up to two years to resolve (Patel and Nelson, 2000).

One of the most common abnormalities involving the knee joint is disturbance of the patellofemoral mechanism (Souza & Gross, 1991). This joint is a major source of pain and dysfunction at the knee (Woodall & Welsh, 1990). Patellofemoral pain syndrome is reported to be the most common cause of anterior knee pain in adolescents. It is found far more commonly in physically active adolescents (Patel & Nelson, 2000). Surgical intervention is not recommended in this population group, and often there is no demonstrable anatomical abnormality (Jackson, 1994; Patel & Nelson, 2000). Conservative treatment should always be the first approach with this condition (Malek & Mangine, 1981). Galanty et al. (1994) reported that seventy to eighty percent of patients experiencing anterior knee pain responded favourably to conservative management, where stretching and strengthening were included in the programme.

It is clear from the literature that conservative treatment in the form of stretching, strengthening and related modalities is a beneficial strategy for treating anterior knee pain. In the context of South African health care, it is perceived that a structured biokinetics rehabilitation programme based on sound clinical and scientific principles has the potential to endear positive outcomes in the treatment of anterior knee pain.

STATEMENT OF THE PROBLEM

The focus of this study is to validate the efficacy of a biokinetics rehabilitation programme in the alleviation of anterior knee pain in adolescents.

There are many causes of anterior knee pain, and in some instances it is idiopathic. In cases where anterior knee pain is as a result of instability or faulty mechanics, the rehabilitation programme should improve the condition by enhancing muscle strength, flexibility and proprioception. Once the knee is stabilised, it is tentatively postulated that the perception of pain and the ensuing disability will be improved. The study will also investigate whether these benefits are long-term in nature.

In many cases it appears that the onset of anterior knee pain coincides with the period of the adolescent growth spurt (Rogan, 1995). This is postulated to be as a result of a loss of proprioception that occurs during this period of accelerated linear growth. The condition is reported to be more prevalent in girls than boys, and among the more physically active (Jacobson & Flandry, 1989; Nimon et al., 1998; Patel & Nelson, 2000).

A biokinetics programme is a cost-effective means of rehabilitation. In this population group, conservative physical therapy programmes are preferable to surgical and pharmacological interventions. It, therefore, appears to be a desirable solution to a difficult and sometimes debilitating condition.

RESEARCH HYPOTHESIS

The general hypothesis of this study is that a biokinetics rehabilitation programme alleviates anterior knee pain in adolescents. The rehabilitation programme is aimed at stabilising the knee joint by stretching and strengthening the involved musculature, and improving proprioception of the lower limb. Stabilisation of the knee joint should result in decreased subjective ratings of pain and disability. Thus, improvements in strength, flexibility, proprioception and subjective ratings of pain and disability should be a consequence of the biokinetics programme. Furthermore, these improvements should be long-term effects.

It is also hypothesised that the condition is more prevalent in girls, and among the more physically active.

TEST HYPOTHESES

Hypothesis 1: The null hypothesis states that a biokinetics programme for the lower limb does not result in increased muscle strength.

a) Ho: $\mu s_{pre} = \mu s_{post}$

b) Ho: $\mu s_{pre} = \mu s_{post\text{-}post}$

Where:

μs_{pre} = Pre-intervention muscle strength measurements

μs_{post} = Post- intervention muscle strength measurements

$\mu s_{post\text{-}post}$ = Muscle strength measurements taken 4 weeks after completion of intervention programme

Hypothesis 2: The null hypothesis states that a biokinetics programme for the lower limb does not result in increased muscle flexibility.

a) Ho: $\mu\, f_{pre} = \mu\, f_{post}$

b) Ho: $\mu\, f_{pre} = \mu\, f_{post\text{-}post}$

Where:

f_{pre} = Pre- intervention flexibility measurements

f_{post} = Post- intervention flexibility measurements

$f_{post-post}$ = Flexibility measurements taken 4 weeks after completion of intervention programme

Hypothesis 3: The null hypothesis states that a biokinetics programme for the lower limb does not result in improved proprioception of the lower limb.

a) Ho: $\mu\ p_{pre} = \mu\ p_{post}$

b) Ho: $\mu\ p_{pre} = \mu\ p_{post-post}$

Where:

p_{pre} = Pre- intervention measurements of proprioception of the lower limb

p_{post} = Post- intervention measurements of proprioception of the lower limb

$p_{post-post}$ = Measurements of proprioception of the lower limb taken 4 weeks after completion of intervention programme

Hypothesis 4: The null hypothesis states that a biokinetics programme for the lower limb does not result in decreased subjective ratings of anterior knee pain in adolescents.

a) Ho: $\mu\ pa_{pre} = \mu\ pa_{post}$

b) Ho: $\mu\ pa_{pre} = \mu\ pa_{post-post}$

Where:

pa_{pre} = Pre- intervention subjective rating of anterior knee pain

pa_{post} = Post- intervention subjective rating of anterior knee pain

$pa_{post-post}$ = Subjective rating of anterior knee pain taken 4 weeks after completion of intervention programme

Hypothesis 5: The null hypothesis states that a biokinetics programme for the lower limb does not result in decreased subjective ratings of functional disability in adolescents with anterior knee pain.

a) Ho: $\mu\ d_{pre} = \mu\ d_{post}$

b) Ho: $\mu\ d_{pre} = \mu\ d_{post-post}$

Where:

d_{pre} = Pre- intervention subjective rating of functional disability as a result of anterior knee pain.

d_{post} = Post- intervention subjective rating of functional disability as a result of anterior knee pain.

$d_{post\text{-}post}$ = Subjective rating of functional disability as a result of anterior knee pain taken 4 weeks after completion of intervention programme

Hypothesis 6: The null hypothesis states that there will be no difference in the post-intervention variables between the experimental and control groups.

Ho: $\mu c = \mu e$

Where:

c = Post-intervention measures of the control group

e = Post-intervention measures of the experimental group

Hypothesis 7: The null hypothesis states that anterior knee pain is not more prevalent in adolescent girls than boys.

Ho: $\mu b = \mu g$

Where:

b = The number of boys complaining of anterior knee pain

g = The number of girls complaining of anterior knee pain

Hypothesis 8: The null hypothesis states that anterior knee pain is not more prevalent among adolescents that tend to be more physically active than those that are less active.

Ho: $\mu a = \mu la$

Where:

a = Adolescents that tend to be more physically active

la = Adolescents that tend to be less physically active

LIMITATIONS AND DELIMITATIONS

Limitations

A possible limitation is the use of self-report instruments. They are subjective in nature and thus, may be influenced by the human element, whereby individuals respond differently to similar stimuli or experiences. Another limitation is subject compliance with respect to the unsupervised home programme. A closed kinetic chain knee flexion/extension machine was used to measure muscle strength, which was recorded in Kilograms. This means that the data cannot be compared with other studies where the classic open kinetic chain methods were used. However, closed kinetic chain measurement is more closely related to everyday activities and the test reveals strength deficits between legs and strength improvements.

Delimitations

The subject group is comprised of individuals between the ages of 10 and 17 years. It only included adolescents from one geographical area.

ASSESSMENT PROTOCOL

A. Questionnaire

B. Self-evaluation

1. Level of activity using the Activity Rating Scale developed by Marx et al. (2001).
2. Rating of disability using the Patient-Specific Functional Scale described by Chatman et al. (1997).
3. Rating of pain using a Visual Analogue Scale (Thomee, 1997; Witvrouw et al., 2000; Crossley et al., 2002; Kane et al., 2005).
4. Overall improvement by the final session using the Scale for Change in Condition described by Harrison et al. (1995).

C. Handedness

The dominant hand and foot was recorded

D. Anthropometric assessment

1. Height
2. Weight
3. Anthropometric measurement of leg length:
   3.1 Distance between trochanterion and external tibiale
   3.2 Distance between external tibiale and lateral malleolus
4. Anthropometric measurement of foot length

E. Structural assessment

1. Flexibility
   1.1 Hamstring: Straight leg hamstring test
   1.2 Quadriceps: Modified Thomas test
   1.3 Gastrocnemius: Straight leg gastrocnemius test
   1.4 Iliotibial band: Ober's test
2. Q-angle
3. Valgus and varus stress tests
4. Test for the presence of crepitus
5. Assessment of the lower leg and foot. Record the presence of:
   5.1 Genu valgum
   5.2 Genu varum
   5.3 Genu recurvatum
   5.4 Pes cavus/ planus
   5.5 Tibial internal/ external rotation (Standing and walking)
   5.6 Pronation/ Supination

F. Functional assessment

1. Strength
   1.1 Quadriceps
   1.2 Hamstring

   Measurements of maximal muscle strength were recorded using a hydraulically-braked closed kinetic chain knee flexion/extension machine attached to a static dynamometer.

2. Proprioception: Measured on the Willknox wobbleboard. Time spent unbalanced was recorded.
3. Static balance: The Stork Stand as described by Bosco & Gustafson (1983).
4. Dynamic balance: Bass Test of Dynamic Balance as described by Bosco & Gustafson (1983).

STUDY DESIGN AND DATA ANALYSIS

The study design was the Pretest-posttest Randomised-groups design. Data was analysed using descriptive statistics, t-Tests and the Wilcoxon Signed Rank test.

CHAPTER 2: REVIEW OF LITERATURE

STRUCTURE AND FUNCTION OF THE KNEE JOINT

The knee joint is the largest and one of the most complex joints in the body (Dye, 1996; Winkel et al., 1997; Thompson & Floyd, 1998; Arnheim & Prentice, 2000). Dye (1996) proposed that the knee could be considered as an intricate assemblage of moving parts whose purpose is to accept, transfer and ultimately dissipate the potentially high loads generated at the ends of the long mechanical lever arms of the femur and tibia. The joint is designed to function optimally, that is, it has a large degree of stability in order to accommodate large loads, and it has mobility so as to facilitate its major movements, namely: walking, squatting and kneeling (Winkel et al., 1997). The knee joint complex is comprised of a number of articulations between the femur and the tibia, femur and patella, femur and fibula, and tibia and fibula (Larson & Grana, 1993; Arnheim & Prentice, 2000). The tibiofemoral and patellofemoral joints are the major joints of relevance (Brukner & Khan, 2002). The ligaments, joint capsule and muscles that surround the joint primarily stabilise the knee joint (Larson & Grana, 1993; Arnheim & Prentice, 2000; Williams et al., 2001).

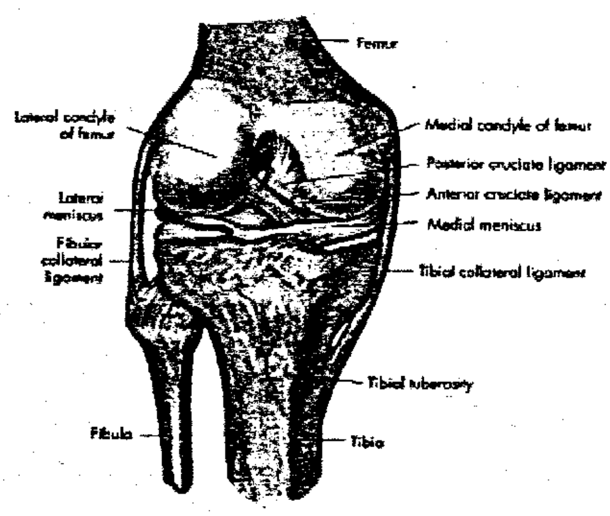


Figure 1: Anterior view of the knee joint

(Thompson & Floyd, 1998 p134)

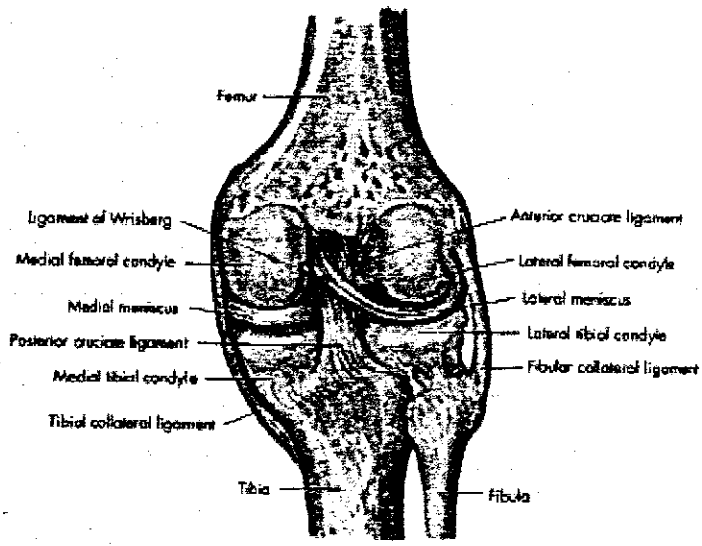


Figure 2: Posterior view of the knee joint

(Thompson & Floyd, 1998 p134)

The ligaments and joint capsule are the major static stabilisers of the joint. The anterior cruciate ligament is comprised of three twisted bands: anteromedial, intermediate and posterolateral bands. It runs superiorly and posteriorly from the attachment at the anterior region of the tibial plateau to the femoral insertion at the posterolateral region of the intercondylar notch. It prevents anterior translation of the tibia on the femur during weight bearing, and controls rotation of the tibia (Larson & Grana, 1993; Kakarlapudi & Bickerstaff, 2000; Brukner & Khan, 2002). The posterior cruciate ligament is the stronger of the two. It runs between the posterior region of the tibial plateau and the medial aspect of the intercondylar notch of the femur, and prevents forward translation of the femur and hyperextension of the knee. The medial collateral ligament provides medial stability to the knee. The ligament originates from the medial femoral epicondyle above the joint line and attaches to the anteromedial aspect of the tibia (Arnheim & Prentice, 2000; Kakarlapudi & Bickerstaff, 2000; Brukner & Khan, 2002). Some fibres merge into the deep posterior capsular ligament and semimembranosus muscle as well as the medial meniscus (Arnheim & Prentice, 2000; Kakarlapudi & Bickerstaff, 2000). It prevents lateral tilting of the tibia on the femur during valgus stress, and external rotary forces. The lateral collateral ligament provides lateral stability to the knee. It runs between the lateral epicondyle of the femur and the head of the fibula (Larson & Grana, 1993; Arnheim & Prentice, 2000; Brukner & Khan, 2002; Dugan, 2005). It prevents medial tilting of the tibia on the femur during varus stress (Arnheim & Prentice, 2000; Kakarlapudi & Bickerstaff, 2000).

The menisci are two oval fibrocartilages attached to the tibial plateau medially and laterally (Arnheim & Prentice, 2000; Brukner & Khan, 2002). The medial meniscus is C-shaped while the lateral meniscus is smaller and circular (Winkel et al., 1997; Arnheim & Prentice, 2000). They increase the concavity of the articular facets of the tibia resulting in increased stabilisation of the joint. They protect the joint by absorbing some of the forces passing through the joint as well as maintaining the spacing between the femoral condyles and tibial plateau (Larson & Grana, 1993; Arnheim & Prentice, 2000; Brukner & Khan, 2002; Dugan, 2005). The menisci reportedly transmit between thirty and fifty-five percent of the load transmitted through the knee (Winkel et al., 1997; Arnheim & Prentice, 2000). The menisci also serve to enlarge the contact area on the tibia and aid in joint lubrication (Larson & Grana, 1993; Winkel et al., 1997; Brukner & Khan, 2002). The joint capsule encloses the articular surfaces of the knee (Arnheim & Prentice, 2000). It is composed of a fibrous membrane and a synovial membrane (Winkel et al., 1997). It is divided into four regions, namely: posterolateral, posteromedial, anterolateral, and anteromedial (Arnheim & Prentice, 2000).

Dynamic muscle stabilisation provided predominantly by the quadriceps, hamstring and gastrocnemius muscles protects the knee joint, allowing the knee to withstand the considerable stresses and strains placed on the knee during locomotion and weight-bearing (Huston & Wojtys, 1996; Thompson & Floyd, 1998). The quadriceps mechanism is comprised of the rectus femoris, vastus medialis, vastus lateralis and vastus intermedius (Larson & Grana, 1993; Arnheim & Prentice, 2000). These muscles are the dynamic supporters of the patella, as well as being extensors of the knee (Woodall & Welsh, 1990; Larson & Grana, 1993; Thompson & Floyd, 1998). They are attached to the proximal pole of the patella by the quadriceps tendon (Woodall & Welsh, 1990; Larson & Grana, 1993). The vastus medialis is divided into the vastus medialis longus, which has longitudinally oriented fibres, and vastus medialis obliquus which has more obliquely oriented fibres. The vastus medialis obliquus is the primary patellar stabiliser, ensuring that the patella remains centralised within the sulcus during movement (Larson & Grana, 1993; Thompson & Floyd, 1998). The pes anserine group and biceps femoris are other dynamic structures which affect patella stability by controlling internal and external tibial rotation respectively, which has a notable effect on patella tracking (Malek & Mangine, 1981; Woodall & Welsh, 1990). The biceps femoris, along with the semimembranosus and semitendinosus make up the hamstring muscle group. The hamstrings and gastrocnemius are responsible for knee flexion (Thompson & Floyd, 1998; Arnheim & Prentice, 2000). The popliteus muscle is another internal rotator of the tibia and provides rotatory stability by opposing forward translation of the tibia on the femur during flexion (Larson & Grana, 1993; Thompson & Floyd, 1998; Arnheim & Prentice, 2000).

A number of physiological and arthrokinematic motions occur between the patella, femur and tibia. These include flexion, extension, rotation, rolling and gliding (Larson & Grana, 1993; Arnheim & Prentice, 2000). The tibiofemoral joint is classified as a ginglymus joint. This is as it functions like a hinge during flexion and extension. It is sometimes referred to as a trochoginglymus joint as a result of the internal and external rotation that can occur during flexion (Thompson & Floyd, 1998). The femoral condyles are curved such that the anterior section is oval-shaped and posterior section sphere-shaped. During knee flexion the anterior portions articulate with the tibia which is deepened by the menisci and basically functions as a modified ball-and-socket joint with limited rotatory motion (Larson & Grana, 1993). The patellofemoral joint is classified as an arthrodial joint due to the gliding motion of the patella on the femoral condyles (Thompson & Floyd, 1998; Walters, 2004). Normal knee range of motion includes 180 degrees extension to 140 degrees flexion, and about 30 degrees of internal rotation and 45 degrees external rotation when the knee is flexed to 30 degrees or more (Thompson & Floyd, 1998).

The patella and its articulation with the femur is called the patellofemoral joint (PFJ) (Malek & Mangine, 1981; Heng & Haw, 1996; Arnheim & Prentice, 2000). Anatomically the patellofemoral joint forms part of the knee joint complex, however, it is functionally distinct from the condylar tibio-femoral joint (Heng & Haw, 1996). The patella is the largest sesamoid bone in the body, and is embedded in the quadriceps tendon (Malek & Mangine, 1981; Heng & Haw, 1996; Arnheim & Prentice, 2000). Its longest axis is in the transverse plane and its superior surface is a convex dome while the articular surface is divided by a midline ridge into a medial facet which is usually convex, and a lateral facet which is usually concave (Heng & Haw, 1996).

The patellofemoral joint is placed under substantial compression and shear forces which are transmitted through continually changing points of contact during movement (Larson & Grana, 1993; Jackson, 1994). The magnitude of the compressive force on the patella, known as the patellofemoral joint reaction force, varies according to the activity being performed, and the resultant angle of flexion, quadriceps muscle tension and patella tendon tension (Woodall & Welsh, 1990; Larson & Grana, 1993; Powers et al., 1996; Powers, 1998; Erasmus, 2004). During an activity where there is minimal knee flexion such as ambulation, the largest reaction force exerted on the patellofemoral joint is approximately half of the body weight of the individual. During stair climbing with the knee flexed to 90 degrees, the reaction force can be up to three times the individual's body weight (Woodall & Welsh, 1990; Larson & Grana, 1993; Erasmus, 2004). Compressive forces decrease from thirty to zero degrees flexion (Woodall & Welsh, 1990). Contact areas stretch over both patellar facets and both trochlear condyles (Erasmus, 2004). These areas change according to the degree of flexion at the knee (Zappala et al., 1992; Powers, 1998; Erasmus, 2004). The contact areas increase with increased knee flexion, which results in the distribution of the increasing compressive force over a larger surface area, thus reducing the contact stress (Larson & Grana, 1993). The area of contact acts as a fulcrum, with a contact band sweeping along the patella from the inferior to superior aspect as the knee moves from full extension to 90 degrees flexion (Woodall & Welsh, 1990; Larson & Grana, 1993; Jackson, 1994).

Articulation occurs with the anterior aspect of the distal femur which is notched to accommodate the patella. During quadriceps contraction, patella tracking within the femoral groove depends on the pull of the quadriceps muscle and patella tendon, depth of femoral condyles and shape of the patella (Woodall & Welsh, 1990; Zappala et al., 1992; Larson & Grana, 1993; Holmes & Clancy, 1998; Arnheim & Prentice, 2000; Erasmus, 2004). The patella follows an S-curve as the knee moves from flexion to extension. With full flexion the patella is situated medially and it moves laterally with progressive extension, until the knee reaches terminal extension, where the patella moves slightly medially (Larson & Grana, 1993; Erasmus, 2004). Normal alignment and functioning of the patella is dependant on a balance of the medial and lateral forces exerted on the patella by the passive structures and active muscular forces (Karst & Jewett, 1993; Holmes & Clancy, 1998; Cowan et al., 2002). The neuromotor control systems also play a role in patellar tracking (Cowan et al., 2002).

The vastus medialis obliquus is the only dynamic medial stabiliser of the patella, and it prevents excessive lateral movement of the patella (Antich & Brewster, 1986; Arno, 1990; Hanten & Schulthies, 1990; Hilyard, 1990; Woodall & Welsh, 1990; Zappala et al., 1992; McConnell, 1993; Powers, 1998; Juhn, 1999). The oft cited work of Lieb and Perry (1968) showed that this is the only function of the vastus medialis obliquus, as it is not a knee extensor (Antich & Brewster, 1986; McConnell, 1993; Powers, 1998). The distal fibres of the vastus medialis are reported to be positioned at about 55 degrees to the longitudinal axis of the femur, making it ideally suited for opposing the lateral pull of the vastus lateralis (Antich & Brewster, 1986; Powers et al., 1996; Powers, 1998).

The function of the patella is to increase the efficiency of the quadriceps muscle during knee extension by increasing the distance of the patella tendon from the axis of knee extension, thus increasing the mechanical advantage of the levering mechanism (Malek & Mangine, 1981; Woodall & Welsh, 1990; Zappala et al., 1992; Heng & Haw, 1996; Thomee et al., 1999; Erasmus, 2004). It transmits quadriceps force to the tibia which places a large compressive force on the articular cartilage of the patella and femur. It also plays a protective role with respect to the anterior aspect of the knee joint (Malek & Mangine, 1981; Woodall & Welsh, 1990; Thomee et al., 1999).

ANTERIOR KNEE PAIN

There is a lack of consensus in the literature, especially in earlier studies, as to the exact definition of the term. Anterior knee pain, patellofemoral pain, chondromalacia patella and patellofemoral arthralgia were used interchangeably in the past. For a number of years chondromalacia patella was thought to be the leading cause of anterior knee pain and was thus the accepted clinical diagnosis for patients presenting with these symptoms (Malek & Mangine, 1981; Karlsson et al., 1996; Holmes & Clancy, 1998; Dye, 2004). The term has largely fallen into disuse except in cases where articular cartilage softening and fibrillation is identified during arthroscopy.

A clinical examination alone may not necessarily identify the source of pain, and costly, invasive procedures are not indicated for most patients. As a result, these non-specific terms listed above, have been used to describe the symptoms of this common clinical condition (Crossley et al., 2002). These terms are used synonymously in the literature. In this study, the term anterior knee pain was used to describe the symptom complex characterised by pain in the anterior region of the knee during activity and prolonged sitting in the absence of an identifiable pathologic condition. Patellofemoral dysfunction was taken to be a common cause of anterior knee pain. There are reportedly no reliable clinical measures of patellar tracking, and this is thought to be a major cause of patellofemoral pain (Crossley et al., 2002). Thus, as the pathogenesis is unknown, and there are no valid clinical tests to diagnose the condition, it was included in the umbrella term, anterior knee pain.

Regardless of the terminology, a number of stereotypical symptoms have been identified, namely: pain in the vicinity of the patella worsened by prolonged sitting, ascending or descending stairs, squatting and vigorous physical activity (Malek & Mangine, 1981; Carson et al., 1984; Sandow & Goodfellow, 1985; Jacobson & Flandry, 1989; Whitelaw et al., 1989; Arno, 1990; Hilyard, 1990; Woodall & Welsh, 1990; Tria et al., 1992; Zappala et al., 1992; Reid, 1993; Ruffin & Kinningham, 1993; Jackson, 1994; Kannus & Niittymaki, 1994; Heng & Haw, 1996; Cutbill et al., 1997; Nimon et al., 1998; Powers, 1998; Cesarelli et al., 1999; Juhn, 1999; Thomee et al., 1999; Witonski, 1999; Clark et al., 2000; Cowan et al., 2002; Crossley et al., 2002; Shea et al., 2003; Crossley et al., 2005).

The pain can usually be related to the anterior structures of the knee, but is often poorly localised (Carson et al., 1984; Sandow & Goodfellow, 1985; Hilyard, 1990; Souza & Gross, 1991; Tria et al., 1992; Ruffin & Kinningham, 1993; Stanitski, 1993; Powers, 1998). The onset of anterior knee pain is insidious, and tends to be bilateral (Hilyard, 1990; Ruffin & Kinningham, 1993; Stanitski, 1993; Powers, 1998; Lichota, 2003; Shea et al., 2003; Pollock, 2004). The condition is common among adolescents and young adults, especially females (Fairbank et al., 1984; Sandow & Goodfellow, 1985; Jacobson & Flandry, 1989; Tria et al., 1992; Stanitski, 1993; Galanty et al., 1994; Heng & Haw, 1996; Karlsson et al., 1996; Powers et al., 1996; Natri et al., 1998; Nimon et al., 1998; Cesarelli et al., 1999; Thomee et al., 1999; Clark et al., 2000; Price & Jones, 2000; Roush et al., 2000; Calmbach & Hutchens, 2003; Lichota, 2003; Shea et al., 2003; Dugan, 2005). The ratio may be as high as two to one in females versus males (Powers, 1998; Lichota, 2003). It is also widespread among physically active individuals and sportspeople, and makes up a large proportion of visits to sports clinics (O'Neill et al., 1992; Stanitski, 1993; Kannus & Niittymaki, 1994; Brody & Thein, 1998; Thomee et al., 1999; Crossley et al., 2005). It frequently interferes with exercise and sports participation and as a result, a large number of adolescents may be forced to limit their level of physical activity or perform sub-optimally on the sports field (Fairbank et al., 1984; Galanty et al., 1994; Thomee et al., 1999; Crossley et al., 2002).

The exact aetiology is unknown but a number of predisposing factors have been suggested as possible causes (Wilson, 1990; Heng & Haw, 1996; Powers, 1998; Wilk et al., 1998; Thomee et al., 1999). These include overuse, muscle imbalance, muscle tightness, trauma, overweight, genetic predisposition, valgus or varus knee, external tibial torsion, increased Q angle, abnormal mechanics of the foot and ankle, especially pronation, and generalised ligament laxity (Fairbank et al., 1984; Woodall & Welsh, 1990; O' Neill et al., 1992; Stanitski, 1993; Kannus & Niittymaki, 1994; Karlsson et al., 1996; Teitz, 1997; Post, 1998; Cesarelli et al., 1999; Juhn, 1999; Thomee et al., 1999; Roush et al., 2000; Pollock, 2004). It has also been suggested that growth-related factors unique to the adolescent population may be important contributing factors in the epidemiology of anterior knee pain (Teitz, 1997; Holmes & Clancy, 1998; Juhn, 1999; Stathopulu & Baildam, 2003). In many cases it appears that the onset of anterior knee pain coincides with the period of the adolescent growth spurt (Rogan, 1995). Malalignment between the patella and femur is the most commonly accepted mechanism for pain in the patellofemoral region (Powers et al., 1996; Holmes & Clancy, 1998; Thomee et al., 1999; Dye, 2004). Malalignment refers to insufficient action from the static and dynamic restraints of the patellofemoral joint to allow normal patellar tracking. This includes abnormal bony alignment of the lower limb, insufficient static soft tissue restraints and abnormal dynamic soft tissue restraints (Holmes & Clancy, 1998).

Muscle imbalance is a common finding, and appears to be associated with reduced strength possibly due to hypotrophy or inhibition. While reduced knee extensor strength is common, it is not known whether this is the cause or effect of anterior knee pain (Thomee, 1997; Powers, 1998; Thomee et al., 1999). Many studies report an abnormal relationship between vastus medialis obliquus and vastus lateralis activation patterns. The onset of vastus medialis obliquus activity is delayed in comparison with vastus lateralis (Hanten & Schulthies, 1990; Souza & Gross, 1991; Zappala et al., 1992; Heng & Haw, 1996; Powers et al., 1996; Post, 1998; Powers, 1998; Thomee et al., 1999; Roush et al., 2000; Cowan et al., 2002; Crossley et al., 2005). It is possible that this asynchronous muscle activity affects normal patella tracking, which would lead to areas of increased stress in the patellofemoral joint (Powers, 1998; Crossley et al., 2005). This issue is contentious as studies by Powers et al. (1996) and Karst and Willett (1995) dispute this vasti timing difference.

Having mentioned the difficulty in diagnosing this condition, many articles refer to disturbances of the patellofemoral mechanism as being a common abnormality involving the knee joint (Souza & Gross, 1991; Tria et al., 1992; Caylor et al., 1993; Powers, 1998). This joint is a major source of pain and dysfunction at the knee (Woodall & Welsh, 1990). Many authors have associated abnormal tracking of the patella in the femoral trochlear groove with the development of patellofemoral pain. This abnormal lateral tracking is thought to produce areas of increased stress on the patellofemoral joint (Powers, 1998; Cowan et al., 2002; Crossley et al., 2002). Crossley et al. (2002) went on to say that the management of patella tracking and alignment is difficult, and the relationship between patella tracking and patellofemoral pain is unclear.

Patellofemoral pain syndrome is reported to be the most common cause of anterior knee pain in adolescents (Tria et al., 1992; Nimon et al., 1998). It is found far more commonly in physically active adolescents (Patel & Nelson, 2000). Patellofemoral pain syndrome is a common cause of anterior knee pain in general, and is said to affect 20% of the general population, and an even greater percentage of the sporting population (Hilyard, 1990). Studies report that 2-30% of patients seen at sports medicine practices present with patellofemoral pain syndrome (Kannus & Niitymaki, 1994; Natri et al., 1998; Crossley et al., 2002).

Incidence of anterior knee pain

Ruffin and Kinningham (1993) reported that of 16 748 patients presenting to family doctors with musculoskeletal complaints as a result of a variety of sports, 11.3% had anterior knee pain, while Brody and Thein (1998) estimate that the condition accounts for 21-40% of all complaints within the clinical environment. The condition is said to affect 5 -10% of all patients presenting at sports injury clinics, and between 20% and 40% of all knee conditions seen at these sports injuries clinics (Price, 1987; Wilson, 1990; Kannus & Niittymaki, 1994; Heng & Haw, 1996; Johnson, 1997; Thomee et al., 1999; Roush et al., 2000; Bizzini et al., 2003).

While these figures refer to the general and sporting population, a study by Fairbank et al. (1984) found that 136 out of 446 randomly selected pupils from a school of 1850 had suffered knee pain in the previous year. This is a fairly high incidence, at 30.5%. Twenty-five subjects had stopped playing any form of sport due to their knee pain. This figure is supported by Harrison et al. (1995) who reported the prevalence within the adolescent population to be 30%. In another study on school children aged between 10 and 18 years, it was found that as many as 45% of the cross-section of adolescents had anterior knee pain on physical examination. The authors do acknowledge that it is likely that adolescents with the condition would be more likely to volunteer for the study than those without knee pain (Galanty et al., 1994). Thomee et al. (1999) cited a study done by Hording in the eighties, where anterior knee pain was the most common complaint reported by a subject group of 1990 pupils aged 10 to 19 years. In this study the incidence was only 3.3% of the group, with 10% falling within the 15 year old age group. Cutbill et al. (1997) found that of all reported general knee complaints the 10 to 19 year old group was the second highest, accounting for 19% of patients.

Clinical Findings

Generally, there is a lack of abnormal physical findings in patients with anterior knee pain (Sandow & Goodfellow, 1985). The physical examination should focus on the entire lower extremity, observing gait, malalignment of the lower extremity (increased femoral anteversion, inward squinting patella, tibial torsion and foot pronation), patella tracking (abnormal patella tilt, excessive lateral tracking and increased Q-angle), and crepitus (Malek & Mangine, 1981; Carson et al., 1984; Jacobson & Flandry, 1989; Cutbill et al., 1997; Holmes & Clancy, 1998; Post, 1998; Thomee et al., 1999; Lichota, 2003; Shea et al., 2003; Pollock, 2004). It should also include palpation of the joint, assessment of joint stability, location of pain sites and the presence of effusion (Malek & Mangine, 1981; Ruffin & Kinningham, 1993; Stanitski, 1993; Cutbill et al., 1997; Post, 1998; Lichota, 2003; Dye, 2004; Pollock, 2004). Muscle strength and co-ordination, flexibility, and range of motion of the lower limb should also be assessed (Malek & Mangine, 1981; Reid, 1993; Stanitski, 1993; Post, 1998). Assessment of dynamic stability is also important (Reid, 1993). Radiographs are necessary to rule out any other cause for the pain. In most cases the radiographs do not show anything remarkable (O' Neill et al., 1992; Heng & Haw, 1996; Nimon et al., 1998; Shea et al., 2003).

Studies report a variety of findings which indicate impaired muscle function of the lower limb in patients with anterior knee pain. Findings include reduced muscle strength, reduced EMG activity and reduced functional ability (Zappala et al., 1992; Thomee, 1997; Thomee et al., 1999; Cowan et al., 2002).

Studies report a 10-18% quadriceps strength deficit in patients with anterior knee pain (Kannus & Niitymaki, 1994; Thomee, 1997). Thomee (1997) found reduced vertical jump ability, decreased isometric, concentric and eccentric isokinetic knee extensor torque and reduced EMG activity in patients with anterior knee pain compared with an age- and gender-matched control group in the range close to full extension. There were also differences in EMG activity between vastus medialis and rectus femoris muscles (Souza & Gross, 1991; Zappala et al., 1992; Thomee, 1997). However, there are studies that refute these findings (Powers, 1998). Powers et al. (1996) reported decreased recruitment of the entire quadriceps muscle group during gait activities in patients with anterior knee pain. This reduction in recruitment was similar for all vasti, thus they did not find selective vastus medialis obliquus insufficiency.

Some patients complain of the knee giving way (Malek & Mangine, 1981; Fairbank et al., 1984; Arno, 1990; Shelton, 1992; Holmes & Clancy, 1998; Post, 1998; Powers, 1998; Thomee et al., 1999). This is reportedly due to the sudden relaxation of muscles due to pain-related inhibition of the quadriceps during loading of the patellofemoral joint (Holmes & Clancy, 1998; Post, 1998; Thomee et al., 1999). This occurs more frequently during standing, ascending stairs or walking downhill (Thomee et al., 1999).

Decreased flexibility is an important finding. Both hamstring and quadriceps tightness can result in increased patellofemoral joint reaction forces and increased stress on the patella tendon (Jacobson & Flandry, 1989; Shelton, 1992; Wilk et al., 1998). Tightness of the hamstrings can lead to reduced stride length and may cause the quadriceps to contract more powerfully in order to overcome the passive resistance of the tight hamstrings (Wilk et al., 1998). Tightness of the gastrocnemius-soleus complex can result in compensatory pronation of the foot which leads to increased tibial rotation and increased stress on the patellofemoral joint, while iliotibial band tightness can result in lateral tracking of the patella (Shelton, 1992; Zappala, 1992; Wilk et al., 1998).

Possible leg length discrepancy should be investigated, as this may have a significant effect on the lower limb mechanics and patellofemoral joint. Excessive pronation and flexed knee gait and stance may occur in compensation, and will directly affect the patellofemoral joint. Intrinsic imbalances of the foot may also affect lower extremity mechanics by resulting in excessive pronation. This leads to internal rotation of the tibia and lateral displacement of the patella (Wilk et al., 1998).

Galanty et al. (1994) found no relationship between any intrinsic variable and diagnosis of anterior knee pain.

Prognosis

In most cases anterior knee pain is self-limiting, but it can take up to 2 years to resolve (Patel & Nelson, 2000). The condition appears to have a benign natural history (Ruffin & Kinningham, 1993; Karlsson et al., 1996; Shea et al., 2003). Sandow & Goodfellow (1985) support this finding as they reported a high percentage of significant improvement over time in adolescents with untreated idiopathic anterior knee pain, with most patients' symptoms being completely resolved. Symptom reduction occurs with the reduction of rapid growth, and the natural history is one of improvement and resolution in most cases (Juhn, 1999; Shea et al., 2003). It does not appear to lead to premature arthrosis (Stanitski et al., 1993; Shea et al., 2003). Stathopulu & Baildam (2003) were not convinced, however, concluding that anterior knee pain in childhood may not be as benign as previously thought.

Conservative Treatment

Conservative treatment for anterior knee pain should always be the first approach (Malek & Mangine, 1981; Wilson, 1990; Shelton & Thigpen, 1991; Shelton, 1992; Cutbill et al., 1997; Holmes & Clancy, 1998; Wilk et al., 1998; Juhn, 1999; Crossley et al., 2002; Dye, 2004). Surgery is rarely indicated in this population group, especially as the pathological basis of the clinical syndrome is often unclear (Sandow & Goodfellow, 1985; Jackson, 1994; Thomee et al., 1999; Patel & Nelson, 2000). In fact, most authors reported better results with conservative treatment than surgical intervention (Shelton, 1992). A study by McConnell (1996) on individuals with patellofemoral pain syndrome reported that subjects who underwent surgery progressed at one-third of the rate of those who followed a physical therapy programme.

A comprehensive conservative rehabilitation programme comprises a number of components, namely: muscle strengthening, flexibility, proprioception, endurance and functional training (Shelton & Thigpen, 1991; Shelton, 1992; Thomee et al., 1999). Each component is essential for complete rehabilitation, but the greatest emphasis is placed on quadriceps strengthening (Arno, 1990; Shelton & Thigpen, 1991; Zappala et al., 1992; Kannus & Niittymaki, 1994; Powers, 1998). The aim is to address any possible abnormalities with stretching and strengthening exercises for the entire lower limb (Teitz, 1997). Muscle balance will result in the distribution of patellofemoral joint reaction forces over as large a surface area as possible (McConnell, 1993; Brody & Thein, 1998). The critical outcome of a rehabilitation programme is the reduction of pain and disability (Crossley et al., 2005).

Patients in the studies were encouraged to avoid or minimise symptom-producing activities and some were given non-steroidal anti-inflammatories (Shelton & Thigpen, 1991; O'Neill et al., 1992; Stanitski, 1993; Kannus & Niitymaki, 1994; Brody & Thein, 1998; Post, 1998; Wilk et al., 1998; Thomee et al., 1999; Shea et al., 2003; Dye, 2004; Pollock, 2004). This is to reduce the loading of the knee joint and to decrease pain, which is necessary for the rehabilitation exercises to be effective.

Rehabilitation programmes reported in the literature ran for between 6 and 12 weeks (Arno, 1990; Kannus & Niittymaki, 1994; Karlsson et al., 1996; Thomee et al., 1999; Crossley et al., 2002). Strength training of the muscles improves force production in the peripatellar musculature, resulting in increased stability in the knee (Brody & Thein, 1998). Much variation exists in the different quadriceps training protocols: open kinetic chain versus closed kinetic chain, eccentric work, isometrics, straight leg raises, short arc terminal extensions and isokinetic training (Malek & Mangine, 1981; Bennett & Stauber, 1986; Arno, 1990; Shelton & Thigpen, 1991; O'Neill et al., 1992; Tria et al., 1992; Stanitski, 1993; Galanty et al., 1994; Karlsson et al., 1996; Teitz, 1997; Thomee, 1997; Post, 1998; Thomee et al., 1999). A number of researchers advocate selective strengthening of the vastus medialis obliquus, especially if the apparent cause of pain is patellofemoral dysfunction (Arno, 1990; Hanten & Schulthies, 1990; Shelton, 1992; Zappala et al., 1992; Kannus & Niittymaki, 1994; Holmes & Clancy, 1998; Powers, 1998; Wilk et al., 1998). Rehabilitation programmes can either be followed with or without supervision of a therapist (Woodall & Welsh, 1990; Karlsson et al., 1996; Thomee, 1997). Progression is important to avoid exacerbating the condition (Hilyard, 1990; Shelton & Thigpen, 1991; Shelton, 1992; Thomee, 1997; Thomee et al., 1999). Functional training is an essential component of a complete rehabilitation programme, and refers to functionally oriented activities performed with good vastus medialis obliquus control. The traditional physical rehabilitation phases precede the functional phase, thus ensuring that normal joint motion, muscle strength and endurance is restored before progressing onto the functional phase (Lephart & Henry, 1995). It is a process of motor relearning, and progresses from basic to advanced activities (Shelton, 1992; Nyland et al., 1994).

A myriad studies report good results with primary conservative treatment. Malek and Mangine (1981) reported a 77% success rate which is supported by Karlsson et al. (1996) who reported an 80% remission in pain. Galanty et al. (1994) reported a 70-80% success rate. Tria (1992) and Cutbill et al. (1997) claim that as many as 95% of patients respond favourably. Bennett and Stauber (1986) employed a 4-week eccentric isokinetic programme, and reported significant strength gains in all 41 subjects. McMullen et al. (1990) reported significant functional improvements in their patients compared with the control group. This study showed no difference between a programme of isometric training and isokinetic training. Doucette and Goble (1992) reported an 84% success rate of pain-free patients with an 8-week comprehensive programme which included a progression from isometrics to concentric exercises, including both open- and closed kinetic chain exercises. Stiene et al. (1996) compared open- and closed kinetic chain exercises and concluded that both regimes showed a significant increase in knee extensor strength. Ingersoll and Knight (1991) reported favourable results by using EMG feedback to selectively strengthen the vastus medialis obliquus and thus correct faulty patella tracking. A study on sportsmen by DeHaven et al. (1979) concurs with this figure, reporting a 66% return to unrestricted sporting activities following conservative treatment.

Research indicates that these results are long-term in effect, as many subjects continued to experience improved function a number of months or even years after completion of rehabilitation. Thomee et al. (1999) cited a study by Hording which involved 34 patients between the ages of 8 and 19 years who were given a programme of isometric exercises to strengthen the quadriceps. At follow-up after 4 months, half the group was symptom-free. Karlsson et al. (1996) claimed an 85% success rate at an 11-year follow-up. Kannus and Niittymaki (1994) reported a 70% success rate following a 6-week conservative programme which included activity modification, non-steroidal anti-inflammatory drugs, isometric training and straight leg raises. Quadriceps strength gains remained stable at the 6 month follow-up. O'Neill et al. (1992) found an 80% improvement on a programme of isometrics and stretching at 12-16 month follow-up in a group comprised of adolescents and adults. Thomee (1997) investigated a 12-week conservative programme which involved pain monitoring and a progressive exercise programme. They reported a significant reduction in pain, increased muscle strength and level of physical activity. At the 12-month follow-up subjects still reported reduced pain, and 85% were involved in either competitive or recreational sporting activities.

Kannus and Niittymaki (1994) and Crossley et al. (2002) could not find a general or biomechanical factor which reliably predicted the success of non-operative treatment of anterior knee pain. Young age was the only variable that had a moderate relationship with success rate.

Proprioception and Dynamic Joint Stability

The term proprioception is not clearly defined in the literature. Nyland et al. (1994) state that in the 1940's a scientist by the name of Sherrington is said to have introduced the term "proprioception", describing the awareness of posture, movement, alterations in equilibrium and mechanical inertia that generate pressures and strains at the joints. Higgins (1991) used a much broader definition, referring to the assimilation of any information related to body position and movement. Seaman (1997) describes proprioception of the limb as an awareness of position and movement of the limb, while Sharma (1999) elaborates by referring to both a conscious and unconscious awareness of the position of the limb in space, joint position and joint movement. Two sub-modalities are described: joint position sense, or the awareness of the stationary position, and kinaesthesia, or the sense of limb movement (Seaman, 1997; Hiemstra et al., 2001).

The somatosensory system is often referred to as proprioception. It is responsible for detecting sensory stimuli such as pain, pressure and touch, and movements such as joint displacement. The somatosensory system receives input from mechanoreceptors in the skin, muscles, tendons, ligaments, capsules and joints (Lephart et al., 1997; Lephart et al., 1998; Fuchs et al., 1999; Sharma, 1999). These mechanoreceptors are also referred to as proprioceptors. They act as so-called biological transducers by converting the environmental stimuli they detect into action potentials within the associated afferent fibre (Seaman, 1997). These receptors signal changes in muscle length and tension, and joint position and motion. The most important contributors to joint proprioception are the peripheral articular and musculotendinous receptors. Specialised mechanoreceptors in the knee joint, specifically located in the joint capsule and ligaments, are sensitive to joint acceleration and deceleration. Receptors within the skeletal muscles detect changes in muscle length and tension. Together they contribute towards joint proprioception. This information is relayed to the central nervous system, which is primarily responsible for mediating the perception and execution of musculoskeletal control and movement (Lephart et al., 1997; Lephart et al., 1998; Sharma, 1999; Williams et al., 2001).

The central nervous system generates a motor response from the integrated input provided by the mechanoreceptors as well as the visual and vestibular receptors. These responses fall under three levels of motor control, namely: spinal reflexes, brainstem activity and cognitive programming. When the joint is placed under a mechanical load, spinal reflexes stimulate reflex muscular stabilisation (Lephart et al., 1997; Williams et al., 2001). Spinal reflexes form part of a neural network within the spinal cord that seems to result in the control of limb mechanics and rapid postural responses during movement (Williams et al., 2001). Cognitive programming involves the highest level of central nervous system function. It involves the motor cortex, basal ganglia and cerebellum, and refers to

voluntary movements that are repeated and stored as central commands (Lephart et al., 1997). Thus, input provided by the afferent system via its spinal and cortical projections results in control of movement and joint stability via reflex and centrally driven muscle activity (Sharma, 1999).
Proprioception is traditionally defined as the ability to determine the position of a joint in space at any given instant. It is usually tested using equipment that measures the threshold to detection of passive motion, passive and active limb repositioning and visual estimation of a passive angle change (Lephart et al., 1998; Fuchs et al., 1999; Rozzi et al., 1999; Sharma, 1999; Arnheim & Prentice, 2000; Roberts et al., 2000; Hiemstra et al., 2001; Williams et al., 2001). The focus of the present study, however, is on proprioception as it relates to neuromuscular control and articular function. The traditional methods are inappropriate for the present study as accurate measures of proprioception under dynamic conditions. It has yet to be proven how proprioceptive acuity, as measured by the traditional tests, gives an indication of joint position sensibility during activity, or neuromuscular joint protection (Sharma, 1999).

The central nervous system is the primary mediator of neuromuscular control and joint stability. Sensory information is received and processed by the brain and spinal cord, resulting in a conscious awareness of joint position and motion, unconscious joint stabilisation through protective spinal-mediated reflexes and the maintenance of posture and balance (Lephart et al., 1998). Proprioception and the accompanying neuromuscular feedback mechanisms are an important component in the establishment and maintenance of functional joint stability. Of particular importance are the receptors located in the articular and musculotendinous structures (Lephart et al., 1998). Solomonow and Krogsgaard (2001) describe joint stability as the harmonious functioning of the bones, joint capsule, muscles, and tendons as well as the sensory receptors and their spinal and cortical neural projections.

An integrated relationship exists between proprioception, neuromuscular control and dynamic joint stability (Lephart et al., 1997; Lephart et al., 1998; Sharma, 1999; Laskowski et al., 2000). Joint stability can be viewed as a continuum, with absolute stability on one end and severe instability on the other end. Proprioception, or the somatosensory system, and motor reaction determine the position of the knee joint on this continuum. Disrupted sensory control results in a shift towards the instability side. Pain causes inhibition of the stabilising muscles, which leads to joint instability, resulting in a cycle of pain and further inhibition. Any number of factors may affect this sensory control, including structural abnormalities, overuse, under use, injury, growth and muscle weakness (Lephart et al., 1997;

Lephart et al., 1998; Sharma, 1999). An essential part of a rehabilitation programme involves the training of the sensorimotor control system to generate adaptive neuromuscular activation patterns timeously in response to perturbations of normal joint motion. Strong muscles reacting quickly to correct abnormal joint movement serve to effectively stabilise the joint.

Barrett (1991) went so far as to suggest that proprioception is a greater contributor to normal limb function during activity than muscle strength. Proper knee function is integral to the integrity of the lower limb kinetic chain, hence proprioceptive deficits may have a significant effect on performance (Lephart et al., 1998). It may lead to alterations in joint stability and control of joint motion (Lattanzio et al., 1997).

Joint stability is essential to the proper functioning of the knee joint during movement. Dynamic joint stability refers to the ability of the knee joint to remain stable when subjected to rapidly changing loads during activity. This is brought about by the integrated contribution of articular form, soft tissue stabilisers and loads applied to the knee during weight-bearing and muscle action (Zatterstrom & Friden, 1994; Kakarlapudi & Bickerstaff, 2000; Williams et al., 2001). Proprioceptive input functions essentially in an adaptive role, enabling changes in motor strategy to be initiated based on information received upon changes in body, and hence joint position (Nyland et al., 1994). Proprioception acts as a protective mechanism in the knee joint, preventing excessive strain on the passive joint stabilisers during activity and as a means of preventing recurrent injury (Borsa et al., 1997). The role of the anterior cruciate ligament and other passive stabilisers in the knee joint in triggering muscular contractions in synergists as a protective reflex is well documented (Kennedy et al., 1982; Biedert et al., 1992; Zatterstrom & Friden, 1994). Proprioception is essential for the maintenance of knee joint stability under dynamic conditions. Afferent input results in controlled movement and joint stability through both reflex and centrally driven muscular activity (Sharma, 1999).

The restoration of proprioception and neuromuscular control is essential in a comprehensive conservative rehabilitation programme (Lephart et al., 1998). Rehabilitation programmes have previously tended to emphasize muscle strength, flexibility and endurance (Nyland et al., 1994). Disturbances in the afferent pathway of the somatosensory system may be a major contributing factor to the cycle of microtrauma and re-injury (Lephart et al., 1997; Lephart et al., 1998). The aim of a rehabilitation programme is the restoration of normal function so that the individual is able to participate in normal activities of daily living (Rutherford, 1988). If proprioceptive deficits are not ameliorated, the individual will not be completely rehabilitated and will thus be predisposed to re-injury because of deficiencies within the neuromuscular pathway. Kennedy et al. (1982) showed how ligament injury in the knee resulted in reduced mechanoreceptor function and reduced proprioception, which lead to reduced protective muscular stabilization, repetitive injury and progressive joint laxity.

→	→	Ligament injury	→
↑		↓	↓
Repetitive injury		Instability	Proprioceptive deficits
↑		↓	↓
←	Functional instability	←	↓ Neuromuscular control

(Lephart et al., 1998)

Thus, the programme needs to focus on the re-training of these pathways to improve the awareness of joint motion. Activities need to be aimed at all three levels of motor control: spine, brainstem and the higher centres, namely: the motor cortex, basal ganglia and cerebellum. The spinal level of control is responsible for reflex joint stabilisation. Enhancement of this neuromuscular mechanism probably occurs through dynamic joint stabilisation exercises of the lower limb. The brainstem is primarily responsible for the maintenance of posture and balance and is most likely trained by means of reactive neuromuscular activities. The higher control centres provide cognitive awareness of body position and movement where motor commands are initiated for voluntary movements. This mechanism is improved through kinaesthetic and proprioceptive training (Lephart et al., 1998).

The ultimate aim of the proprioceptive component is the promotion of dynamic joint and functional stability (Lephart et al., 1997).

Quadriceps Inhibition

Weakness of the quadriceps muscles is a common clinical finding in patients with anterior knee pain (Manal & Snyder-Mackler, 2000). There are a number of factors that may cause this quadriceps weakness. These include damage to the knee joint, muscle atrophy and reflex inhibition of the quadriceps (Stokes & Young, 1984). Reflex inhibition of the muscle, also referred to as arthrogenous muscle inhibition, is the inability to voluntarily contract the quadriceps muscle, and has been demonstrated in the presence of a painful knee, a knee in which there is chronic effusion, and a normal knee in which there is experimentally induced effusion (Antich & Brewster, 1986; Snyder-Mackler et al., 1994; Palmieri et al., 2003). Reflex inhibition is directly responsible for muscle weakness, and may also lead to muscle atrophy (Stokes & Young, 1984). General quadriceps weakness is often secondary to pain (Wild et al., 1982). Inhibition is difficult to measure, but measurement of maximal force output and EMG activity are indicators of the degree of inhibition (Wild et al., 1982; Antich & Brewster, 1986; Snyder-Mackler et al., 1994; Manal & Snyder-Mackler, 2000). Immobilisation, whether forced or voluntary, also leads to atrophy (Stokes & Young, 1984; Young, 1993). Muscle weakness predisposes the joint to further damage resulting in a vicious cycle of events (Wild et al., 1982; Stokes & Young, 1984; Young, 1993).

Joint damage

↗ ↓ ↘

Weakness ← Reflex inhibition ← Immobilisation

↖ ↓ ↙

Muscle wasting

(Young, 1993)

Afferent stimuli from the receptors located within and around the damaged knee joint inhibit activation of the alpha motor neurons found in the anterior horn of the spinal cord. The central pathway of the inhibitory stimuli is unknown.

The extensor strength deficits in patients with anterior knee pain, as detected by reduced muscle torque during isometric, concentric and eccentric contractions, may be due to reflex inhibition caused by afferent signals from the patellofemoral joint, possibly due to pain associated with the testing modality

(Thomee, 1997; Thomee et. al, 1999). The reduced torque was evidently more pronounced in the range close to full extension, and there was a difference in EMG activity between vastus medialis and rectus femoris muscles (Thomee, 1997).

Joint effusion is a major cause of inhibition. However, it is important to note that effusion is not always present in cases of inhibition. Research has shown that artificially induced effusion causes quadriceps inhibition (Kennedy et al., 1982; Wild et al., 1982; Stokes & Young, 1984; Young, 1993). In individuals presenting with effusion following menisectomy, it has been shown that aspiration of the effusion always reduces inhibition but does not completely eliminate it. Thus, it may be concluded that effusion is not the only cause of inhibition in those patients (Stokes & Young, 1984; Young, 1993). Even relatively small amounts of experimentally induced effusion result in substantial inhibition (Kennedy et al., 1982; Arno, 1990; Young, 1993). The effusion in normal knees was also shown to reduce the level of excitation of the quadriceps' anterior horn cells (Young, 1993). There are reports of bilateral quadriceps inhibition in patients with unilateral anterior cruciate ligament tears and patients with osteoarthritis. Palmieri et al. (2003) report that the neurophysiological mechanism resulting in this bilateral activation deficit remains unknown. They suggest that pain and inflammation activate a central response whereby general hyperexcitability in the spinal cord neurons occurs, as well as increased effectiveness of tonic descending inhibition which then counteracts the excitability of the spinal cord neurons.

If pain is present it may result in voluntary inhibition, whereby the patient is unwilling to maximally contract due to pain or the fear of pain (Stokes & Young, 1984; Rutherford, 1988; Powers et al., 1996). Reflex inhibition is a limiting factor in rehabilitation as it restricts full muscle activation, thus preventing restoration of muscle strength (Palmieri et al., 2003).

CHAPTER 3: METHODS AND PROCEDURES

Approval for the study was obtained from the University of Zululand's Faculty of Science and Agriculture Ethics Committee. All subjects and their parents completed an informed consent form prior to testing (Refer to Appendix 2).

SUBJECTS

A questionnaire was distributed to 9 local schools with permission from the headmaster of each school. Pupils between the ages of 10 and 17 years completed the questionnaire. Potential subjects for the intervention programme were recruited from an article that appeared in the local newspaper, referrals from doctors and from the results of the questionnaires completed by pupils at a number of local schools.

Skyline, lateral and antero-posterior view X-rays were taken of potential candidates. A physical examination by an orthopaedic surgeon determined patient eligibility. Subjects were between the ages of 10 and 17 years, 5 males and 18 females, with symptoms of non-traumatic anterior knee pain for more than one month. Subjects with the following conditions were excluded from the study: previously diagnosed ligamentous, meniscal, tendon, fat pad or bursae involvement; previous surgery; history of patella dislocation or subluxation; Osgood-Schlatter's disease; Sinding-Larsen-Johannsen disease.

RESEARCH GROUPS

Subjects were randomly allocated to either the control or experimental group. The control group (N=12) underwent a pre-testing and post-testing 21 days later, and were instructed to continue with normal everyday activity over the period. Refer to Appendix 7 for the testing proforma. The purpose of the control group was to determine whether any other factor besides the intervention programme could have been responsible for any changes observed in the parameters tested. Subjects were then offered the option of joining the intervention programme and thus forming part of the experimental group.

The experimental group (N=18) underwent a pre-testing, 18 day intervention programme, post-testing at 21 days and post-post testing 1 month post-intervention. All tests were carried out by the researcher and a trained research assistant.

The researcher collected the subjects after school and transported them to the testing laboratory at the University of Zululand. Subjects were instructed to wear a t-shirt, shorts and exercise shoes. Testing started at 14h30 and was completed by 16h00. Testing order followed that of the attached proforma (Appendix 7): history of knee pain; handedness; anthropometric measurements; flexibility; structural abnormalities; strength; proprioception; static stability and dynamic stability. The testing and intervention programme ran from June to December 2002.

ASSESSMENT PROTOCOL

A. Questionnaire

The questionnaire was designed based on information gleaned from a number of studies (Reider et al., 1981b; Galanty et al., 1994; Harrison et al., 1995). It contains 20 questions printed either in English or Afrikaans, aimed at discovering the level of physical activity, lower limb injury profile, and incidence, duration and severity of anterior knee pain. The age at onset of the pain is also included. (Refer to Appendix 1). The questionnaire was distributed to the various schools, and was completed under the guidance of either a researcher or the parents. All subjects who participated in the intervention programme also completed a questionnaire if they had not already done so.

B. Self-evaluation

1. Level of activity was measured using the Activity Rating Scale for Disorders of the Knee developed by Marx et al. (2001) (Refer to Appendix 3). The instrument is useful in assessing the general level of activity of the patient, not the most recent activity in the preceding days and weeks. Subjects were asked to indicate their peak level of activity in the past year to obtain a more accurate estimate of their baseline activity when actively participating in sport. Particular emphasis was placed on activities that are difficult for patients with knee conditions. The scale can be completed in a short time period and has demonstrated excellent construct validity (Marx et al., 2001).

2. Rating of disability using the Patient-Specific Functional Scale (PSFS) described by Chatman et al. (1997) (Refer to Appendix 4). The instrument aids clinicians in assessing the change in health or functional status of individual patients (Chatman et al., 1997; Westaway et al., 1998; Stratford et al., 2004). The PSFS should be administered at the initial assessment, prior to the assessment of any impairment measures. Patients were asked to identify up to five activities that they were experiencing difficulty with or were unable to perform because of their knee pain (Chatman et al., 1997; Westaway et al., 1998; Jolles et al., 2005). They were then asked to rate the current level of difficulty associated with each activity on an 11-point scale with the anchors, 0 (unable to perform activity) to 10 (able to perform activity at same level as before injury or problem) (Chatman et al., 1997; Westaway et al., 1998; Pietroban et al., 2002; Walker, 2004). The higher the score, the better the function (Westaway et al., 1998; Jolles et al., 2005). The scale was also used at re-assessments. As patients were asked to identify activities particular to their case, the PSFS is not a comprehensive measure of disability and was not designed to compare disabilities among patients. The scale is quick to administer and does not require special tools or training (Chatman et al., 1997; Jolles et al., 2005). Test-retest reliability is excellent, and it is a valid and responsive tool (Chatman et al., 1997; Pietroban et al., 2002; Walker, 2004; Jolles et al., 2005).

3. Rating of pain using a Visual Analogue Scale (VAS).
   The VAS is a 10-cm horizontal line marked at 1-cm intervals, the ends of which define the minimum (no pain) and maximum (severe pain) of perceived pain (Thomee, 1997; Witvrouw et al., 2000; Crossley et al., 2002; Kane et al., 2005) (Refer to Appendix 5). Each subject indicated the intensity of their pain by making a mark on the line. Normal, least and worst pain experienced in the past week was measured (Harrison et al., 1995; Witvrouw et al., 2000; Crossley et al., 2002). The Visual Analogue Scale has been found to be a reliable and valid tool for measuring pain (Thomee et al., 1999; Kane et al., 2005). It has also been shown to be a valid indicator of pain changes in patients with anterior knee pain (Powers et al., 1996).

4. Overall improvement by the final session using the Scale for Change in Condition described by Harrison et al. (1995) (Refer to Appendix 6).
   This 4-point scale was administered at the post-test and post-post-test, where patients indicated whether there was any change in their condition. The scale is useful for assessing the change in

functional status of individual patients (Harrison et al., 1995).

C. Handedness (Refer to Appendix 7)

The dominant hand and foot were recorded.

D. Anthropometric assessment (Refer to Appendix 7)

1. Height

   The stretch stature technique was used. The measurement was taken as the maximum distance from the floor to the vertex of the head with the head held in the Frankfort plane. The subject was barefoot and stood erect with heels together and arms hanging at the sides. The heels, buttocks, upper back and back of the head were in contact with the vertical wall. The subject was instructed to look ahead and take a deep breath. One tester ensured that the subject's heels were not elevated while the other applied a stretch force by cupping the subject's head and applying gentle traction alongside the mastoid processes. The first measurer then brought the headpiece firmly down and into contact with the vertex. The subject then stepped away from the wall, and the vertical distance from the floor to the headpiece was recorded (Gore, 2000).

2. Body Mass

   Taken on a beam-type balance and recorded to the nearest tenth of a kg.

3. Anthropometric measurement of leg length

   The distance between the trochanterion and external tibiale, and distance between external tibiale and lateral malleolus were measured to determine leg length (Steinkamp et al., 1993). Measurements were taken standing, to identify any functional limb length discrepancies (Holmes & Clancy, 1998). The landmarks were marked with the subject standing. Measurements were taken using large sliding calipers.

4. Anthropometric measurement of foot length

   The distance between the Acropodian and Pternion was measured on the standing subject using a sliding caliper. The caliper was held parallel to the long axis of the foot. The tester held the branch end of the caliper in the left hand and grasped the shaft with the second, third, and fourth digits of the right hand in opposition to the fifth digit while manipulating the cursor with the thumb. The sites were encompassed with minimal pressure (Gore, 2000).

E. Structural assessment (Refer to Appendix 7)

1. Flexibility

1.1 Hamstring: Straight Leg Hamstring Test

This test is commonly used to measure hamstring flexibility (SISA, 1998; Witvrouw et al., 2000). The subject lay supine on the plinth with one leg secured to the plinth to prevent hip flexion. The other leg was passively rotated about the hip joint as far as possible with the knee in full extension by the research assistant. The tester placed one hand anteriorly just below the knee and the other at the base of the ankle, keeping the knee fully extended. The researcher then measured the angle of hip flexion using a goniometer. The fulcrum of the goniometer was held over the greater trochanter, and the mobile arm was aligned with the midline of the femur using the lateral epicondyle as a reference point. The stationary arm of the goniometer was then aligned with the lateral midline of the pelvis. The angle measured was the angle of displacement from the horizontal. The procedure was repeated for both legs (SISA, 1998).

1.2 Quadriceps: Modified Thomas Test

This test was used to measure flexibility of the quadriceps muscles. The subject sat on the end of the plinth, and rolled back pulling both knees to the chest. This ensured that the pelvis was in posterior rotation and that the lumbar spine was flat on the plinth. The subject then lowered one leg towards the floor whilst holding the contralateral limb in maximum flexion with the arms. The angle of knee flexion was measured to determine the length of the quadriceps. The fulcrum of the goniometer was placed over the lateral epicondyle of the femur, the stationary arm of the goniometer was aligned with the lateral midline of the thigh using the greater trochanter as the reference point, and the mobile arm was aligned with the lateral midline of the fibula using the lateral malleolus as the reference point (SISA, 1998; Harvey, 1998).

1.3 Gastrocnemius: Straight Leg Gastrocnemius test

The patient was instructed to place the tested leg on a mark 0.6 meters from the plinth and to lean forward. The other leg was placed closer to the plinth for balance, and was bent. The tested leg was kept extended and the subject was instructed to maximally flex the tested ankle while keeping the heel on the ground (Witvrouw et al., 2000). The fulcrum of the goniometer was placed over the lateral malleolus, the fixed arm of the goniometer was aligned with the foot, and the mobile arm was aligned with the lateral midline of the fibula, using the lateral epicondyle of the femur as the reference point.

1.4 Iliotibial band: Ober's Test

The subject lay on the side with the hip and knee of the bottom leg flexed to flatten any lumbar lordosis and stabilise the pelvis (Kendall et al., 1993; Ruffin & Kinningham, 1993; Post, 1998). The knee of the top leg was held at a right angle and the hip was flexed to 90 degrees while fully abducted, brought into extension and allowed to adduct. The knee of the top leg should fall into adduction when released (Kendall et al., 1993; Ruffin & Kinningham, 1993). For normal length, the thigh drops approximately 10 degrees (Kendall et al., 1993). A tight iliotibial band prevents this from happening, causing the knee to remain abducted (Kendall et al., 1993; Ruffin & Kinningham, 1993; Post, 1998).

2. Q-angle

The subject stood with the feet together, knees extended and quadriceps muscle group relaxed (Livingston & Mandigo, 1998). Lines were drawn connecting the anterior superior iliac spine and the centre of the tibial tubercle with the geometric centre of the patella (Reider et al., 1981a; Holmes & Clancy, 1998; Arnheim & Prentice, 2000). A transparent, flexible plastic full circle goniometer was used to measure the Q-angle. The centre of the goniometer was placed at the midpoint of the patella. One arm of the goniometer was aligned with the line leading to the anterior superior iliac spine, and the other arm was aligned with the tibial tubercle (Caylor et al., 1993).

3. Valgus and varus stress tests

Valgus and varus stress tests reveal laxity of the medial and lateral collateral ligaments. The tests were performed with the subject supine, and the knee in 0 degrees and 30 degrees flexion. When testing the medial collateral ligament, the examiner's hand supported at the ankle, and the opposite hand applied a valgus force to the lateral aspect of the knee. The examiner assessed for the onset of pain, extent of valgus movement, and the end point. When testing the lateral collateral ligament, the tester's hands were reversed, and a varus force was applied to the medial aspect of the knee (Arnheim & Prentice, 2000; Brukner & Khan, 2002).

4. Test for the presence of crepitus

    Crepitus was felt for during passive knee flexion and extension.

5. Assessment of the lower leg and foot. The presence of the following was recorded:

    5.1 Genu valgum

    5.2 Genu varum

    5.3 Genu recurvatum

    5.4 Pes cavus/ planus

    5.5 Pronation/ Supination

F. Functional assessment (Refer to Appendix 7)

1. Strength

    1.1 Quadriceps

    1.2 Hamstring

    Measurements of maximal muscle strength were recorded using a hydraulically-braked closed kinetic chain knee flexion/extension machine attached to a static dynamometer. The Akron which was to be used to test isokinetic quadriceps and hamstring strength broke down beyond repair just prior to the commencement of testing. The closest testing device was 2 hours drive away, hence it was decided to modify a closed kinetic chain piece of rehabilitation equipment into a muscle strength testing device. The machine was tested on healthy subjects and the pilot study to determine test-retest reliability.

    Subjects were strapped into the seat and positioned by means of a goniometer to record the force generated during knee flexion and extension with the knee positioned at 90 degrees flexion. Subjects were given one practice trial, and then the highest value of three attempts was recorded. Subjects were given a 30-second rest break between attempts.

Figure 3: The testing of muscle strength

2. Proprioception: Measured on the Willknox wobbleboard placed on a flat wooden surface. Time spent unbalanced during a two minute period was recorded.

Figure 4: Testing proprioception on the Willknox wobbleboard

3. Static balance: The Stork Stand as described by Bosco & Gustafson (1983).

The subject stood on the dominant leg, placing the other foot flat on the medial aspect of the supporting knee, with the hands on the hips. At the signal to begin, the subject raised the heel of the supporting leg and attempted to maintain balance for as long as possible without moving the ball of the supporting foot or letting its heel touch the ground. Time, in seconds, was recorded from the time the heel was raised to the time the balance was lost or the hands were *removed from the hips. Three trials were given, and the highest of three scores was recorded to* the nearest second. A test-retest reliability coefficient of 0.87 was reported for the best of three trials given on different days (Bosco & Gustafson, 1983).

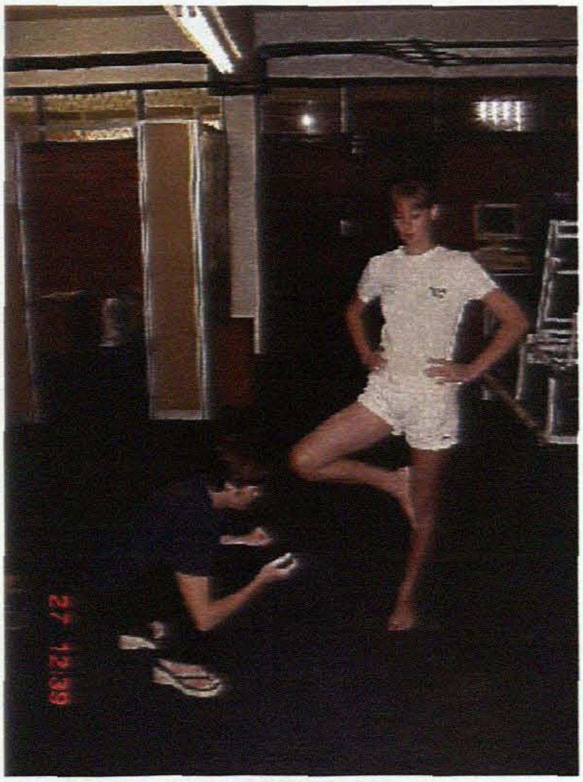


Figure 5: The Stork stand

4. Dynamic balance: Bass Test of Dynamic Balance as described by Bosco & Gustafson (1983). The subject stood with the right foot in the starting circle and leapt into the first circle with the left foot, then leapt from circle to circle, alternating feet (Refer to Figure 6). The subject must land on the ball of the foot, and not allow the heel to touch the ground. Errors were counted: each error counted as a penalty point every time it occurred. Errors included the following: 1) the heel touching the ground; 2) moving or hopping on the supporting foot while in the circle; 3) touching the floor outside a circle with the supporting foot; and 4) touching the floor with the free foot or any other part

of the body. The timer counted the seconds (up to five seconds) out loud, beginning the count as the subject landed in the circle. Counting was restarted if the performer leapt to the next circle in less than five seconds. If the subject spent more than five seconds in the circle, the extra time was deducted from the total time. Errors were counted silently and cumulatively by the tester who followed the subject closely. A total of five trials were given, three of which were practice runs. The score of the better of the last two trials was the recorded score. The final score was the total time plus 50, minus three times the total errors. The greater the time taken and the fewer the errors, the better the score. A reliability coefficient of 0.95 was obtained with female college students as subjects. The test is easy to administer and is applicable to both sexes and various age groups (Bosco & Gustafson, 1983).

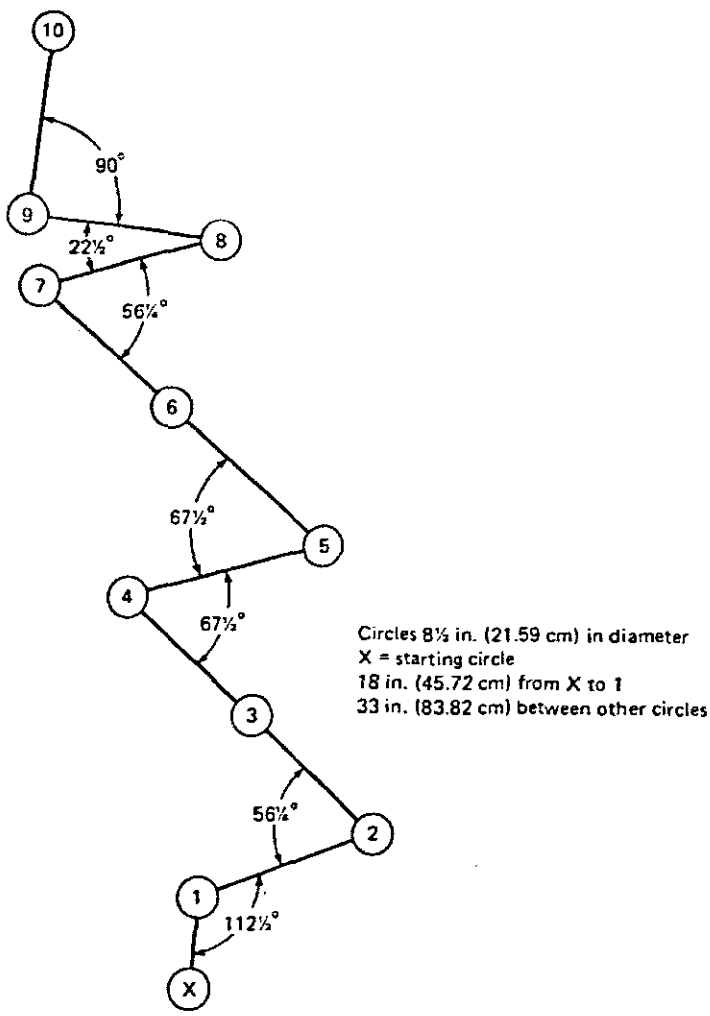


Figure 6: Layout for Bass Test for assessing dynamic stability

(Bosco and Gustafson, 1983 p122)

INTERVENTION PROGRAMME

The programme included muscle strength training, proprioceptive work and dynamic stability training (Refer to Appendix 8). Knee flexion and extension exercises to strengthen the quadriceps and hamstring muscles were performed on a seated flexion-extension machine designed on isokinetic principles. The exercise was performed at 5 different resistance settings. Three sets of repetitions were performed at each resistance, with a 20-second rest between each set. The repetitions performed at the lowest resistance setting served as the warm-up. Subjects also performed wobbleboard exercises and a routine on the mini-trampoline. From the third session, subjects were progressively introduced to a functional jumping routine.

A home programme was given in the second contact session, and included flexibility and strength training exercises for the lower limb, which subjects were to follow concurrently with the rehabilitation programme (Refer to Appendix 9). The home programme was aimed at stretching and strengthening the lower limb as a whole, and included proprioception exercises. Flexibility training focused on static stretching of the calf, hamstring and hip flexor muscles. The muscle strengthening portion consisted of closed kinetic chain hip, knee and ankle exercises (step-ups; calf raises; toe raises; pelvic lift; leg curls), while the proprioceptive exercises involved maintaining balance on an unstable surface, such as a narrow plank. An exercise log was kept by subjects to enhance compliance (Refer to Appendix 10).

Subjects in general attended 5 contact sessions of approximately 45 minutes over the 21 day period. They were encouraged to continue with the home programme on their own on completion of the programme.

CHAPTER 4: RESULTS AND DISCUSSION

SECTION 1

THE INCIDENCE OF ANTERIOR KNEE PAIN AMONG ADOLESCENTS

1. Incidence of anterior knee pain

A total of 2414 questionnaires were distributed to nine local junior and high schools, of which 1870 were returned. The return rate was thus 77.5%. Thirty-four questionnaires were spoilt or completed by children younger than 10 years of age. 475 subjects were excluded as they had a history of traumatic knee injury, and an additional 147 were excluded as their answers on the questionnaire were inconclusive.

1.1 Percentage of total population affected and incidence in males versus females

Table 1. Number and percentage of subjects per category and per gender (N=1210)

Category	Number of subjects	Percentage of total subjects	Male		Female	
			N	%	N	%
Positive AKP	331.0	27.4	142.0	42.9	189.0	57.1
No knee pain	879.0	72.6	338.0	38.5	541.0	61.5

Results from the questionnaires indicate that 27.4% of adolescents who participated in the study had experienced non-traumatic anterior knee pain at some time between the ages of 10 and 17 years. This is comparable to the 20-40% reported in the literature for this age group (Kannus & Niittymaki, 1994; Heng & Haw, 1996; Johnson, 1997; Roush et al., 2000). Of this group, 42.9% was male and 57.1% was female. While this does indicate that more females than males were affected, the ratio is lower than that reflected in the literature. In some studies the ratio was reported to be as high as two to one in females versus males (Powers, 1998; Lichota, 2003).

1.2 Incidence of anterior knee pain according to age group

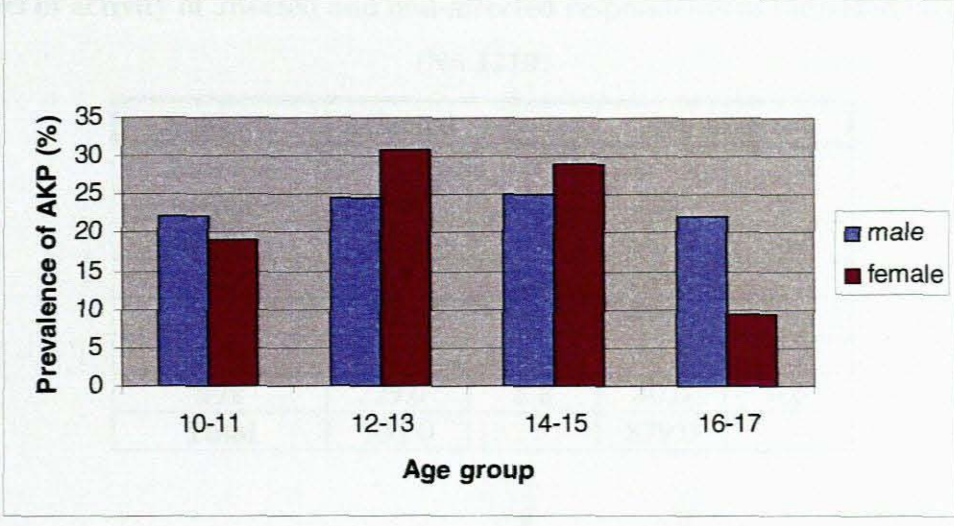


Figure 7: The prevalence of anterior knee pain per age group, represented as a percentage of all the respondents, as indicated on the knee pain questionnaire

The highest incidence of anterior knee pain in girls was at 13 years of age while in boys it was at 14 years of age. While the girls showed a definite peak in the incidence of anterior knee pain around 12 to 13 years, it was less defined for the boys. The highest incidence of anterior knee pain reported for 12 to 13 year old girls and 14 to 15 year old boys correlates with the period of the adolescent growth spurt. The growth spurt begins at roughly 10.5 to 11 years in girls, and 12.5 to 13 years in boys, and lasts for approximately 2 years. However, there is wide variation, and the spurt may occur anywhere between 10.5 and 16 years of age (Sinclair, 1989).

1.3 Knee affected by condition

Of the subjects that reported anterior knee pain, 21% experienced it in the left knee only, 34% in the right knee only and 45% bilaterally. The literature supports this finding, stating that the condition tends to be bilateral (Powers, 1998; Lichota, 2003; Shea et al., 2003; Pollock, 2004).

1.4 Medical treatment sought

31% of subjects had visited a medical doctor because of their knee pain. 37% of the subjects had visited a Physiotherapist or Biokineticist, 43% of which reported that the intervention they received was successful.

2. Level of activity of respondents

Table 2: Level of activity of affected and non-affected respondents as indicated on questionnaire (N= 1210)

Subjects	Affected		Non-affected	
Level of activity	No.	%	No.	%
Never	20.0	6.1	141.0	16.0
<3x	169.0	51.1	484.0	55.1
3-4x	82.0	24.7	155.0	17.6
5-7x	31.0	9.4	59.0	6.7
>7x	29.0	8.8	40.0	4.6
Total	331.0		879.0	

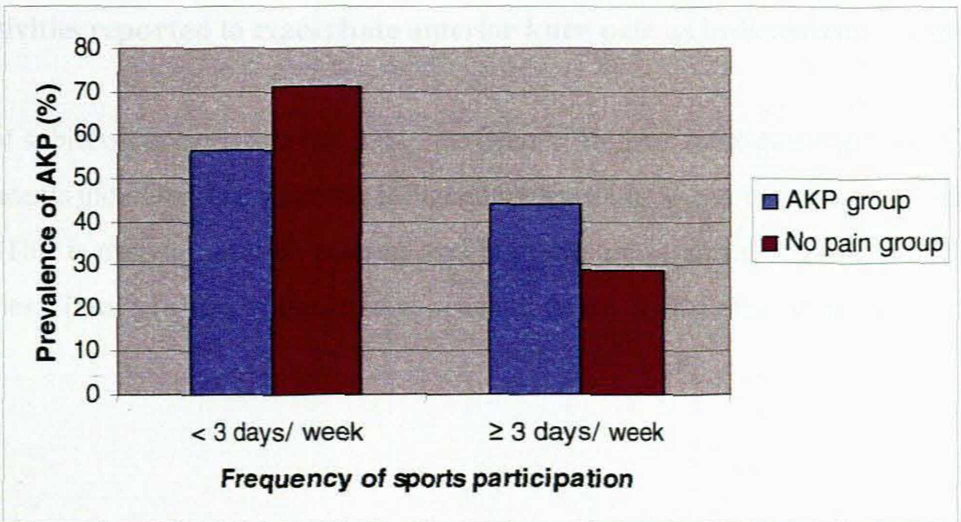


Figure 8: The prevalence of anterior knee pain compared with level of activity as indicated on the questionnaire

57.2% of the affected group and 71.1% of the non-affected group participated in sport less than 3 times per week. 42.9% of the affected group and 28.9% of the non-affected group participated in sport 3 or more times per week. Thus, while most respondents participated less then 3 times per week, those that participated more then 3 times per week appear more likely to experience anterior knee pain. Thus, a greater percentage of respondents with anterior knee pain than those without were active at least 3 times per week for at least 30 minutes per session.

3. *Activities exacerbating condition*

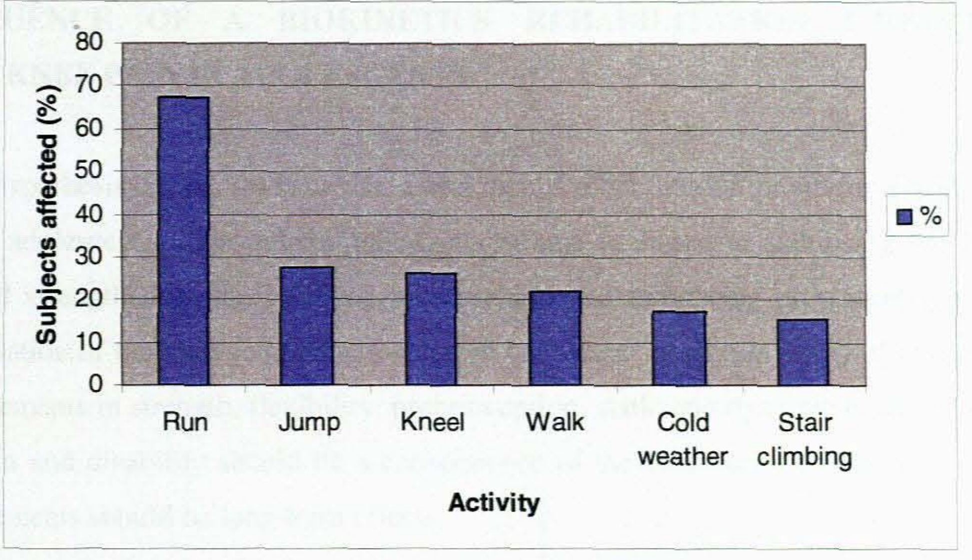


Figure 9: Activities reported to exacerbate anterior knee pain as indicated on the questionnaire

82% of subjects reported that the pain interfered with their sport participation. The majority of respondents indicated that running, followed by jumping, was a major source of increased knee pain. This is relevant as both running and jumping are essential components of most sporting activities. Thus, alleviating the knee pain would result in greater sports participation.

SECTION 2

THE INFLUENCE OF A BIOKINETICS REHABILITATION PROGRAMME ON ANTERIOR KNEE PAIN IN ADOLESCENTS

The general hypothesis of this study is that a biokinetics rehabilitation programme alleviates anterior knee pain in adolescents. The rehabilitation programme is aimed at stabilising the knee joint by stretching and strengthening the involved musculature, and improving proprioception of the lower limb. Stabilisation of the knee joint should result in decreased subjective rating of pain and disability. Thus, improvements in strength, flexibility, proprioception, static and dynamic balance, and subjective ratings of pain and disability should be a consequence of the biokinetics programme. Furthermore, these improvements should be long-term effects.

1. Baseline Descriptive Data and Characteristics of the Subjects of the Experimental and Control groups.

1.1 Age, height, weight and level of body fat

Table 3: Descriptive data of the control (N=12) and experimental (N=18) groups

		Age (yrs)	Height (m)	Weight (kg)	Body fat (%)
Control	Mean	14.6	1.7	63.6	19.5
	SD	1.9	0.1	16.4	7.3
Experimental	Mean	14.0	1.6	57.9	19.9
	SD	1.4	0.1	12.2	7.0
Difference (%)		-4.1**	-5.9**	-9.0**	2.1**

(**= p>0.05)

There is a strong similarity between the control and experimental groups. While the control group was slightly older, taller and heavier, these differences were not significant ($p>0.05$).

1.2 Duration of anterior knee pain

Table 4: Mean duration of anterior knee pain as reported by the control (N=12) and experimental (N=18) groups

		Duration of pain (months)
Control	Mean	15.6
	SD	14.5
Experimental	Mean	16.2
	SD	13.6

Both groups had a mean duration of anterior knee pain in excess of 1 year prior to commencing with the rehabilitation programme. The literature reports that the condition can take up to 2 years to resolve, with symptoms improving with the reduction of rapid growth (Juhn, 1999; Patel & Nelson, 2000; Shea et al., 2003).

1.3 Dominant knee versus non-dominant knee

Table 5: Injured knees in control (N=12) and experimental (N=18) groups

	Bilateral	Right	Left
Control	5	3	4
Experimental	7	6	5

There was no difference of injury in the dominant or non-dominant knee, as 11 of the control subjects and 16 of the experimental subjects claimed to be right-footed.

1.4 Q-angle

Table 6: Q-angles of the control (N=12) and experimental groups (N=18)

		Q-angle (R) (degrees)	**Q-angle (L) (degrees)**
Control	Mean	15.5	16.0
	SD	4.0	4.1
	Min	8.0	8.0
	Max	22.0	21.0
Experimental	Mean	14.6	14.7
	SD	4.4	4.3
	Min	7.0	8.0
	Max	22.0	21.0

The normal range for Q-angles is 10 to 20 degrees (Reider et al., 1981a; Livingston & Mandigo, 1998; Arnheim & Prentice, 2000). As the minimum and maximum values for the control and experimental groups indicate, not all subjects fell within this range. According to the literature this is an indication of patella maltracking, which can cause symptoms of anterior knee pain (Arnheim & Prentice, 2000).

1.5 Level of activity

Table 7: Mean activity levels according to the Activity Rating Scale (Marx et al., 2001) of the control (N=12) and experimental (N=18) groups

		Activity Level (Total)	Activity Level (Females)	Activity Level (Males)
Control	Mean	12.4	12.2	13.0
	SD	2.0	2.2	1.7
Experimental	Mean	13.1	13.0	13.3
	SD	2.2	2.4	1.5

The above table indicates the average level of activity for the control and experimental groups according to the Activity Rating Scale designed by Marx et al. (2001). The scores indicate that on average both groups participated in activities involving twisting, cutting and decelerating three times per week. There is a strong similarity between the groups.

1.6 Activities exacerbating anterior knee pain

Table 8: Activities most-commonly reported by subjects to cause pain on the Patient-Specific Functional Scale (Chatman et al., 1997)

Activity	Experimental (N=18)	Control (N=12)
Run	94.4%	91.7%
Jump	55.6%	66.7%
Stairclimbing	55.6%	41.7%
Sit	38.9%	41.7%
Sit cross-legged	22.8%	25.0%
Twist	16.7%	16.7%

Running was the most commonly cited activity exacerbating knee pain in both the control and experimental groups. Both running and jumping are integral components of most sports codes. Improved ability to perform these activities results in improved ability to perform sporting and everyday activities.

2. Subjective Ratings of Pain and Disability of the Control and Experimental Groups in the Pre-, Post- and Post-post Tests

Pain in the anterior region of the knee is the symptom common amongst all subjects. The pain results in decreased ability, and/or reluctance to perform certain activities. Thus, a real measure of improvement in condition as experienced by the subjects would be decreased pain and an associated improvement in function.

2.1 Subjective Ratings of Pain

Table 9: Baseline values of pain as indicated on a Visual Analogue Scale (VAS) for the control (N=12) and experimental (N=18) groups

	Pain	**Worst**	**Least**	**Normal**
Control	Mean	6.6	2.5	4.6
	SD	0.9	0.9	1.4
Experimental	Mean	7.1	3.3	5.4
	SD	1.2	1.8	1.9
Difference (%)		7.6**	32.0**	17.4**

(**= $p>0.05$)

The groups are similar in their ratings of pain as there is no significant difference between the two groups ($p>0.05$). It would appear that there is a large difference in the reported 'Least

Pain', but it is not significant and is probably due to the low values reported. The experimental group did report higher levels of pain than the control group in all three categories.

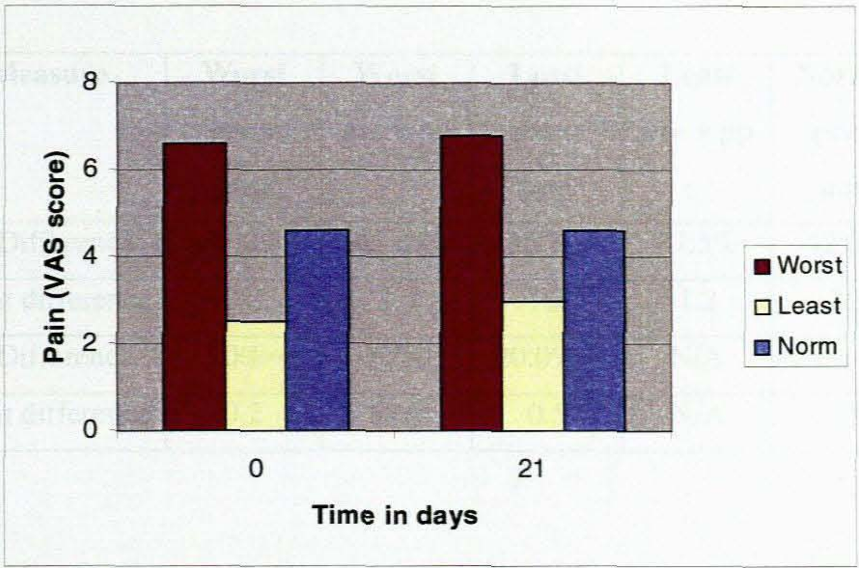
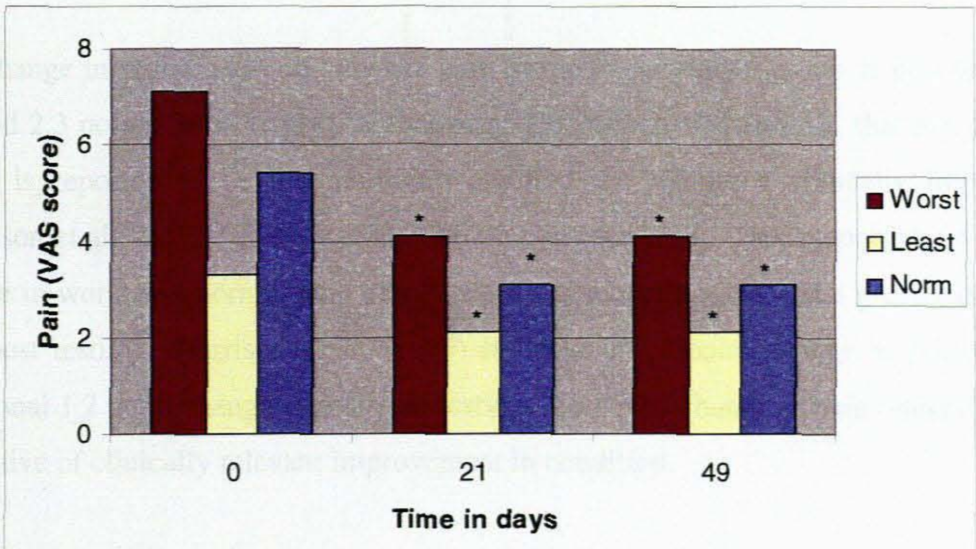


Figure 10: The control group's mean ratings of worst, least and normal pain as indicated on a visual analogue scale at the pre- and post-testing (N=12)



(*=p<0.01)

Figure 11: The experimental group's mean ratings of worst, least and normal pain as indicated on a visual analogue scale at the pre, post- and post-post testing (N=18)

Table 10: Percentage change and change in scores of mean ratings of worst, least and normal pain as indicated on a VAS at the post- and post-post testing, for the control (N=12) and experimental (N=18) groups

Group	Measure	Worst pre v post	Worst pre v pp	Least pre v post	Least pre v pp	Normal pre v post	Normal pre v pp
Exp	% Difference	-43.0%*	-42.8%*	-35.3%*	-37.5%*	-42.0%*	-41.6%*
	Point difference	3.0	3.0	1.2	1.2	2.3	2.3
Control	% Difference	3.0%**	N/A	20.0%**	N/A	0%**	N/A
	Point difference	0.2	N/A	0.5	N/A	0	N/A

(*= $p<0.01$)

(**= $p>0.01$)

There was a significant improvement in worst, least and normal pain ratings of the experimental group at the post-testing, and this was maintained at the post-post testing ($p<0.01$). There was no significant change in the control group, however the worst and least pain did increase at the post-test ($p>0.01$).

The change in worst, least and normal pain in the experimental group at post-testing was 3.0, 1.2 and 2.3 points respectively. A change of 1.0cm on a 10-cm VAS, that is a difference of 1 point, is reported to be the minimum required to indicate a clinically important change (Harrison et al., 1995; Crossley et al., 2002). Crossley et al. (2002) reported a 4- and 3.5 point change in worst and normal pain after 6 weeks of rehabilitation, and a greater improvement at post-post testing. Harrison et al. (1995) reported a 1.1 point change at post-testing and an additional 1.2 point change at post-post testing. Thus, the change in pain ratings in this study is indicative of clinically relevant improvement in condition.

It can therefore be assumed that the intervention programme resulted in a reduction in pain in the subjects, which was maintained after completion of the programme.

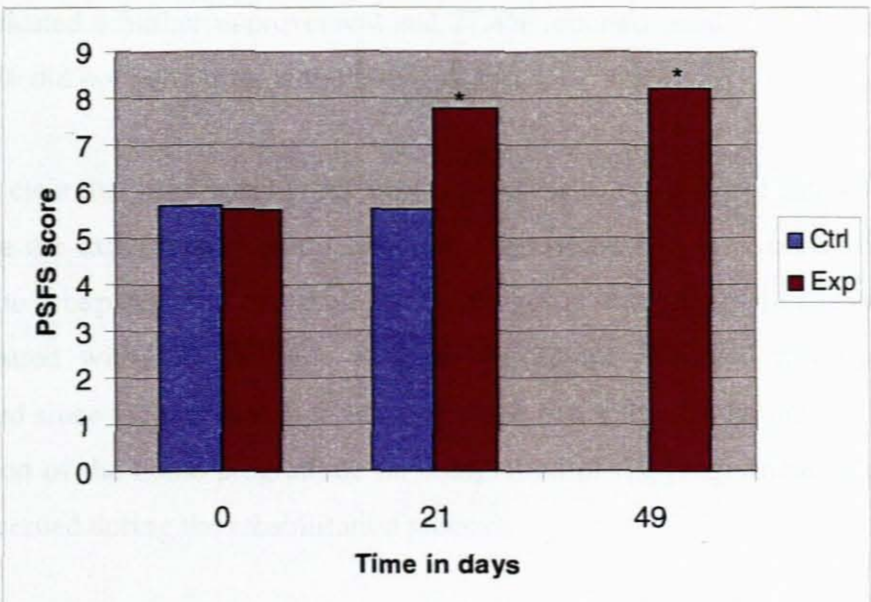
2.2 Subjective Ratings of Disability

Table 11: Baseline values of disability as indicated on the Patient-Specific Functional Scale (Chatman et al., 1997)

		PSFS
Control	Mean	5.7
	SD	1.2
Experimental	Mean	5.6
	SD	1.4
Difference(%)		1.8**

(**= p>0.05)

At the pre-test the control and experimental groups were very similar with respect to levels of disability experienced due to knee pain. There was no significant difference between the groups (p>0.05).



(* = p<0.01)

Figure 12: Mean ratings of ability to perform various activities as indicated on the Patient-Specific Functional Scale (Chatman et al., 1997) at the pre, post- and post-post testing of the control (N=12) and experimental (N=18) groups

The intervention programme resulted in a significant improvement in the ability of the subjects from the experimental group to perform activities indicated by individual subjects on the Patient-Specific Functional Scale ($p<0.01$). No such change occurred in the control group ($p>0.01$). Subjects indicated particular activities which they were experiencing difficulty with due to their knee pain. On completion of the intervention programme, subjects reported a greatly improved ability to perform these same activities. This reduced disability was maintained at the post-post testing ($p<0.01$). Thus, it would appear that participation in the intervention programme resulted in decreased disability due to anterior knee pain, which was maintained in the long-term.

3. Change in condition

75 % of the control group indicated that there was no change in their condition at the post-test, while 25% indicated that their condition was worse than at the pre-test. 66.7% of the experimental group indicated that their condition was improved at the post-test, and 33.3% indicated that their condition was greatly improved. At the post-post test 16.7% indicated that their condition had deteriorated since the post-test, 11.1% reported no change in condition, 27.8% indicated a further improvement and 27.8% reported good improvement since the post-test. 16.7% did not participate in the post-post test.

Thus, it is clear that the control group experienced the same or worse pain over the period. All subjects in the experimental group indicated improvement in their condition at the post-test. Most of the group reported that their condition was at least as good or better at the post-post test compared with the post-test. A small percentage indicated that their condition had deteriorated since the post-test, but was still much better than at the pre-test. This supports the continuation of the home programme on completion of the programme so as to maintain the benefits accrued during the rehabilitation process.

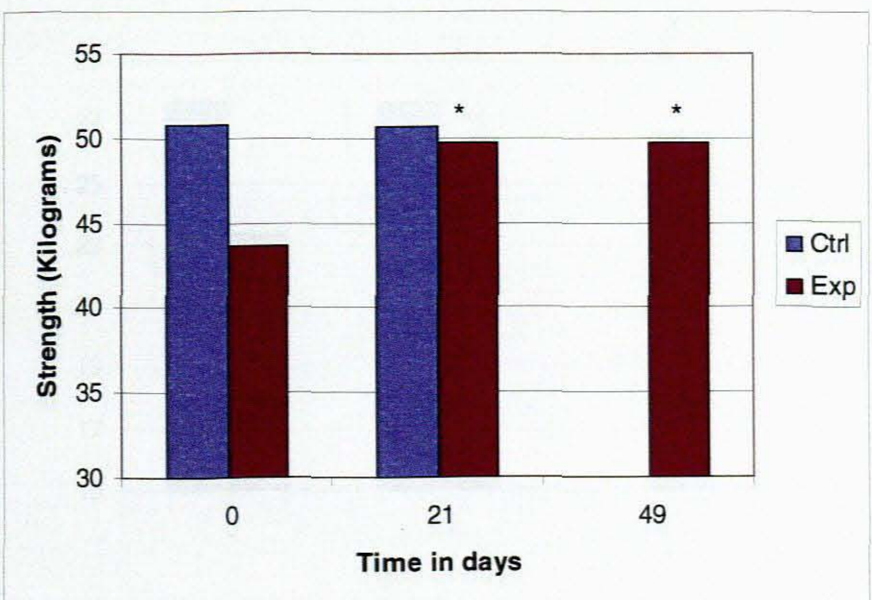
4. Structural and Functional Variables Measured

The following structural and functional variables were measured during testing. Changes in these variables were assumed to account for the change in condition.

4.1 Muscle strength

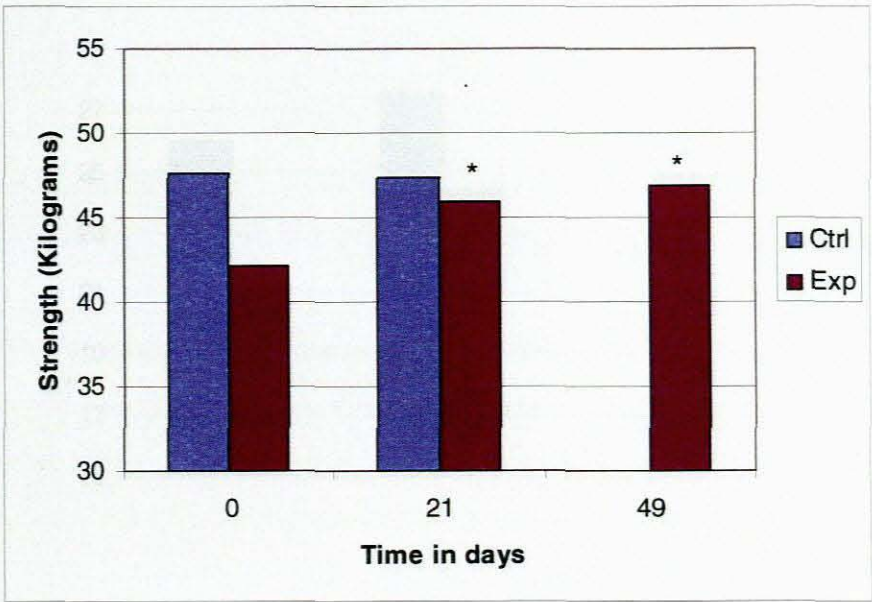
Table 12: Baseline values of mean muscle strength and percentage difference of the control (N=12) and experimental (N=18) groups

		R Quads pre (kg)	L Quads pre (kg)	R Hams pre (kg)	L Hams pre (kg)
Control	Mean	50.8	47.6	27.7	26.0
	SD	18.1	14.1	9.6	10.1
Experimental	Mean	43.6	42.1	23.4	21.2
	SD	10.8	9.8	4.9	4.5
Difference (%)		-14.2	-11.6	-15.5	-18.5



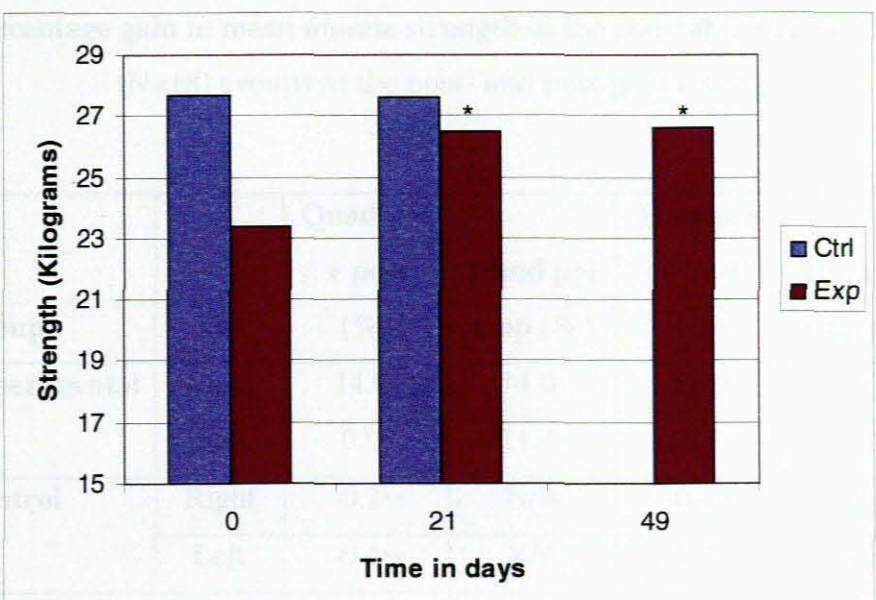
(* = p<0.01)

Figure 13: Mean values of right quadriceps strength of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing



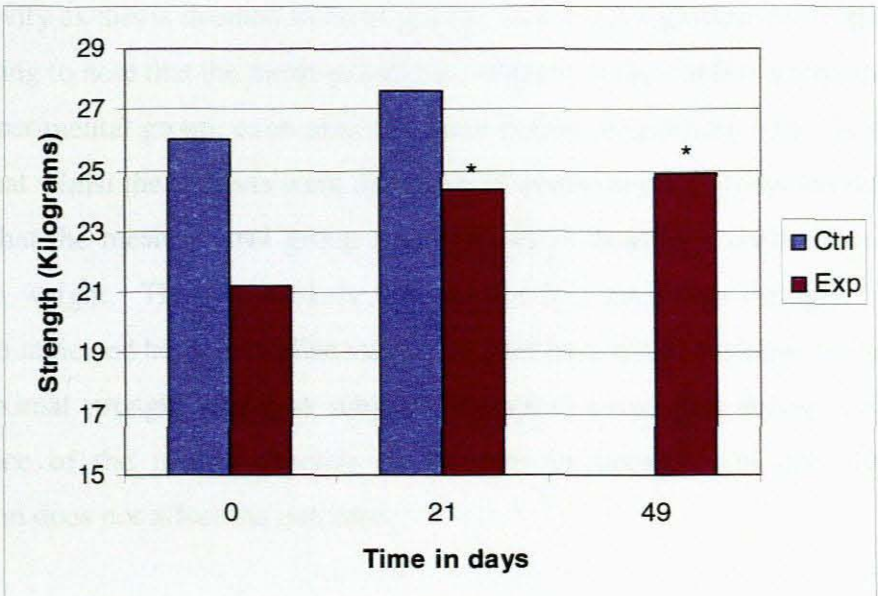
(* = p<0.01)

Figure 14: Mean values of left quadriceps strength of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing



(* = p<0.01)

Figure 15: Mean values of right hamstring strength of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing



(* = p<0.01)

Figure 16: Mean values of left hamstring strength of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing

Table 13: Percentage gain in mean muscle strength of the control (N=12) and experimental (N=18) groups at the post- and post-post testing

Group	Side	Quad pre v post (%)	Quad pre v pp (%)	Ham pre v post (%)	Ham pre v pp (%)
Experimental	Right	14.0*	14.0*	13.2*	13.7*
	Left	9.0*	11.4*	15.1*	17.5*
Control	Right	-0.2**	N/A	-0.4**	N/A
	Left	-0.4**	N/A	-2.7**	N/A

(* = p<0.01)
(**= p>0.01)

There was a significant gain in muscle strength in both the quadriceps and hamstring muscle groups at the post- and post-post testing of the experimental group (p<0.01). There was no significant change in the control group (p>0.01). Strength testing was performed as a closed chain activity as this is deemed to be of greater functional significance (Roush et al., 2000). It is interesting to note that the mean quadriceps strength of the control group was higher than that of the experimental group, even after the intervention programme. This is most likely due to the fact that whilst the subjects were randomly allocated to each group, the descriptive statistics indicate that the mean control group was older by 6 months, 4 centimetres taller and 3.5 kg heavier in weight. Thus, it is likely that the control group was stronger. The experimental group also indicated higher baseline values for pain on a visual analogue scale, which can result in submaximal strength scores as subjects attempt to avoid pain during testing. Because the significance of the results depends on changes in strength and not initial strength, this observation does not affect the outcome.

The right quadriceps and hamstring muscle groups were stronger for both the control and experimental groups. This reflects right-sided dominance as 11 out of 12 and 16 out of 18 subjects in the control and experimental groups respectively indicated that they were right-footed. The percentage increase in muscle strength of the experimental group ranged between 9.0 and 17.5%. While there is a dearth of literature with actual strength figures, this value does concur with other studies. A number of studies measured changes in isometric strength following a training or rehabilitation programme. Changes in strength ranged from 10.0 to 37% after 8 to 12 weeks, depending on the training regimen (Rutherford, 1988; Thomee, 1997; Clark et al., 2000; Smith & Bruce-Low, 2004). The aforementioned studies ran for a much longer time period than the current study, however, Rutherford (1988) reported a 5% improvement in isometric quadriceps strength after 2 weeks of strength training, while Maitland et al. (1993) reported 10.0 to 16% improvement after 25 days of training. Thomee (1997) noted continued strength improvement by an additional 7.0% at a 6 month follow-up. While the actual results of this study cannot be compared with the aforementioned studies due to different testing procedures, the percentage gain in muscle strength can be compared.

In the current study concentric muscle strength was measured. Again, the strength improvements obtained with the Biokinetics programme concur with the literature. Smith & Bruce-Low (2004) cited a study where the 1-repetition maximum was measured, and reported a 5.5 – 11.6% increase after 10 weeks of training. Thomee (1997) reported a 12.0% increase in concentric muscle strength at 3 months follow-up and 17.0% increase at 12 months. Colak et al. (1998) reported improvements in quadriceps and hamstring concentric strength of 13.5 and 7.4% respectively after 4 weeks of training. Witvrouw et al. (2000) reported a 11.7% and 8.0% improvement in quadriceps strength and 16.7% and 14.0% improvement in hamstring strength at 5 weeks and 3 months respectively, after following an open kinetic chain rehabilitation programme for 5 weeks.

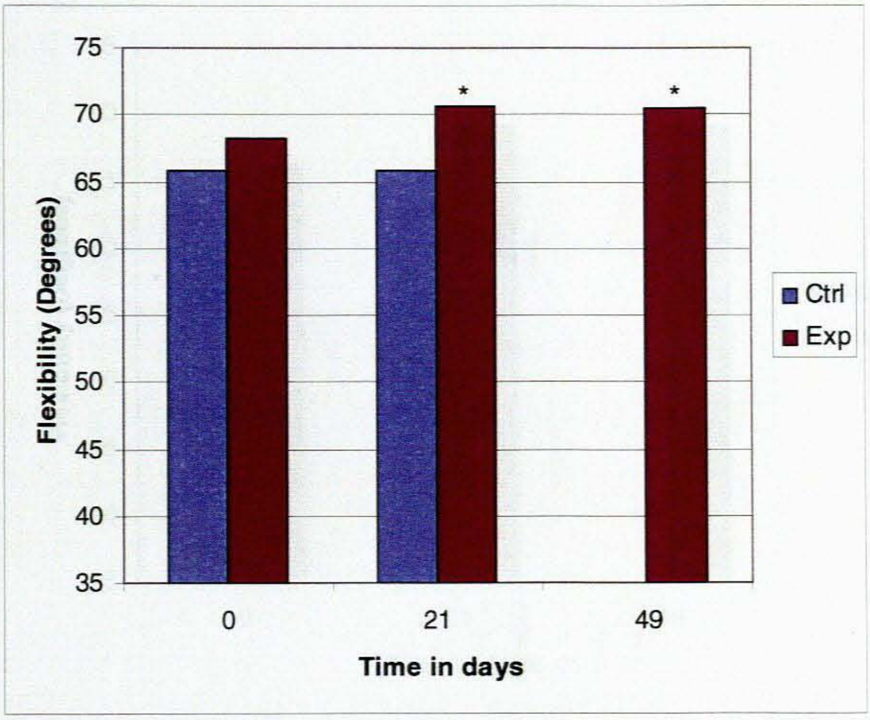
Initially the increase in strength is due to more efficient activation of the muscle. Thus, the changes are the result of improvements in the neuromuscular system, especially within the first 4 weeks of training, rather than muscle hypertrophy (BASES, 2002; Deschenes & Kraemer, 2002; Singh, 2002). Singh (2002) reported improvements of 20.0 to 40.0% in strength during the first few weeks of training without a significant improvement in muscle size. After 4 to 6 weeks of resistance training significant muscle fibre hypertrophy becomes evident (Deschenes & Kraemer, 2002). A study on prepubertal boys undergoing 10 weeks of training indicated increased motor unit activation of the elbow flexors by 9.0% and knee extensors of 12.0% (Benjamin & Glow, 2003).

During the initial testing, in order to avoid pain, subjects may not have given a maximal attempt which would truly reflect their strength. This fact coupled with improvements in the neuromuscular system and decreased inhibition would have accounted for the reasonably large improvement in muscle strength over a short time period. The above studies refer predominantly to adult improvements, which would be slightly different to values for adolescents. Due to the special circumstances of the strength test, actual values cannot be compared, but percentage improvement in strength can be compared. The rehabilitation programme nonetheless resulted in significant improvement in muscle strength values.

4.2 Muscle flexibility

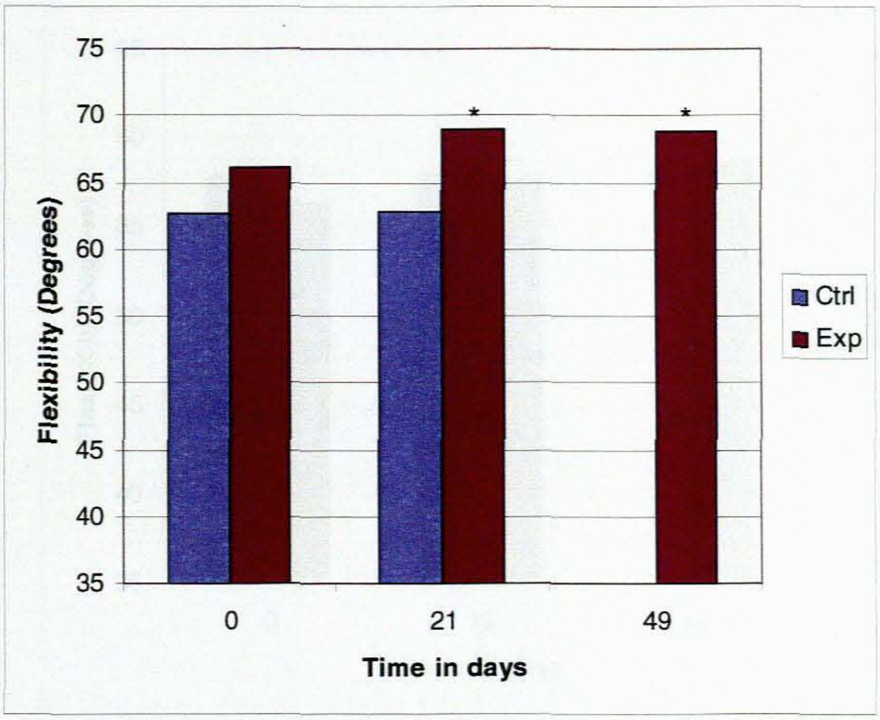
Table 14: Baseline mean muscle flexibility values and percentage difference of the control (N=12) and experimental (N=18) groups

Side	Group		Quads pre (°)	Hams pre (°)	Gastroc pre (°)
Right	Control	Mean	65.9	57.4	67.8
		SD	9.6	7.7	4.8
	Experimental	Mean	68.2	57.7	66.7
		SD	12.1	8.3	3.8
	Difference (%)		3.5	0.5	-1.6
Left	Control	Mean	62.6	58.0	69.6
		SD	10.3	5.5	6.2
	Experimental	Mean	66.1	56.5	66.8
		SD	10.8	8.0	6.0
	Difference (%)		5.6	-2.6	-4.0



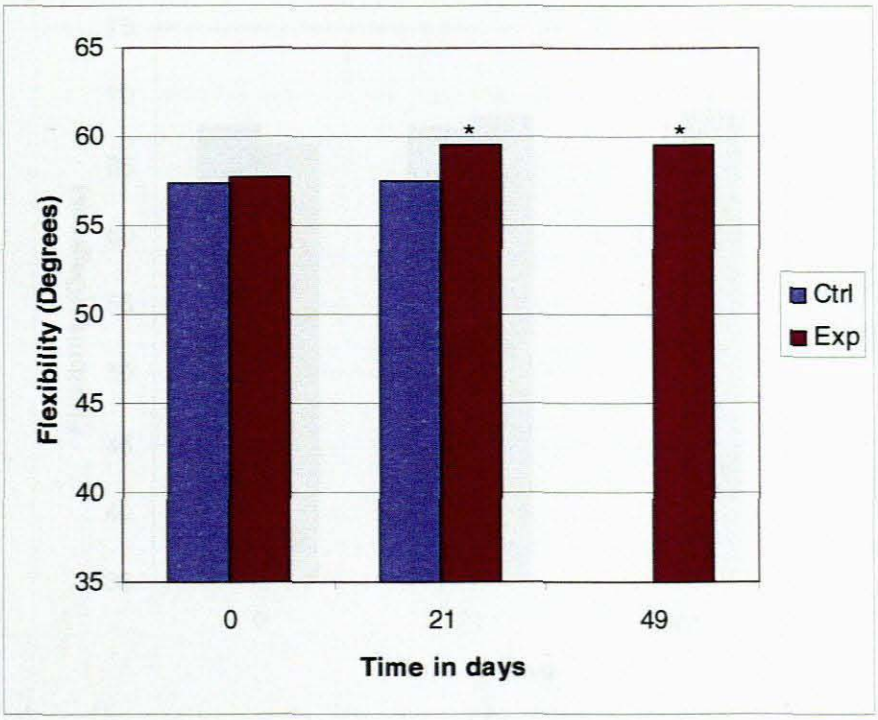
(*= p < 0.01)

Figure 17: Mean values of right quadriceps flexibility of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing



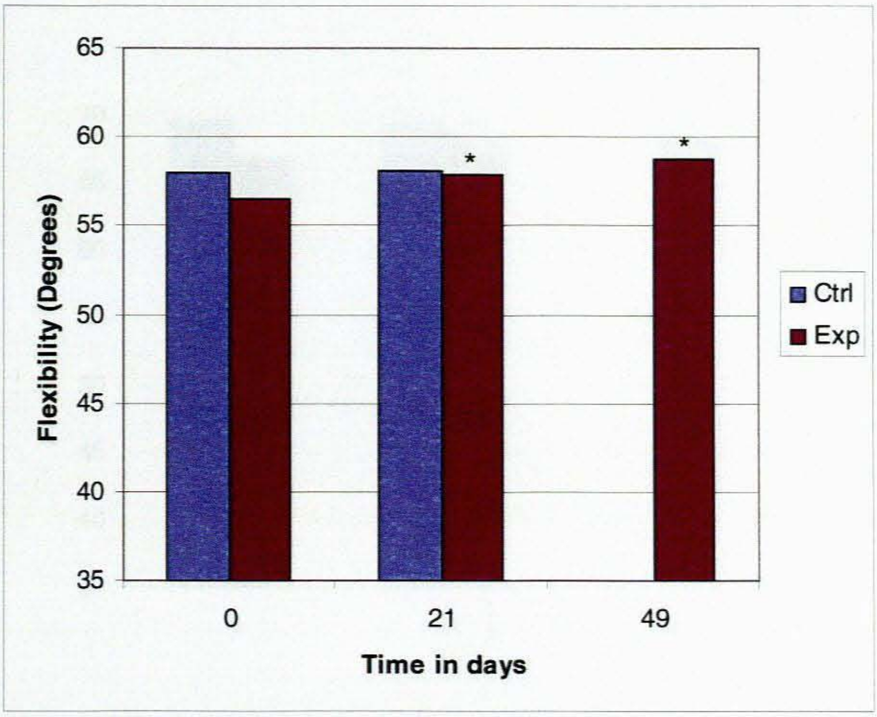
(*= p < 0.01)

Figure 18: Mean values of left quadriceps flexibility of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing



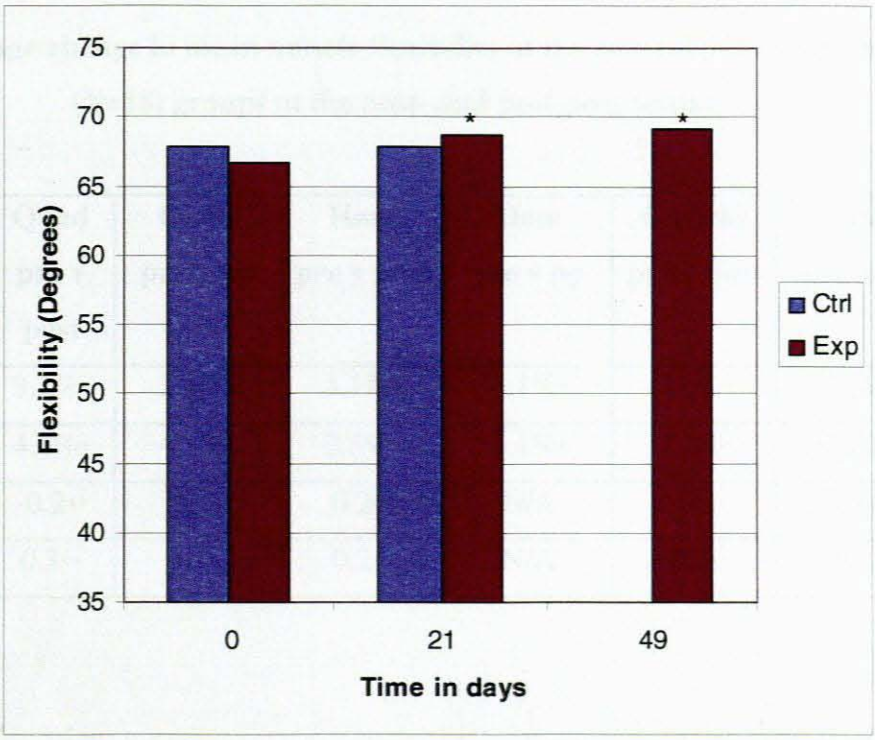
(*= p < 0.01)

Figure 19: Mean values of right hamstring flexibility of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing



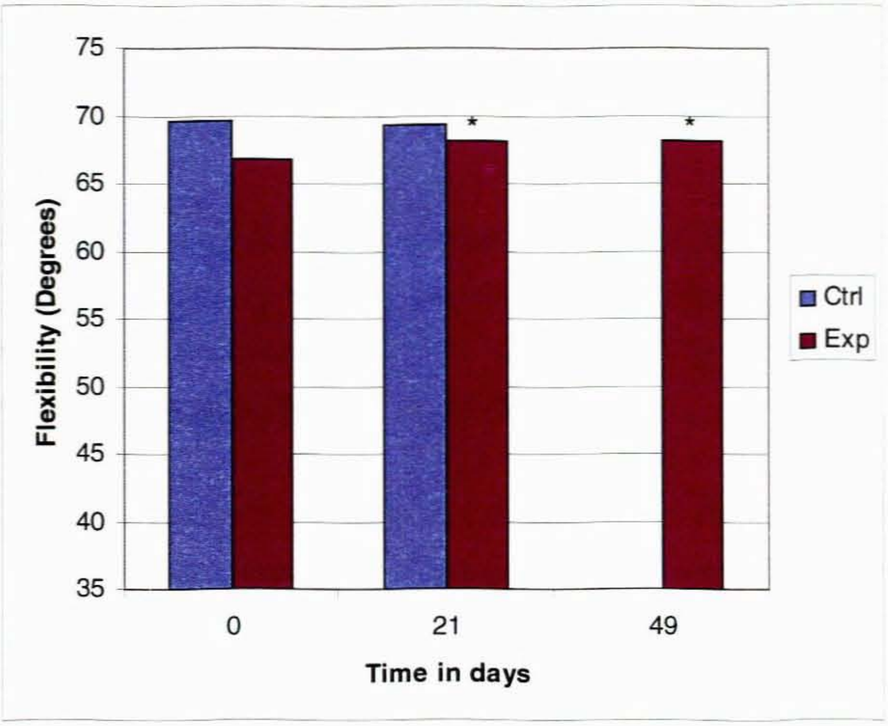
(*= p < 0.01)

Figure 20: Mean values of left hamstring flexibility of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing



(*= p < 0.01)

Figure 21: Mean values of right gastrocnemius flexibility of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing



(*= p < 0.01)

Figure 22: Mean values of left gastrocnemius flexibility of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing

Table 15: Percentage change in mean muscle flexibility of the control (N=12) and experimental (N=18) groups at the post- and post-post testing

Group	Side	Quad pre v post	Quad pre v pp	Ham pre v post	Ham pre v pp	Gastroc pre v post	Gastroc pre v pp
Exp	Right	3.7%*	3.4%*	3.1%*	3.1%*	3.0%*	3.7%*
	Left	4.4%*	4.1%*	2.5%*	4.1%*	2.2%*	2.2%*
Control	Right	-0.2**	N/A	0.2**	N/A	0**	N/A
	Left	0.3**	N/A	0.2**	N/A	-0.3**	N/A

(*= p < 0.01)

(**= p>0.01)

There was a small but significant improvement in quadriceps, hamstring and gastrocnemius flexibility of the experimental group at the post- and post-post testing (p<0.01). There was no significant change in the control group ($p>0.01$). Stretching formed part of the home programme which was done without supervision, concurrently with the intervention programme, thus the small change was expected.

Stretching improves joint range of motion and is necessary for successful physical performance (Arnheim & Prentice, 2000). Adequate muscle flexibility allows the muscle tissue to accommodate additional stress associated with physical activity more easily and allows efficient and effective movement (Bandy et al., 1998).

Improvement in muscle flexibility was between 2.2 and 4.4% for the different muscle groups. The actual values for the quadriceps are much greater than those reported by Harvey (1998) for adult sportspeople. This may be due to the fact that female adolescents go through a period of increased flexibility during puberty. The opposite is true for adolescent males, but they made up a small portion of the study (Chandy & Grana, 1985; Kibler & Chandler, 2003). The hamstring flexibility values are lower than those reported for junior athletes which were between 76.0 and 80.0° (Chandler et al., 1990). This is most likely as junior athletes follow a regular complete stretching programme for any number of months or years, while these subjects only stretched for a few weeks.

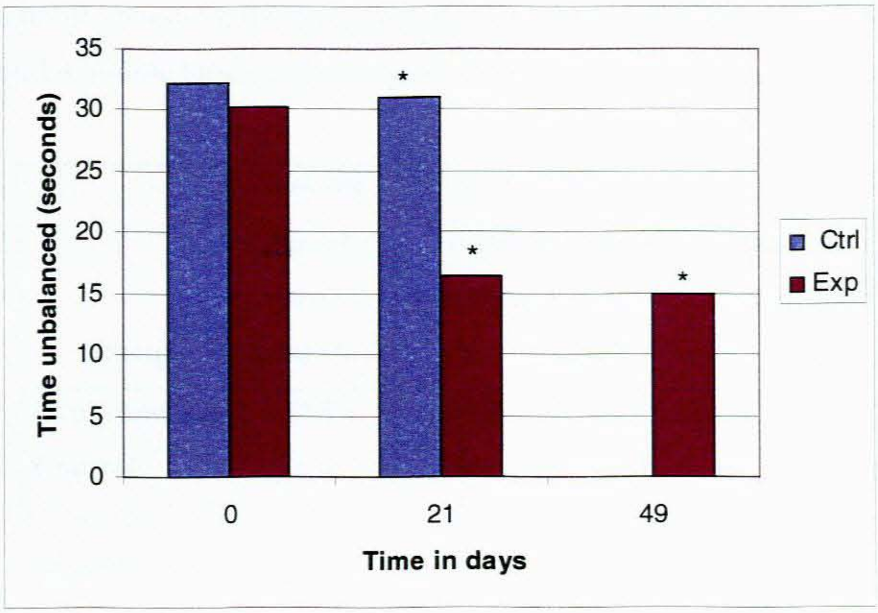
Piva (2005) reported the following improvements in flexibility in adults after 3 months: Quadriceps: 2.3%; Hamstrings: 3.7%; Gastrocnemius: 1.9%. Bandy et al. (1998) reported an 11.0% improvement in hamstring flexibility after 6 weeks of static stretching. Witvrouw et al. (2000) reported improvements of between 5.1% and 8.8% for quadriceps, hamstrings and gastrocnemius at 5 weeks post-testing and between 6.7% and 18.8% at 3 months post-post testing. Studies report varying changes in muscle flexibility in children of between 5.0 and 12.0% (BASES, 2002). Kibler and Chandler (2003) concur. Their findings in junior tennis players indicated an average 7.3% improvement in hamstring flexibility at 1 year follow up with subjects following the stretching programme twice per week. Bandy et al. (1998) reported greater increases after 6 weeks of varying protocols for static hamstring stretching, in the range of 23.8 to 26.9%. These improvements in flexibility are dynamic and reversible, and therefore the exercises need to be continued over an extended period of time to maintain the gains (Kibler & Chandler, 2003).

None of the studies available were run for as short a time period as the current study, but the results do appear to follow the trend evident in the literature. Thus, as there was no change in the control group, it can be stated that the rehabilitation programme resulted in improved flexibility of the quadriceps, hamstrings and gastrocnemius muscle groups. These improvements were maintained or improved further at the 1 month follow up.

4.3 Measures of Proprioception, Dynamic Balance and Static Balance

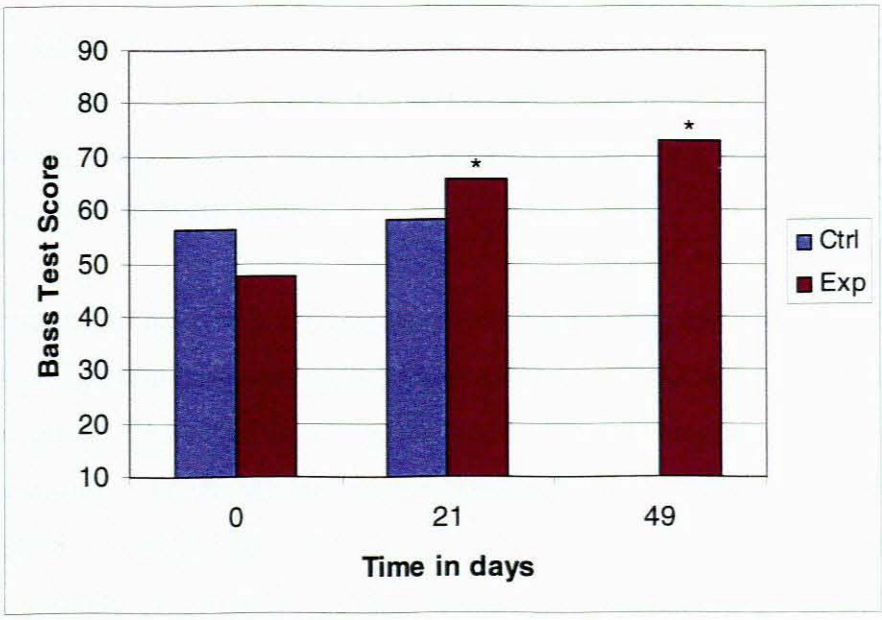
Table 16: Baseline values of proprioception as measured on the Willknox Wobbleboard, dynamic balance as measured using the Bass Test (Bosco & Gustafson, 1983), and static balance as measured with the Stork Stand (Bosco & Gustafson, 1983) of the control (N=12) and experimental (N=18) groups and the percentage difference between the groups

		Wobble board (sec)	Bass test	Stork stand R (sec)	Stork stand L (sec)
Control	Mean	32.2	56.4	10.7	7.2
	SD	13.4	15.1	6.5	4.0
Experimental	Mean	30.3	47.7	9.5	6.3
	SD	13.5	17.1	7.0	3.6
Difference (%)		-5.9	-15.4	-11.2	-12.5



(*= p < 0.01)

Figure 23: Mean wobbleboard scores of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing, as measured by recording time in seconds unbalanced on the Willknox Wobbleboard



(*= p < 0.01)

Figure 24: Mean Bass Test scores of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing as measured by the Bass Test (Bosco & Gustafson, 1983)

Table 17: Percentage change in the performance of activities of proprioception (wobbleboard) and dynamic balance (Bass Test) at the post- and post-post testing

Group	Wobble board pre v post (%)	Wobble board pre v pp (%)	Bass test pre v post (%)	Bass test pre v pp (%)
Experimental	-45.9 *	-50.8*	37.5 *	53.2*
Control	-3.4*	N/A	3.4**	N/A

(* = p<0.01)

(**= p>0.01)

There was a large significant improvement in both proprioception and dynamic balance of the experimental group at the post- and post-post testing (p<0.01). While there was an overall improvement in performance of the Stork Stand at the post- and post-post testing, it was not significant (p>0.01). There was no significant change in the bass test and stork stand in the control group (p>0.01), but there was a very small significant change in the wobbleboard scores (p<0.01). The improvement in the control group was much smaller than that seen in the experimental group. This improvement in wobbleboard scores after just one session is seen in practice, where the time spent unbalanced improves with every session. A degree of learning must thus occur with every session.

The programme did not result in improved static balance as measured by the Stork Stand. This may be as greater emphasis was placed on proprioception and dynamic stability in the form of wobbleboard training as well as trampoline and functional jumping exercises in the supervised contact sessions. There are no norms available for wobbleboard scores. This is as proprioception is traditionally tested using equipment that measures the threshold to detection of passive motion, passive and active limb repositioning and visual estimation of a passive angle change (Lephart et al., 1998; Fuchs et al., 1999; Rozzi et al., 1999; Sharma, 1999; Arnheim & Prentice, 2000; Roberts et al., 2000; Hiemstra et al., 2001; Williams et al., 2001). These tests were not considered to give meaningful results within the spectrum of dynamic knee function as was the focus of this study. The noteworthy improvement in proprioception and dynamic balance is indicative of improved stability of the knee joint complex. These components are important for pain-free sport participation and the execution of activities of daily living. It is interesting to note that both these factors improved to an even greater extent at the post-post testing. This may be due to the fact that once the pain is reduced, subjects are able to return to sporting activities fully which further improves function.

It can thus be reasonably assumed that the rehabilitation programme resulted in improved proprioception, as measured on a wobbleboard, and dynamic stability, and continued improvement at the follow up testing.

There was 100% subject compliance with respect to the intervention programme and post-testing. Unfortunately there was a small drop-out of 16.7% of subjects in the experimental group who did not participate in the post-post test. This high compliancy is probably due to the fairly rapid results attained and the short duration of the intervention programme.

CHAPTER 5: CONCLUSION

The general hypothesis of this study, that a Biokinetics rehabilitation programme alleviates anterior knee pain in adolescents, can be accepted. The programme resulted in significantly reduced subjective ratings of pain and disability. There was an improvement in condition following completion of the programme. This improvement in condition can be attributed to the increase in strength, flexibility, proprioception and dynamic balance components tested. These variables improved as a consequence of the Biokinetics rehabilitation programme. Furthermore, the improvements were long-term effects.

There was a significant improvement in worst, least and normal pain ratings of the experimental group at the post-testing, and this was maintained at the post-post testing ($p<0.01$). The decrease in pain was in the range of 35.3 – 43.0% at the post- and post-post testing in comparison with the initial pain ratings. There was no significant change in the control group, however the worst and least pain did increase at the post-test ($p>0.01$). There was a significant improvement in the ability to perform activities indicated by individual subjects on the Patient-Specific Functional Scale ($p<0.01$). No such change occurred in the control group ($p>0.01$). On completion of the intervention programme subjects reported a greatly improved ability to perform the particular activities that they were previously experiencing difficulty with due to their knee pain. This reduced disability was maintained at the post-post testing ($p<0.01$). Thus, it would appear that participation in the intervention programme resulted in decreased pain and disability due to anterior knee pain, which was maintained in the long-term.

The control group indicated that there was either no change in their condition or that the condition was worse at the post-test. Thus, it is clear that the control group experienced the same or worse pain over the period. All subjects in the experimental group indicated improvement in their condition at the post-test. Most of the group reported that their condition was at least as good or better at the post-post test compared with the post-test. A small percentage indicated that their condition had deteriorated since the post-test, but was still much better than at the pre-test. This supports the continuation of the home programme on completion of the programme so as to maintain the benefits accrued during the rehabilitation process.

There was a significant gain in muscle strength in both the quadriceps and hamstring muscle groups at the post- and post-post testing of the experimental group ($p<0.01$). The percentage increase ranged between 9.0 and 17.5%. There was no significant change in the control group ($p>0.01$). The right quadriceps and hamstring muscle groups were stronger for both the control and experimental groups. This reflects right-sided dominance as 11 out of 12 and 16 out of 18 subjects in the control and experimental groups respectively indicated that they were right-footed.

There was a small but significant improvement in quadriceps, hamstring and gastrocnemius flexibility of the experimental group at the post- and post-post testing ($p<0.01$). There was no significant change in the control group ($p>0.01$). Improvement in muscle flexibility was between 2.2 and 4.4% for the different muscle groups. These improvements were maintained or improved further at the 1 month follow up.

There was a large significant improvement in both proprioception and dynamic balance of the experimental group at the post- and post-post testing ($p<0.01$). While there was an overall improvement in performance of the Stork Stand at the post-and post-post testing, it was not significant ($p>0.01$). There was no significant change in the Bass Test and stork stand in the control group ($p>0.01$), but there was a very small significant change in the wobbleboard scores ($p<0.01$). The improvement in the control group was much smaller than that seen in the experimental group. This improvement in wobbleboard scores after just one session is seen in practice, where the time spent unbalanced improves with every session. A degree of learning must thus occur with every session. The noteworthy improvement in proprioception and dynamic balance is indicative of improved stability of the knee joint complex. These components are important for pain-free sport participation and the execution of activities of daily living. Both these factors improved to an even greater extent at the post-post testing. This may be due to the fact that once the pain is reduced, subjects are able to return to sporting activities fully which further improves function. It can thus be reasonably assumed that the rehabilitation programme resulted in improved proprioception as measured on a wobbleboard, and dynamic stability, and continued improvement at the follow up testing.

Results from the questionnaires indicate that 27.4% of children in the study had experienced non-traumatic anterior knee pain at some time between the ages of 10 and 17 years. Of this group, 42.9% was male, 57.1% was female. In the experimental group, 5 subjects were male while 13 subjects were female. Thus, it seems that this study concurs with the literature, and that anterior knee pain is more prevalent among adolescent females than males.

According to the questionnaire results, a greater percentage of respondents with anterior knee pain than those without were physically active 3 times per week or more. 42.9% of the affected group participated in physical activity at least 3 times per week, compared with only 28.9% of the non-affected group. Thus, adolescents who are more physically active appear to be more affected by anterior knee pain.

No subjects withdrew from the study during the intervention programme. The high rate of improvement in pain and disability, and relatively short duration most likely account for this. Thus, it can be concluded that conservative treatment in the form of stretching, strengthening, proprioceptive and dynamic balance training, is a beneficial strategy for this common and often debilitating condition. In the context of South African health care, a structured biokinetics rehabilitation programme based on sound clinical and scientific principles has the potential to endear positive outcomes in the treatment of anterior knee pain.

REFERENCES

ANTICH, T.J. & BREWSTER, C.E. (1986). Modification of quadriceps femoris muscle exercises during knee rehabilitation. *Physical Therapy*, 66(8):1246-1251

ARNHEIM, D.D. & PRENTICE, W.E. (2000). *Principles of athletic training (10th ed.)*. Boston: McGraw-Hill.

ARNO, S. (1990). The A Angle: a quantitative measurement of patella alignment and realignment. *The Journal of Orthopaedic and Sports Physical Therapy*, 12(6):237-242

BANDY, W.D.; IRION, J.M. & BRIGGLER, M. (1998). The effect of static stretch and dynamic range of motion training on the flexibility of the hamstring muscles. *The Journal of Orthopaedic and Sports Physical Therapy*, 27(4):295-300

BARRETT, D.S. (1991). Proprioception and function after anterior cruciate ligament reconstruction. *Journal of Bone and Joint Surgery (Br)*, 73:833-837

BENJAMIN, H.J., & GLOW, K.M. (2003). Strength training for children and adolescents: what can physicians recommend? *The Physician and Sports Medicine*, 31: 19

BENNETT, J.G. & STAUBER, W.T. (1986). Evaluation and treatment of anterior knee pain using eccentric exercise. *Medicine and Science in Sports and Exercise*, 18:526-530

BIEDERT, R.M.; STAUFFER, E. & FRIEDERICH, N.F. (1992). Occurrence of free nerve endings in the soft tissue of the knee joint: A histologic investigation. *The American Journal of Sports Medicine*, 20(4):430-433

BIZZINI, M.; CHILDS, J.D.; PIVA, S.R. & DELITTO, A. (2003). Systematic review of the quality of randomized controlled trials for patellofemoral pain syndrome. *The Journal of Orthopaedic and Sports Physical Therapy*, 33(1):4-20

BORSA, P.A.; LEPHART, S.M.; IRRGANG, J.J; SAFRAN, M.R. & FU, F.H. (1997). The effects of joint position and direction of joint motion on proprioceptive sensibility in anterior cruciate ligament-deficient athletes. *The American Journal of Sports Medicine,* 25(3):336-340

BOSCO, J.S. & GUSTAFSON, W.F. (1983). *Measurement and evaluation in physical education, fitness, and sports.* New Jersey: Prentice-Hall

BRITISH ASSOCIATION OF SPORT AND EXERCISE SCIENCES (BASES) (2002). *Guidelines for Resistance Exercise in Young People.* Liverpool: REACH Group

BRODY, L.T. & THEIN, J.M. (1998). Nonoperative treatment for patellofemoral pain. *The Journal of Orthopaedic and Sports Physical Therapy,* 28(5):336-344

BRUKNER, P. & KHAN, K. (2002). *Clinical Sports Medicine (Revised 2nd ed.).* Sydney: McGraw-Hills Co. Inc.

CALMBACH, W.L. & HUTCHENS, M. (2003). Evaluation of patients presenting with knee pain: Part II. Differential Diagnosis. *American Family Physician,* 68(5):907-912

CARSON, W.G.; JAMES, S.L.; LARSON, R.L.; SINGER, K.M. & WINTERNITZ, W.W. (1984). Patellofemoral disorders: Physical and radiographic evaluation. Part 1: Physical examination. *Clinical Orthopaedics and Related Research,* 185:165-177

CAYLOR, D.; FRITES, R. & WORRELL, T.W. (1993). The relationship between quadriceps angle and anterior knee pain syndrome. *The Journal of Orthopaedic and Sports Physical Therapy,* 17(1):11-16

CESARELLI, M.; BIFULCO, P. & BRACALE, M. (1999). Quadriceps muscles activation in anterior knee pain during isokinetic exercise. *Medical Engineering and Physics,* 21:469-478

CHANDLER, T.J.; KIBLER, W.B.; UHL, T.L.; WOOTEN, B.; KISER, A. & STONE, E. (1990). Flexibility comparisons of junior elite tennis players to other athletes. *The American Journal of Sports*

Medicine, 18(2):134-136

CHANDY, T.A. & GRANA, W.A. (1985). Secondary school athletic injury in boys and girls: A three year comparison. *The Physician and Sports Medicine*, 13(3):106-111

CHATMAN, A.B.; HYAMS, S.P.; NEEL, J.M.; BINKLEY, J.M.; STRATFORD, P.W.; SCHOMBERG, A. & STABLER, M. (1997). The Patient-Specific Functional Scale: Measurement properties in patients with knee dysfunction. *Physical Therapy,* 77(8):820-829

CLARK, D.I.; DOWNING, N.; MITCHELL, J.; COULSON, L.; SYZPRYT, E.P. & DOHERTY, M. (2000). Physiotherapy for anterior knee pain: a randomised controlled trial. *Annals of the Rheumatic Diseases*, 59:700-704

COLAK, S.; DJURDJEVIC, S. & RUDNJANIN, S. (1998). Isokinetic muscular training of pilots of combat aviation. *Physical Education,* 1(5):29-32

COWAN, S.M.; BENNELL, K.L.; CROSSLEY, K.M.; HODGES, P.W. & McCONNELL, J. (2002). Physical therapy alters recruitment of the vasti in patellofemoral pain syndrome. *Medicine & Science in Sports & Exercise*, 34(12):1879-1885

CROSSLEY, K.; BENNELL, K.; GREEN, S.; COWAN, S. & McCONNELL, J. (2002). Physical therapy for patellofemoral pain: A randomized, double-blinded, placebo-controlled trial. *The American Journal of Sports Medicine*, 30(6): 857-865

CROSSLEY, K.; COWAN, S.; McCONNELL, J. & BENNELL, K. (2005). Physical therapy improves knee flexion during stair ambulation in patellofemoral pain. *Medicine and Science in Sports and Exercise*, 37(2):176-183

CUTBILL, J.W.; LADLY, K.O.; BRAY, R.C.; THORNE, P. & VERHOEF, M. (1997). Anterior knee pain: A review. *Clinical Journal of Sports Medicine*, 7:40-45

DeHAVEN, K.E.; DOLAN, W.A. & MAYER, P.J. (1979). Chondromalacia patellae in athletes. *American Journal of Sports Medicine*, 7:5-11

DESCHENES, M.R. & KRAEMER, W.J. (2002). Performance and physiologic adaptations to resistance training. *American Journal of Physical Medicine and Rehabilitation*, 81(Suppl):S3-S16

DIFIORI, J.P. (1999). Overuse injuries in children and adolescents. *The Physician and Sports Medicine*, 27(1):75-89

DOUCETTE, S.A. & GOBLE, E.M. (1992). The effect of exercise on patellar tracking in lateral patellar compression syndrome. *American Journal of Sports Medicine,* 20: 434-440

DUGAN, S.A. (2005). Sports-related knee injuries in female athletes. What gives? *American Journal of Physical Medicine and Rehabilitation,* 84(2):122-129

DYE, S.F. (1996). The knee as a biologic transmission with an envelope of function: A theory. *Clinical Orthopaedics and Related Research*, 323: 10-18

DYE, S.F. (2004). Patello-femoral pain: A mosaic of pathophysiology. *SA Orthopaedic Journal*, 3(4):30-38

ERASMUS, P.J. (2004). Patello-femoral biomechanics. *SA Orthopaedic Journal*, 3(4):12-15

FAIRBANK, J.C.; PYNSENT, P.B. & PHILLIPS, H. (1984). Quantitative measurements of joint mobility in adolescents. *Annals of the Rheumatic Diseases*, 43:288-294

FUCHS, S.; THORWESTERN, L. & NIEWERTH, S. (1999). Proprioceptive function in knees with and without total knee arthroplasty. *American Journal of Physical Medicine and Rehabilitation,* 78(1):39-45

GALANTY, H.L.; MATTHEWS, C. & HERGENROEDER, A.C. (1994). Anterior knee pain in adolescents. *Clinical Journal of Sports Medicine*, 4:176-181

GORE, J.C. (2000). *Physiological Tests for Elite Athletes*. Champaign: Human Kinetics

HANTEN, W.P. & SCHULTHIES, S.S. (1990). Exercise effect on electromyographic activity of the vastus medialis oblique and vastus lateralis muscles. *Physical Therapy*, 70(9):561-565

HARRISON, E.; QUINNEY, H.; MAGEE, D.; SHEPPARD, M.S. & McQUARRIE, A. (1995). Analysis of outcome measures used in the study of patellofemoral pain syndrome. *Physiotherapy Canada*, 47(4):264-272

HARVEY, D. (1998). Assessment of the flexibility of elite athletes using the modified Thomas test. *British Journal of Sports Medicine*, 32:68-70

HENG, R.C. & HAW, C.S. (1996). Patello-femoral pain syndrome: Diagnosis and management from an anatomical and biomechanical perspective. *Current Orthopaedics*, 10:256-266

HIEMSTRA, L.A.; LO, I.K. & FOWLER, P.J. (2001). Effects of fatigue on knee proprioception: Implications for dynamic stabilization. *The Journal of Orthopaedic and Sports Physical Therapy*, 31(10):598-605

HIGGINS, S. (1991). Motor skill acquisition. *Physical Therapy*, 71(2):123-139

HILYARD, A. (1990). Recent advances in the management of patellofemoral pain: the McConnell programme. *Physiotherapy*, 76:559-565

HOLMES, S.W. & CLANCY, W.G. (1998). Clinical classification of patellofemoral pain and dysfunction. *The Journal of Orthopaedic and Sports Physical Therapy*, 28(5):299-306

HUSTON, L.J. & WOJTYS, E.M. (1996). Neuromuscular performance characteristics in elite female athletes. *The American Journal of Sports Medicine*, 24(4):427-436

INGERSOLL, C.D. & KNIGHT, K.L. (1991). Patellar location changes following EMG biofeedback or progressive resistive exercises. *Medicine and Science in Sports and Exercise*, 23:1122-1127

JACKSON, A.M. (1994). Mini-symposium: Lower limb problems in children. *Current Orthopaedics*, 8:83-93

JACOBSON, K.E. & FLANDRY, F.C. (1989). Diagnosis of anterior knee pain. *Clinics in Sports Medicine*, 8:179-195

JOHNSON, R.P. (1997). Anterior knee pain in adolescents and young adults. *Current Opinion in Rheumatology*, 9:159-164

JOLLES, B.M.; BUCHBINDER, R. & BEATON, D.E. (2005). A study compared nine patient-specific indices for musculoskeletal disorders. *Journal of Clinical Epidemiology*, 58: 791-801

JUHN, M.S. (1999). Patellofemoral pain syndrome: A review and guidelines for treatment. *American Family Physician*, 60(7):2012-2022

KAKARLAPUDI, T.K. & BICKERSTAFF, D.R. (2000). Knee instability: isolated and complex. *British Journal of Sports Medicine*, 34: 395-400

KANE, R.L.; BERSHADSKY, B.; ROCKWOOD, T.; SALEH, K. & ISLAM, N.C. (2005). Visual analog scale reporting was standardized. *Journal of Clinical Epidemiology*, 58: 618-623

KANNUS, P. & NIITTYMAKI, S. (1994). Which factors predict outcome in non-operative treatment of patellofemoral pain syndrome? A prospective follow-up study. *Medicine and Science in Sports and Exercise*, 26:289-296

KARLSSON, J.; THOMEE, R. & SWARD, L. (1996). Eleven year follow-up of patello-femoral pain syndrome. *Clinical Journal of Sports Medicine*, 6:22-26

KARST, G.M. & JEWETT, P.D. (1993). Electromyographic analysis of exercises proposed for differential activation of medial and lateral quadriceps femoris muscle components. *Physical Therapy*, 73(5):286-295

KARST, G.M. & WILLETT, G.M. (1995). Onset timing of electromyographic activity in the vastus medialis oblique and vastus lateralis muscles in subjects with and without patellofemoral pain. *Physical Therapy*, 75:813-823

KENDALL, F.P.; McCREARY, E.K. & PROVANCE, P.G. (1993). *Muscles: Testing and Function (4th ed.)*. Baltimore: Williams & Wilkins

KENNEDY, J.C.; ALEXANDER, I.J. & HAYES, K.C. (1982). Nerve supply of the human knee and its functional importance. *The American Journal of Sports Medicine*, 10(6):329-335

KIBLER, W.B. & CHANDLER, T.J. (2003). Range of motion in junior tennis players participating in an injury risk modification program. *Journal of Science and Medicine in Sport*, 6(1):51-62

LARSON, R.L. & GRANA, W.A. (1993). *The Knee: Form, Function, Pathology & Treatment*. Philadelphia: W.B. Saunders Co.

LASKOWSKI, E.R.; NEWCOMER-ANEY, K. & SMITH, J. (2000). Proprioception. *Physical Medicine and Rehabilitation Clinics of North America*, 11(2):323-340

LATTANZIO, P.J.; PETRELLA, R.J.; SPROULE, J.R. & FOWLER, P.J. (1997). Effects of fatigue on knee proprioception. *Clinical Journal of Sport Medicine*, 7:22-27

LEPHART, S.M. & HENRY, T.J. (1995). Functional rehabilitation for the upper and lower extremity. *The Orthopedic Clinics of North America*, 26(3):579-592

LEPHART, S.M.; PINCIVERO, D.M. & ROZZI, S.L. (1998). Proprioception of the ankle and knee. *Sports Medicine*, 25(3):149-155

LEPHART, S.M.; PINCIVERO, D.M.; GIRALDO, J.L. & FU, F.H. (1997). The role of proprioception in the management and rehabilitation of athletic injuries. *The American Journal of Sports Medicine*, 25(1):130-137

LICHOTA, D.K. (2003). Anterior knee pain: symptom or syndrome? *Current Women's Health Reports,* 3:81-86

LIEB, F.J. & PERRY, J. (1968). Quadriceps Function. An anatomical and mechanical study using amputated limbs. *Journal of Bone and Joint Surgery,* 50A:1535-1548

LIVINGSTON, L.A. & MANDIGO, J.L. (1998). Bilateral Q angle asymmetry and anterior knee pain syndrome. *Clinical Biomechanics,* 14:7-13

MAITLAND, M.E.; LOWE, R.; STEWART, S.; FUNG, T. & BELL, G.D. (1993). Does Cybex testing increase knee laxity after anterior cruciate ligament reconstructions? *The American Journal of Sports Medicine,* 21(5):690-695

MALEK, M.M. & MANGINE, R.E. (1981). Patellofemoral pain syndromes: a comprehensive and conservative approach. *The Journal of Orthopaedic and Sports Physical Therapy,* 2(3):108-116

MANAL, T.J. & SNYDER-MACKLER, L. (2000). Failure of voluntary activation of the quadriceps femoris muscle after patellar contusion. *Journal of Orthopaedic & Sports Physical Therapy,* 30(11):654-663

MARX, R.G.; STUMP, T.J.; JONES, E.C.; WICKIEWICZ, T.L. & WARREN, R.F. (2001). Development and evaluation of an activity rating scale for disorders of the knee. *The American Journal of Sports Medicine,* 29(2):213-218

McCONNELL, J. (1993). Commentary. *Physical Therapy,* 73(5):295-297

McCONNELL, J. (1996). Management of patellofemoral problems. *Manipulation Therapy,* 1:60-66

McMULLEN, W.; RONCARATI, A. & KOVAL, P. (1990). Static and isokinetic treatments of chondromalacia patellae: a comparative investigation. *The Journal of Orthopaedic and Sports Physical Therapy,* 12:256-266

NATRI, A.; KANNUS, P. & JARVINEN, M. (1998). Which factors predict the long-term outcome in chronic patellofemoral pain syndrome? A 7-year prospective follow-up study. *Medicine and Science in Sports and Exercise*, 30:1572-1577

NIMON, G.; MURRAY, D.; SANDOW, M. & GOODFELLOW, J. (1998). Natural history of anterior knee pain: A 14- to 20-year follow-up of non-operative management. *Journal of Pediatric Orthopedics*, 18(1):118-122

NYLAND, J.; BROSKY, T.; CURRIER, D.; NITZ, A. & CABORN, D. (1994). Review of the afferent neural system of the knee and its contribution to motor learning. *The Journal of Orthopaedic and Sports Physical Therapy*, 19(1):2-11

O' NEILL, D.B.; MICHELI, L.J. & WARNER, J.P. (1992). Patellofemoral stress: a prospective analysis of exercise treatment in adolescents and adults. *The American Journal of Sports Medicine*, 20(2):151-156

PALMIERI, R.M.; INGERSOLL, C.D.; EDWARDS, J.E.; HOFFMAN, M.A.; STONE, M.B.; BABINGTON, J.P.; CORDOVA, M.L. & KRAUSE, B.A. (2003). Arthrogenic muscle inhibition is not present in the limb contralateral to a simulated knee joint effusion. *American Journal of Physical Medicine & Rehabilitation*, 82(12):910-916

PATEL, D.R. & NELSON, T.L. (2000). Sports injuries in adolescents. *Medical Clinics of North America*, 84(4):983-1005

PIETROBAN, R.; COEYTAUX, R.R.; CAREY, T.S.; RICHARDSON, W.J. & DeVELLIS, R.F. (2002). Standard scales for measurement of functional outcome for cervical pain or dysfunction: A systematic review. *Spine*, 27(5): 515-522

PIVA, S.R. (2005). Association between impairments and function in individuals with patellofemoral syndrome. Unpublished PhD dissertation. Pittsburgh: University of Pittsburgh

POLLOCK, D. (2004). Clinical examination of the patello-femoral joint. *SA Orthopaedic Journal*, 3(4):8-10

POST, W.R. (1998). Patellofemoral pain: Let the physical exam define the treatment. *The Physician and Sports Medicine*, 26(1):68-79

POWERS, C.M. (1998). Rehabilitation of patellofemoral joint disorders: a critical review. *Journal of Orthopaedic and Sports Physical Therapy*, 28(5):345-354

POWERS, C.M.; LANDEL, R. & PERRY, J. (1996). Timing and intensity of vastus muscle activity during functional activities in subjects with and without patellofemoral pain. *Physical Therapy*, 76(9):946-967

PRICE, A. & JONES, J.J. (2000). Chronic traumatic anterior knee pain. *Injury*, 31(5):373-378

PRICE, D.J. (1987). Anterior knee pain in athletes. *Medical News Tribune*, 4(20):24-26

REID, D.C. (1993). The myth, mystic and frustration of anterior knee pain. *Clinical Journal of Sports Medicine*, 3:139-143

REIDER, B.; MARSHALL, J.L. & RING, B. (1981a). Patellar tracking. *Clinical Orthopaedics and Related Research*, 157:143-148

REIDER, B.; MARSHALL, J.L. & WARREN, R.F. (1981b). Clinical characteristics of patellar disorders in young athletes. *The American Journal of Sports Medicine*, 9:270

ROBERTS, D.; FRIDEN, T.; STOMBERG, A.; LINDSTRAND, A. & MORITZ, U. (2000). Bilateral proprioceptive defects in patients with a unilateral anterior cruciate ligament reconstruction: A comparison between patients and healthy individuals. *Journal of Orthopaedic Research*, 18(4):565-571

ROGAN, I.M. (1995). Anterior knee pain in the sporting population: Forum. *SA Bone and Joint Surgery*, 5(2):28-30

ROUSH, M.B.; SEVIER, T.L.; WILSON, J.K.; JENKINSON, D.M.; HELFST, R.H.; GEHLSEN, G.M. & BASEY, A.L. (2000). Anterior knee pain: a clinical comparison of rehabilitation methods. *Clinical Journal of Sports Medicine*, 10(1):22-28

ROZZI, S.L.; LEPHART, S.M.; GEAR, W.S. & FU, F.H. (1999). Knee joint laxity and neuromuscular characteristics of male and female soccer and basketball players. *The American Journal of Sports Medicine*, 27(3):312-319

RUFFIN, M.T. & KININGHAM, R.B. (1993). Anterior knee pain: the challenge of patellofemoral syndrome. *American Family Physician*, 47(1):185-194

RUTHERFORD, O.M. (1988). Muscular coordination and strength training. Implications for injury rehabilitation. *Sports Medicine*, 5:196-202

SANDOW, M.J. & GOODFELLOW, J.W. (1985). Natural history of anterior knee pain in adolescents. *Journal of Bone and Joint Surgery*, 67(1):36-38

SEAMAN, D.R. (1997). Proprioceptor: an obsolete, inaccurate word. *Journal of Manipulative and Physiological Therapeutics*, 20(4):279-284

SHARMA, L. (1999). Proprioceptive impairment in knee osteoarthritis. *Rheumatic Disease Clinics of North America*, 25(2):299-314

SHEA, K.G.; PFEIFFER, R. & CURTIN, M. (2003). Idiopathic anterior knee pain in adolescents. *Orthopedic Clinics of North America*, 34(3):377-383

SHELTON, G.L. (1992). Conservative management of patellofemoral dysfunction. *Primary Care*, 19(2):331-350

SHELTON, G.L. & THIGPEN, L.K. (1991). Rehabilitation of patellofemoral dysfunction: a review of literature. *The Journal of Orthopaedic and Sports Physical Therapy*, 14(6):243-249

SINCLAIR, D. (1989). *Human Growth after Birth (5th ed.)*. Oxford: Oxford University Press

SINGH, R. (2002). The importance of exercise as a therapeutic agent. *Malaysian Journal of Medical Sciences*, 9(2):7-16

SMITH, D. & BRUCE-LOW, S. (2004). Strength training methods and the work of Arthur Jones. *Journal of Exercise Physiology*, 7(6):52-68

SNYDER-MACKLER, L.; DE LUCA, P.F.; WILLIAMS, P.R.; EASTLACK, M.M. & BARTOLOZZI, A.R. (1994). Reflex inhibition of the quadriceps femoris muscle after injury or reconstruction of the anterior cruciate ligament. *The Journal of Bone and Joint Surgery*, 76(4):555-560

SOLOMONOW, M. & KROGSGAARD, M. (2001). Sensorimotor control of knee stability. A review. *Scandinavian Journal of Medicine and Science in Sports*, 11(2):64-80

SOUZA, D.R. & GROSS, M.T. (1991). Comparison of vastus medialis obliquus: vastus lateralis muscle integrated electromyographic ratios between healthy subjects and patients with patellofemoral pain. *Physical Therapy*, 71(4):310-320

SPORTS INSTITUTE OF SOUTH AFRICA (SISA)(1998). *Hockey Manual.*

STANITSKI, C.L. (1993). Anterior knee pain syndromes in the adolescent. *Journal of Bone and Joint Surgery*, 75(9):1407-1416

STATHOPULU, E. & BAILDAM, E. (2003). Anterior knee pain: a long-term follow-up. *Rheumatology*, 42(2):380-382

STEINKAMP, L.A.; DILLINGHAM, M.F. & MARKEL, M.D. (1993). Biomechanical considerations in patellofemoral joint rehabilitation. *The American Journal of Sports Medicine*, 21(3):438-444

STIENE, H.A.; BROSKY, T.; REINKING, M.F.; NYLAND, J. & MASON, M.B. (1996). A comparison of closed kinetic chain and isokinetic joint isolation exercise in patients with patellofemoral dysfunction. *The Journal of Orthopaedic and Sports Physical Therapy*, 24(3):136-141

STOKES, M. & YOUNG, A. (1984). Investigation of quadriceps inhibition: Implication for clinical practice. *Physiotherapy*, 70(11):425-428

STRATFORD, P.W.; KENNEDY, D.M. & HANNA, S.E. (2004). Condition-specific Western Ontario McMaster Osteoarthritis Index was not superior to region-specific Lower Extremity Functional Scale in detecting change. *Journal of Clinical Epidemiology*, 57: 1025-1032

TEITZ, C.C. (1997). The female athlete. *Journal of the American Academy of Orthopaedic Surgeons*, 5(2):89-94

THOMEE, R. (1997). A comprehensive treatment approach for patellofemoral pain syndrome in young women. *Physical Therapy*, 77(12):1690-1703

THOMEE, R.; AUGUSTSSON, J. & KARLSSON, J. (1999). Patellofemoral pain syndrome: A review of current issues. *Sports Medicine*, 28(4):245-262

THOMPSON, C.W. & FLOYD, R.T. (1998). *Manual of Structural Kinesiology (13th ed.).* Singapore: McGraw-Hill

TRIA, A.J.; PALUMBO, R.C. & ALICEA, J.A. (1992). Conservative care for patellofemoral care. *Orthopedic Clinics of North America*, 23(4):545-554

WALKER, M.J. (2004). Manual physical therapy examination and intervention of a patient with radial wrist pain: A case report. *Journal of Orthopaedic & Sports Physical Therapy*, 34(12):761-769

WALTERS, J. (2004). A rational approach to the management of patello-femoral malarticulation. *SA Orthopaedic Journal*, 3(4):16-18

WESTAWAY, M.D.; STRATFORD, P.W. & BINKLEY, J.M. (1998). The Patient-Specific Functional Scale: Validation of its use in persons with neck dysfunction. *Journal of Orthopaedic & Sports Physical Therapy*, 27(5): 331-338

WHITELAW, G.P. Jr; RULLO, D.J.; MARKOWITZ, H.D.; MARANDOLA, M.S. & DEWAELE, M.J. (1989). A conservative approach to anterior knee pain. *Clinical Orthopaedics and Related Research*, 246:234-237

WILD, J.J.; FRANKLIN, T.D. & WOODS, G.W. (1982). Patellar pain and quadriceps rehabilitation: an EMG study. *The American Journal of Sports Medicine*, 10(1):12-15

WILK, K.E.; ROMANIELLO, W.T.; SOSCIA, S.M.; ARRIGO, C.A. & ANDREWS, J.R. (1998). The relationship between subjective knee scores, isokinetic testing, and functional testing in the ACL-reconstructed knee. *Journal of Orthopaedic and Sports Physical Therapy*, 20(2):60-73

WILLIAMS, G.N.; CHMIELEWSKI, T.; RUDOLPH, K.S.; BUCHANAN, T.S. & SNYDER-MACKLER, L. (2001). Dynamic knee stability: Current theory and implications for clinicians and scientists. *Journal of Orthopaedic and Sports Physical Therapy*, 31(10):546-566

WILSON, T. (1990). Anterior knee pain: a new technique for examination and treatment. *Physiotherapy*, 76(7):371-376

WINKEL, D.; MATTHIJS, O. & PHELPS, V. (1997). *Diagnosis and Treatment of the Lower Extremities*. Maryland: Aspen Publishers Inc.

WITONSKI, B. (1999). Anterior knee pain syndrome. *International Orthopaedics*, 23:341-344

WITVROUW, E.; LYSENS, R.; BELLEMANS, J.; PEERS, K. & VANDERSTRAETEN, G. (2000). Open versus closed kinetic chain exercises for patellofemoral pain. *The American Journal of Sports Medicine*, 28(5):687-694

WOODALL, W. & WELSH, J. (1990). A biomechanical basis for rehabilitation programs involving the patellofemoral joint. *Journal of Orthopaedic and Sports Physical Therapy,* 11(11):535-542

YOUNG, A. (1993). Current issues in arthrogenous inhibition. *Annals of the Rheumatic Diseases,* 52:829-834

ZAPPALA, F.G.; TAFFEL, C.B. & SCUDERI, G.R. (1992). Rehabilitation of patellofemoral joint disorders. *Orthopedic Clinics of North America,* 23(4):555-566

ZATTERSTROM, R. & FRIDEN, T. (1994). The effect of physiotherapy on standing balance in chroni anterior cruciate ligament insufficiency. *The American Journal of Sports Medicine*, 22(4):531-536

APPENDICES

APPENDIX 1

Knee pain questionnaire completed by scholars between the ages of 10 and 17 years of age

Knee Pain Questionnaire

Name:______________________________ Telephone no.:_______________
Address:____
Date of birth:________________________ Today's date:________________

Please circle the correct answer

Gender:	Male Female
Do you like playing sport?	Yes No
How many times a week do you play sport for at least 30 minutes?	Never 1-3 times 3-5 times 5-7 times More than 7 times
What type of sport do you play?	Hockey Rugby Soccer Tennis Netball Squash Cricket Dancing Athletics Swimming Gymnastics Other:____________________
Have you ever injured any of the following?	Hip Knee Ankle Foot Thigh Lower leg

Please briefly describe the injury/injuries

____

____

____

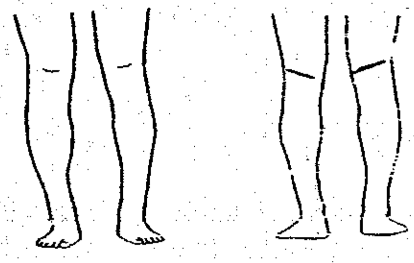
Have you ever had sore knees?	Yes No

If you answered No to the above question, then please hand in the questionnaire.
If you answered Yes to the above question, then please continue.

Which knee is/was sore?	Right Left Both
Please give an approximate date when the pain started	_______________

Where did you feel the pain in your knees?
(Please mark with a **cross** (×) on the diagram)

Front: R L — Back: L R



How long were your knees sore for?

Less than 1 month / 1-3 months / 3-6 months / 6-9 months / 9-12 months / more than 1 year

How often are/were your knees sore?

Often / Sometimes / Hardly ever

How bad is/was the pain?

Severe / Moderate / Mild

Which of these activities make/made your knees sore?

Cold weather / Running / Standing / Walking / Jumping / Kneeling / Sitting / Going downstairs / Going upstairs / Other____________________

Does/Did the knee pain interfere with sport?

Often / Sometimes / Never

Have you got sore knees today?

Yes / No

Have you ever been to the doctor about your knee pain?

Yes / No

When did you go?

____

How many times did you go?

____

Have you ever taken medication for your knee pain?

Often / Sometimes / Never

Have you had any other treatment for your knees?

None / Surgery / Physiotherapy / Biokinetics / Podiatry / Other ____________________

If you have had other treatment, was it successful?

Yes / No / Other____________________

APPENDIX 2

Informed consent and subject assent forms completed by the parents and subjects respectively.

INFORMED CONSENT FORM

I, ______________________________, having been fully informed of the research project entitled *The Role of a Biokinetics Rehabilitation Programme in Alleviating Anterior Knee Pain in Adolescents*, do hereby give consent for my child ________________________ to participate in the aforementioned project.

I have been fully informed of the procedures involved, as well as the potential risks and benefits associated with the study, as explained to me verbally and in writing. In agreeing to my child's participation in this study, I waive any legal recourse against the researchers or the University of Zululand, from any and all claims resulting from personal injuries sustained.

I realise that it is my child's responsibility to promptly report to the researcher any signs or symptoms indicative of an abnormality, pain or distress.

I am aware that part of the programme may involve training without supervision from the researcher, and undertake to ensure my child's compliance.

I am aware that my child can withdraw from participation in the study at any time. I am aware that my child's anonymity will be assured at all times, and agree that the information collected may be used and published for statistical or scientific purposes.

I have read this form, and understand the procedures. I have had an opportunity to ask questions, and these have been answered to my satisfaction.

______________________	____________________	____________
(Parent/Guardian of subject)	Signature	Date
______________________	____________________	____________
Tester	Signature	Date

SUBJECT ASSENT FORM

I, ______________________________, understand that my parent/guardian has given permission for me to participate in the research project entitled *The Role of a Biokinetics Rehabilitation Programme in Alleviating Anterior Knee Pain in Adolescents.*

The procedures involved have been explained to me verbally and in writing. All questions have been answered satisfactorily.

I understand that I must promptly report any signs or symptoms indicating an abnormality, pain or distress to the researcher.

I am taking part of my own free will, and understand that I can withdraw at any time.

______________________________ ________________

Signature Date

______________________________ ________________

Tester Date

APPENDIX 3

Scale to determine subject's level of activity

Activity Rating Scale

Please indicate how often you performed each activity in your healthiest and most active state, in the past year.

	< once a month	Once a month	Once a week	2/3 times a week	4+ times a week
Running: while playing a sport or jogging					
Cutting: changing directions while running					
Decelerating: coming to a quick stop while running					
Pivoting: turning your body with your foot planted while playing a sport (Eg. Kicking, throwing, hitting a ball)					

(Marx et al., 2001)

APPENDIX 4

Patient-Specific Functional Scale

Tester to read and fill in below: Complete at the end of the history and prior to the physical assessment.

Initial assessment:
I am going to ask you to identify up to 3 important activities that you are unable to do or are having difficulty with as a result of your knee pain. Today, are there any activities that you are unable to do or having difficulty with because of your knee pain. (Tester shows scale to subject and has subject rate each activity).

Final assessment:
When I assessed you on ________________ (previous date), you told me you had difficulty with (read all activities from list). Today, do you still have difficulty with: (read and have patient score each item on the list)?

PATIENT-SPECIFIC ACTIVITY SCORING SCHEME (Point to one number)

1 2 3 4 5 6 7 8 9 10

Unable to perform activity

Able to perform activity at same level as before problem

Activity	initial		final
1.			
2.			
3.			
4.			
5.			
Other			

(Chatman et al., 1997)

APPENDIX 5

Visual Analogue Scales for Pain Ratings

Mark the point on the line that best indicates your pain level relative to the pain definers at the end of the line.

Rate your pain at its **worst:**

1 2 3 4 5 6 7 8 9 10

No pain — Pain as severe as it could be

Rate your pain at its **least:**

1 2 3 4 5 6 7 8 9 10

No pain — Pain as severe as it could be

Rate your pain as it is **usually felt:**

1 2 3 4 5 6 7 8 9 10

No pain — Pain as severe as it could be

(Harrison et al., 1995)

APPENDIX 6

Scale for change in condition

1. Significant improvement noted
2. Some improvement noted
3. No improvement noted
4. Condition worse

(Harrison et al., 1995)

APPENDIX 7

Testing proforma

ASSESSMENT FORM

Name: Date:

History:			
Weight:	Height:	Handedness	Hand:
			Foot:

STRUCTURAL	RIGHT	LEFT
Trochanterion – Ext. tib.		
Ext. tib – Lat malleolus		
Foot length		
Q-Angle		
Flexibility		
Hamstring		
Quadriceps		
Abductors		
Gastrocnemius		
Crepitus	None/Slight/ Moderate/ Severe	None/Slight/ Moderate/ Severe
Valgus stress test	None/Slight/ Moderate/ Severe	None/Slight/ Moderate/ Severe
Varus stress test	None/Slight/ Moderate/ Severe	None/Slight/ Moderate/ Severe
Anterior drawer (ACL)	None/Slight/ Moderate/ Severe	None/Slight/ Moderate/ Severe
Genu varum	None/Slight/ Moderate/ Severe	None/Slight/ Moderate/ Severe
Genu valgum	None/Slight/ Moderate/ Severe	None/Slight/ Moderate/ Severe
Genu recurvatum	None/Slight/ Moderate/ Severe	None/Slight/ Moderate/ Severe
Pes cavus/planus		
Tibial Int/Ext rotation		
Pronation/Supination		

FUNCTIONAL	Right		Left	
Peak torque Quads:	1.	2.	1.	2.
Peak torque Hams:	1.	2.	1.	2.
Willknox Wobbleboard	Front:	Back:	Left:	Right:
Stork stand	1. 2. 3.		1. 2. 3.	
Bass test	T1.		T2	
	E1		E2	

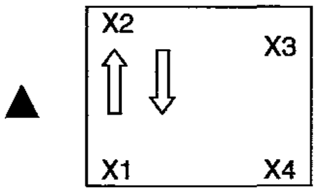
APPENDIX 8

Intervention programme followed during contact sessions

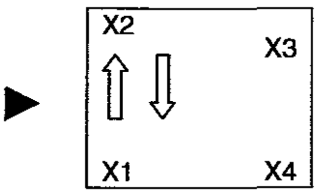
EXERCISE		LEVEL	SETS	REPS	REST
WARM UP		1	3	15	20sec
STRENGTHENING					
		2	2	12	20sec
		3	2	8	20sec
		4	2	6	20sec
		5	2	4	20sec
WOBBLEBOARD			2 min		
MINI-TRAMPOLINE					
	Jog		30 sec		
	2 bounce/leg		30sec		
	3 bounce/leg		30sec		
	1 leg only bounce		2x15 sec		
	2 leg bounce		30sec		
	Twist		30sec		
	1 leg twist		2x15 sec		
JUMP ROUTINE					
(See diagram)	1. Forward - Back		3-5 x		
	2. Side - side		3-5 x		
	3. Clockwise		3-5 x		
	4. Anti-clockwise		3-5 x		
	5. Cross forwards		3-5 x		
	6. Cross backwards		3-5 x		

Jump Routine

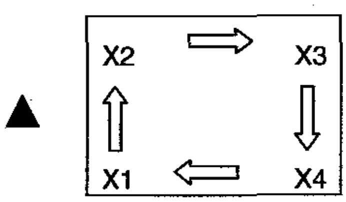
Key: Each diagram represents 4 crosses (0.4x0.4m) drawn on a gym mat
▶/▲ represent the direction the head and body are facing throughout the jump

1


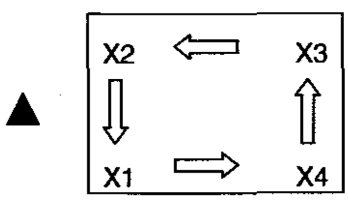
Jump 1: Forward-Back
X1→X2→X1→X2

2


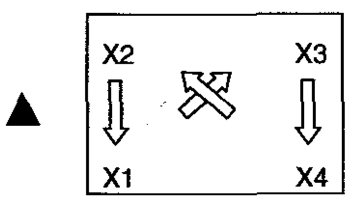
Jump 2: Side-Side
X1→X2→X1→X2

3


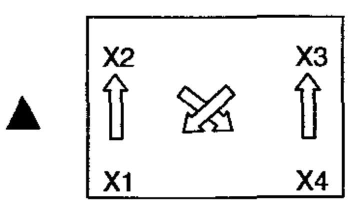
Jump 3: Clockwise
X1→X2→X3→X4→X1

4


Jump 4: Anti-clockwise
X1→X4→X3→X2→X1

5


Jump 5: Cross-forwards
X1→X3→X4→X2→X1

6


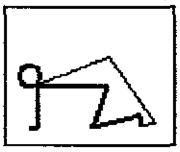
Jump 6: Cross-backwards
X1→X2→X4→X3→X1

APPENDIX 9

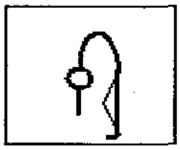
HOME PROGRAMME
Lower limb

Stretching: (Hold each stretch for 30sec, repeat 3 times)

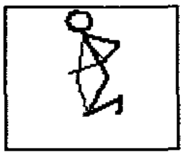
1. Calf
   Stand on the hands and knees with the toes pointed forward. Lift the knees off the floor so that the legs are straight. Push the heels down towards the ground.



2. Hamstrings
   Stand with the feet 50cm apart. Bend over forward, relaxing the upper body and keeping the legs straight. Bend knees after each stretch, then straighten again.

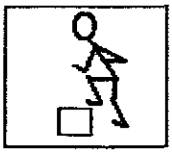


3. Hip flexors
   Kneel on the mat and perform a posterior pelvic tilt. The stretch will be felt in the thigh muscles.

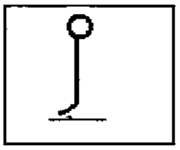


Strengthening:

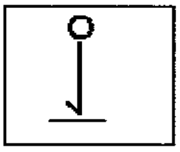
1. Step ups
   Step up and down on a step of about 30cm high. Lead with the right foot for 30 seconds, then repeat on the left side. Keep alternating legs for 5-8 minutes



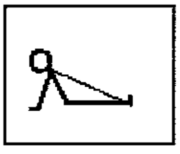
2. Calf raises (1 x 15-20)
   Lift up onto the toes, with the weight centred first onto the little toe, then the centre of the foot, then the big toe.



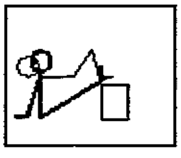
3. Toe raises (1 x 15-20)
   Whilst standing upright, raise the fore foot off the ground. First lift and tilt the soles inwards, then straight up, then outwards.



4. Pelvic lift (1 x 15-20)
   Sit on the mat with the legs straight and hands supporting behind the hips. Lift the hips off the ground until the body is straight. Lower and repeat.



5. Leg curls (1 x 15-20)
   Sit on the ground with the heels resting on a chair/bench. Support the body by placing the hands next to the hips. Lift the body up from the heels, bending the knees. The hips should lift higher than the level of the feet.



Proprioception:

6. Stork stand
   Balance barefoot on one leg on a 2.5cm wide plank for one minute

APPENDIX 10

Exercise Log

Name:										
Date	Str	Ex 1	Ex 2	Ex 3	Ex 4	Ex 5	Ex 6	Ex 7	Ex 8	Comment

THE ROLE OF A BIOKINETICS REHABILITATION PROGRAMME IN ALLEVIATING ANTERIOR KNEE PAIN IN ADOLESCENTS

By

JACQUELINE PHILLIPS

Submitted in fulfilment of the requirements for the degree

MASTER OF SCIENCE (BIOKINETICS)

In the

DEPARTMENT OF HUMAN MOVEMENT SCIENCE

FACULTY OF SCIENCE AND AGRICULTURE

UNIVERSITY OF ZULULAND

For Willem whose love, support and patience made this work possible

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My close circle of friends and family also deserve acknowledgement for keeping my spirits up.

SYNOPSIS

Anterior knee pain is a common condition prevalent within the adolescent population and frequently interferes with sporting and routine activities. The condition is often self-limiting, but can take up to two years to resolve. Surgical intervention is not recommended in this population group, and often there is no demonstrable anatomical abnormality. Conservative treatment should always be the first approach.

A questionnaire designed to determine the incidence of anterior knee pain among adolescents was distributed to various local schools, and was completed under the guidance of either a researcher or the parents. Results from the questionnaires indicate that 27.4% of adolescents who participated in the study had experienced non-traumatic anterior knee pain at some time between the ages of 10 and 17 years. Of this group, 42.9% was male and 57.1% was female.

Subjects in the intervention section of the study followed a Biokinetics rehabilitation programme which aimed at stabilising the knee joint by stretching and strengthening the involved musculature and improving proprioception and dynamic stability of the lower limb. The programme resulted in significantly reduced subjective ratings of pain and disability in the experimental group (N=18) compared to the control group (N=12). This improvement in condition can be attributed to the increase in strength, flexibility, proprioception and dynamic balance components tested. The decrease in pain as indicated on a Visual Analogue Scale was in the range of 35.3 to 43.0% at the post- and post-post testing in comparison with the initial pain ratings ($p<0.01$). There was also significant improvement in the ability to perform activities indicated by individual subjects on the Patient-Specific Functional Scale ($p<0.01$). All subjects in the experimental group indicated improvement in their condition at the post-test. Most of the group reported that their condition was at least as good or better at the post-post test compared with the post-test.

There was an increase of between 9.0 and 17.5% in muscle strength in both the quadriceps and hamstring muscle groups at the post- and post-post testing of the experimental group ($p<0.01$). There was a small but significant improvement of between 2.2 and 4.4% in quadriceps, hamstring and gastrocnemius flexibility of the experimental group at the post- and post-post testing ($p<0.01$). There was also a large significant improvement in both proprioception and dynamic balance of the

experimental group at the post- and post-post testing ($p<0.01$), which is indicative of improved stability of the knee joint complex. Proprioception as measured on a wobbleboard improved by between 49.5 and 50.8%, and dynamic stability scores improved by 37.5 to 53.2% at the post and post-post testing ($p<0.01$).

These variables improved as a consequence of the Biokinetics rehabilitation programme and were maintained or improved further at the one month follow up. In the context of South African health care, a structured Biokinetics rehabilitation programme based on sound clinical and scientific principles has the potential to endear positive outcomes in the treatment of anterior knee pain.

OPSOMMING

Anterior knie pyn is 'n algemene kondisie wat 'n wye verskydenheid pasiënte affekteer. Dit kom algemeen voor in die adolesent populasie en meng dikwels in met sport en roetine aktiwiteite. Die kondisie is gereeld van 'n selfbeperkende aard maar kan tot twee jaar neem voor dit verdwyn. Chirurgie word nie aanbeveel in hierdie populasie groep nie, en daar is dikwels geen demonstreerbare anatomiese abnormaliteit nie. Die kondisie behoort altyd eers op 'n konserwatiewe wyse behandel te word.

Proefpersone in die intervensie deel van die studie het 'n Biokinetiese rehabilitasie program gevolg. Die program se mikpunt was om die kniegewrig te stabiliseer deur die strek en versterking van die omliggende spiere, asook deur die verbetering van propriosepsie en dinamiese stabiliteit van die onderste ledemate. Daar was 'n statisties beduidende vermindering van subjektiewe evaluering van pyn en gestremdheid in die eksperimentele groep (N=18) in vergelyking met die kontole groep (N=12). Hierdie verbetering in die kondisie van proefpersone kan toegeskryf word aan verhoogde krag, soepelheid, propriosepsie en dinamiese balans komponente wat getoets is in die studie. Die pyn wat op 'n *Visual Analogue Scale* aangedui was, was tussen 35.3 en 43.0% minder tydens die post- en post-post toetse in vergelyking met die eerste pyn evalueringe ($p<0.01$). Daar was ook 'n statisties beduidende verbetering in die vermoë om sekere aktiwiteite uit te voer ($p<0.01$). Hierdie aktiwiteite was op die *Patient-Specific Functional Scale* aangedui. Die hele eksperimentele groep het aangedui dat hulle kondisie verbeter het op die post-toets, en meeste van die groep het aangedui dat hulle kondisie dieselfde of beter was tydens die post-post-toets.

Daar was 'n verbetering van tussen 9.0 en 17.5% in die quadriceps en hamstringspiere krag op die post- en post-post-toets ($p<0.01$). Soepelheid van die quadriceps, hamstring en gastrocnemiusspiere het tussen 2.2 en 4.4% verbeter op die post en post-post-toets ($p<0.01$). Daar was ook 'n groot verbetering in propriosepsie en dinamiese stabiliteit van die eksperimentele groep op die post- en post-post-toetse ($p<0.01$). Propriosepsie wat op 'n wobbleboard gemeet was, het tussen 49.5 en 50.8% verbeter, asook dinamiese stabiliteit wat tussen 37.5 en 53.2% verbeter het ($p<0.01$).

Hierdie komponente het verbeter as gevolg van die Biokinetiese rehabilitasie program en het verder verbeter of dieselfde gebly teen die opvolg sessie 'n maand later. In die konteks van Suid Afrikaanse

gesondheidssorg het 'n gestruktureerde Biokinetiese rehabililitasie program, gebaseer op streng kliniese en wetenskaplike beginsels, die potensiaal om positiewe uitkomste te hê vir die behandeling van anterior kniepyn.

CONTENTS

SYNOPSIS....iv
OPSOMMING....vi
LIST OF TABLES....x
LIST OF FIGURES....xii

CHAPTER 1: INTRODUCTION....1
Overview....1
Statement of the problem....2
Research hypothesis....3
Test hypotheses....3
Limitations and delimitations....6
Assessment protocol....6
Study design and data analysis....8

CHAPTER 2: REVIEW OF LITERATURE....9
Structure and function of the knee joint....9
Anterior knee pain....14
Incidence of anterior knee pain....17
Clinical findings....18
Prognosis....19
Conservative treatment....20
Proprioception and dynamic joint stability....22

CHAPTER 3: METHODS AND PROCEDURES....29
Subjects....29
Research groups....29
Assessment protocol....30
Intervention programme....39

CHAPTER 4: RESULTS AND DISCUSSION....40
Section 1: The incidence of anterior knee pain among adolescents....40

Incidence of anterior knee pain..40
Level of activity of respondents..42
Activities exacerbating condition..43

Section 2: The influence of a Biokinetics rehabilitation programme
on anterior knee pain in adolescents..44
Subjective ratings of pain and disability..48
Change in condition..52
Structural and functional variables measured..52

CHAPTER 5: CONCLUSION..68

REFERENCES..71

APPENDICES..86

LIST OF TABLES

Table **Page**

1: Number and percentage of subjects per category and per gender.................. 40
2: Level of activity of affected and non-affected respondents as
indicated on questionnaire..42
3: Descriptive data of the control and experimental groups....................................44
4: Mean duration of anterior knee pain as reported by the control
and experimental groups..45
5: Injured knees in control and experimental groups...45
6: Q-angles of the control and experimental groups..46
7: Mean activity levels according to the Activity Rating
Scale (Marx et al., 2001) of the control and experimental groups.................47
8: Activities most-commonly reported by subjects to cause pain
on the Patient-Specific Functional Scale (Chatman et al., 1997)...................47
9: Baseline values of pain as indicated on a Visual Analogue
Scale (VAS) for the control and experimental groups..................................48
10: Percentage change and change in scores of mean ratings
of worst, least and normal pain as indicated on a VAS at the post-
and post-post testing, for the control and experimental groups.......................50
11: Baseline values of disability as indicated on the Patient-
Specific Functional Scale...51
12: Baseline values of mean muscle strength and percentage
difference of the control and experimental groups...53
13: Percentage gain in mean muscle strength of the control
and experimental groups at the post- and post-post testing............................55
14: Baseline mean muscle flexibility values and percentage
difference of the control and experimental groups...58
15: Percentage change in mean muscle flexibility of the control
and experimental groups at the post- and post-post testing............................62

16: Baseline values of proprioception as measured on the Willknox Wobbleboard, dynamic balance as measured using the Bass Test, and static balance as measured with the Stork Stand of the control and experimental groups and the percentage difference between the groups....................64
17: Percentage change in the performance of activities of proprioception (wobble board) and dynamic balance (bass test) at the post- and post-post testing....................66

LIST OF FIGURES

Figure **Page**

1: Anterior view of the knee joint....9

2: Posterior view of the knee joint....10

3: The testing of muscle strength....36

4: Testing proprioception on the Willknox wobbleboard....36

5: The Stork stand....37

6: Layout for Bass test for assessing dynamic stability....38

7: The prevalence of anterior knee pain per age group, represented as a percentage of all the respondents, as indicated on the knee pain questionnaire....41

8: The prevalence of anterior knee pain compared with level of activity as indicated on the questionnaire....42

9. Activities reported to exacerbate anterior knee pain as indicated on the questionnaire....43

10: The control group's mean ratings of worst, least and normal pain as indicated on a visual analogue scale at the pre- and post-testing....49

11: The experimental group's mean ratings of worst, least and normal pain as indicated on a visual analogue scale at the pre, post- and post-post testing....49

12: Mean ratings of ability to perform various activities as indicated on the Patient-Specific Functional Scale at the pre, post- and post-post testing of the control and experimental groups....51

13: Mean values of right quadriceps strength of the control and experimental groups at pre-, post- and post-post testing....53

14: Mean values of left quadriceps strength of the control and experimental groups at pre-, post- and post-post testing.....54
15: Mean values of right hamstring strength of the control and experimental groups at pre-, post- and post-post testing.....54
16: Mean values of left hamstring strength of the control and experimental groups at pre-, post- and post-post testing.....55
17: Mean values of right quadriceps flexibility of the control and experimental groups at pre-, post- and post-post testing.....59
18: Mean values of left quadriceps flexibility of the control and experimental groups at pre-, post- and post-post testing.....60
19: Mean values of right hamstring flexibility of the control and experimental groups at pre-, post- and post-post testing.....60
20: Mean values of left hamstring flexibility of the control and experimental groups at pre-, post- and post-post testing.....61
21: Mean values of right gastrocnemius flexibility of the control and experimental groups at pre-, post- and post-post testing.....61
22: Mean values of left gastrocnemius flexibility of the control and experimental groups at pre-, post- and post-post testing.....62
23: Mean wobbleboard scores of the control and experimental groups at pre-, post- and post-post testing, as measured by recording time in seconds unbalanced on the Willknox Wobbleboard.....65

24: Mean Bass Test scores of the control and
experimental groups at pre-, post- and post-post
testing as measured by the Bass Test 65

CHAPTER 1: INTRODUCTION

OVERVIEW

The knee joint is the largest and one of the most complex joints in the body (Thompson & Floyd, 1998; Arnheim & Prentice, 2000). The knee joint complex is comprised of a number of articulations between the femur and the tibia, femur and patella, femur and fibula, and tibia and fibula. The ligaments, joint capsule and muscles that surround the joint primarily stabilise the knee joint (Arnheim & Prentice, 2000). Dynamic muscle stabilisation provided by the quadriceps, hamstring and gastrocnemius muscles protects the knee joint, allowing the knee to withstand stresses and strains (Huston & Wojtys, 1996). The major functions of the knee involve weight bearing and locomotion, which place considerable strain on the joint (Thompson & Floyd, 1998).

Anterior knee pain is a common condition that affects a wide age range of patients (Cutbill et al., 1997). It is prevalent within the adolescent population and frequently interferes with sporting and routine activities. As a result, a large number of adolescents may be forced to limit their physical activity or perform sub-optimally in the sporting arena (Galanty et al., 1994). Sport plays a central role in the lives of many adolescents. Cessation of physical activity is detrimental to the developing individual, negatively affecting physical development, general fitness, body composition, the development of motor skills and psychosocial development (DiFiori, 1999; Patel & Nelson, 2000). It may also lead to the adoption of lifelong sedentary lifestyle habits. The condition is often self-limiting, but can take up to two years to resolve (Patel and Nelson, 2000).

One of the most common abnormalities involving the knee joint is disturbance of the patellofemoral mechanism (Souza & Gross, 1991). This joint is a major source of pain and dysfunction at the knee (Woodall & Welsh, 1990). Patellofemoral pain syndrome is reported to be the most common cause of anterior knee pain in adolescents. It is found far more commonly in physically active adolescents (Patel & Nelson, 2000). Surgical intervention is not recommended in this population group, and often there is no demonstrable anatomical abnormality (Jackson, 1994; Patel & Nelson, 2000). Conservative treatment should always be the first approach with this condition (Malek & Mangine, 1981). Galanty et al. (1994) reported that seventy to eighty percent of patients experiencing anterior knee pain responded favourably to conservative management, where stretching and strengthening were included in the programme.

It is clear from the literature that conservative treatment in the form of stretching, strengthening and related modalities is a beneficial strategy for treating anterior knee pain. In the context of South African health care, it is perceived that a structured biokinetics rehabilitation programme based on sound clinical and scientific principles has the potential to endear positive outcomes in the treatment of anterior knee pain.

STATEMENT OF THE PROBLEM

The focus of this study is to validate the efficacy of a biokinetics rehabilitation programme in the alleviation of anterior knee pain in adolescents.

There are many causes of anterior knee pain, and in some instances it is idiopathic. In cases where anterior knee pain is as a result of instability or faulty mechanics, the rehabilitation programme should improve the condition by enhancing muscle strength, flexibility and proprioception. Once the knee is stabilised, it is tentatively postulated that the perception of pain and the ensuing disability will be improved. The study will also investigate whether these benefits are long-term in nature.

In many cases it appears that the onset of anterior knee pain coincides with the period of the adolescent growth spurt (Rogan, 1995). This is postulated to be as a result of a loss of proprioception that occurs during this period of accelerated linear growth. The condition is reported to be more prevalent in girls than boys, and among the more physically active (Jacobson & Flandry, 1989; Nimon et al., 1998; Patel & Nelson, 2000).

A biokinetics programme is a cost-effective means of rehabilitation. In this population group, conservative physical therapy programmes are preferable to surgical and pharmacological interventions. It, therefore, appears to be a desirable solution to a difficult and sometimes debilitating condition.

RESEARCH HYPOTHESIS

The general hypothesis of this study is that a biokinetics rehabilitation programme alleviates anterior knee pain in adolescents. The rehabilitation programme is aimed at stabilising the knee joint by stretching and strengthening the involved musculature, and improving proprioception of the lower limb. Stabilisation of the knee joint should result in decreased subjective ratings of pain and disability. Thus, improvements in strength, flexibility, proprioception and subjective ratings of pain and disability should be a consequence of the biokinetics programme. Furthermore, these improvements should be long-term effects.

It is also hypothesised that the condition is more prevalent in girls, and among the more physically active.

TEST HYPOTHESES

Hypothesis 1: The null hypothesis states that a biokinetics programme for the lower limb does not result in increased muscle strength.

a) Ho: $\mu s_{pre} = \mu s_{post}$

b) Ho: $\mu s_{pre} = \mu s_{post\text{-}post}$

Where:

μs_{pre} = Pre-intervention muscle strength measurements

μs_{post} = Post- intervention muscle strength measurements

$\mu s_{post\text{-}post}$ = Muscle strength measurements taken 4 weeks after completion of intervention programme

Hypothesis 2: The null hypothesis states that a biokinetics programme for the lower limb does not result in increased muscle flexibility.

a) Ho: $\mu\ f_{pre} = \mu\ f_{post}$

b) Ho: $\mu\ f_{pre} = \mu\ f_{post\text{-}post}$

Where:

f_{pre} = Pre- intervention flexibility measurements

f_{post} = Post- intervention flexibility measurements

$f_{post-post}$ = Flexibility measurements taken 4 weeks after completion of intervention programme

Hypothesis 3: The null hypothesis states that a biokinetics programme for the lower limb does not result in improved proprioception of the lower limb.

a) Ho: $\mu\ p_{pre} = \mu\ p_{post}$

b) Ho: $\mu\ p_{pre} = \mu\ p_{post-post}$

Where:

p_{pre} = Pre- intervention measurements of proprioception of the lower limb

p_{post} = Post- intervention measurements of proprioception of the lower limb

$p_{post-post}$ = Measurements of proprioception of the lower limb taken 4 weeks after completion of intervention programme

Hypothesis 4: The null hypothesis states that a biokinetics programme for the lower limb does not result in decreased subjective ratings of anterior knee pain in adolescents.

a) Ho: $\mu\ pa_{pre} = \mu\ pa_{post}$

b) Ho: $\mu\ pa_{pre} = \mu\ pa_{post-post}$

Where:

pa_{pre} = Pre- intervention subjective rating of anterior knee pain

pa_{post} = Post- intervention subjective rating of anterior knee pain

$pa_{post-post}$ = Subjective rating of anterior knee pain taken 4 weeks after completion of intervention programme

Hypothesis 5: The null hypothesis states that a biokinetics programme for the lower limb does not result in decreased subjective ratings of functional disability in adolescents with anterior knee pain.

a) Ho: $\mu\ d_{pre} = \mu\ d_{post}$

b) Ho: $\mu\ d_{pre} = \mu\ d_{post-post}$

Where:

d_{pre} = Pre- intervention subjective rating of functional disability as a result of anterior knee pain.

d_{post} = Post- intervention subjective rating of functional disability as a result of anterior knee pain.

$d_{post\text{-}post}$ = Subjective rating of functional disability as a result of anterior knee pain taken 4 weeks after completion of intervention programme

Hypothesis 6: The null hypothesis states that there will be no difference in the post-intervention variables between the experimental and control groups.

Ho: $\mu c = \mu e$

Where:

c = Post-intervention measures of the control group

e = Post-intervention measures of the experimental group

Hypothesis 7: The null hypothesis states that anterior knee pain is not more prevalent in adolescent girls than boys.

Ho: $\mu b = \mu g$

Where:

b = The number of boys complaining of anterior knee pain

g = The number of girls complaining of anterior knee pain

Hypothesis 8: The null hypothesis states that anterior knee pain is not more prevalent among adolescents that tend to be more physically active than those that are less active.

Ho: $\mu a = \mu la$

Where:

a = Adolescents that tend to be more physically active

la = Adolescents that tend to be less physically active

LIMITATIONS AND DELIMITATIONS

Limitations

A possible limitation is the use of self-report instruments. They are subjective in nature and thus, may be influenced by the human element, whereby individuals respond differently to similar stimuli or experiences. Another limitation is subject compliance with respect to the unsupervised home programme. A closed kinetic chain knee flexion/extension machine was used to measure muscle strength, which was recorded in Kilograms. This means that the data cannot be compared with other studies where the classic open kinetic chain methods were used. However, closed kinetic chain measurement is more closely related to everyday activities and the test reveals strength deficits between legs and strength improvements.

Delimitations

The subject group is comprised of individuals between the ages of 10 and 17 years. It only included adolescents from one geographical area.

ASSESSMENT PROTOCOL

A. Questionnaire

B. Self-evaluation

1. Level of activity using the Activity Rating Scale developed by Marx et al. (2001).
2. Rating of disability using the Patient-Specific Functional Scale described by Chatman et al. (1997).
3. Rating of pain using a Visual Analogue Scale (Thomee, 1997; Witvrouw et al., 2000; Crossley et al., 2002; Kane et al., 2005).
4. Overall improvement by the final session using the Scale for Change in Condition described by Harrison et al. (1995).

C. Handedness

The dominant hand and foot was recorded

D. Anthropometric assessment

1. Height
2. Weight
3. Anthropometric measurement of leg length:
   3.1 Distance between trochanterion and external tibiale
   3.2 Distance between external tibiale and lateral malleolus
4. Anthropometric measurement of foot length

E. Structural assessment

1. Flexibility
   1.1 Hamstring: Straight leg hamstring test
   1.2 Quadriceps: Modified Thomas test
   1.3 Gastrocnemius: Straight leg gastrocnemius test
   1.4 Iliotibial band: Ober's test
2. Q-angle
3. Valgus and varus stress tests
4. Test for the presence of crepitus
5. Assessment of the lower leg and foot. Record the presence of:
   5.1 Genu valgum
   5.2 Genu varum
   5.3 Genu recurvatum
   5.4 Pes cavus/ planus
   5.5 Tibial internal/ external rotation (Standing and walking)
   5.6 Pronation/ Supination

F. Functional assessment

1. Strength
   1.1 Quadriceps
   1.2 Hamstring

   Measurements of maximal muscle strength were recorded using a hydraulically-braked closed kinetic chain knee flexion/extension machine attached to a static dynamometer.

2. Proprioception: Measured on the Willknox wobbleboard. Time spent unbalanced was recorded.
3. Static balance: The Stork Stand as described by Bosco & Gustafson (1983).
4. Dynamic balance: Bass Test of Dynamic Balance as described by Bosco & Gustafson (1983).

STUDY DESIGN AND DATA ANALYSIS

The study design was the Pretest-posttest Randomised-groups design. Data was analysed using descriptive statistics, t-Tests and the Wilcoxon Signed Rank test.

CHAPTER 2: REVIEW OF LITERATURE

STRUCTURE AND FUNCTION OF THE KNEE JOINT

The knee joint is the largest and one of the most complex joints in the body (Dye, 1996; Winkel et al., 1997; Thompson & Floyd, 1998; Arnheim & Prentice, 2000). Dye (1996) proposed that the knee could be considered as an intricate assemblage of moving parts whose purpose is to accept, transfer and ultimately dissipate the potentially high loads generated at the ends of the long mechanical lever arms of the femur and tibia. The joint is designed to function optimally, that is, it has a large degree of stability in order to accommodate large loads, and it has mobility so as to facilitate its major movements, namely: walking, squatting and kneeling (Winkel et al., 1997). The knee joint complex is comprised of a number of articulations between the femur and the tibia, femur and patella, femur and fibula, and tibia and fibula (Larson & Grana, 1993; Arnheim & Prentice, 2000). The tibiofemoral and patellofemoral joints are the major joints of relevance (Brukner & Khan, 2002). The ligaments, joint capsule and muscles that surround the joint primarily stabilise the knee joint (Larson & Grana, 1993; Arnheim & Prentice, 2000; Williams et al., 2001).

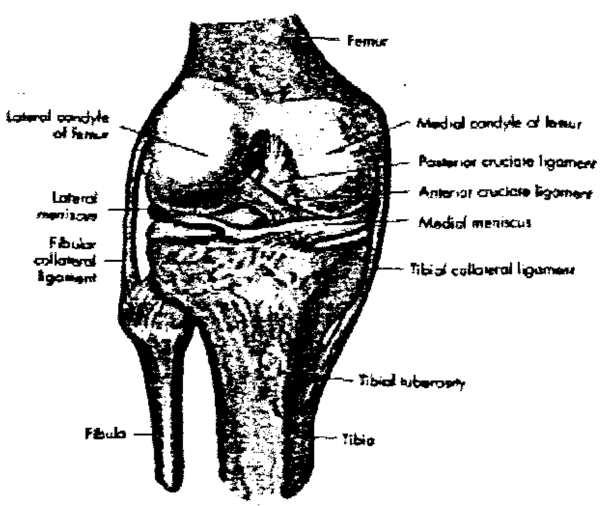


Figure 1: Anterior view of the knee joint

(Thompson & Floyd, 1998 p134)

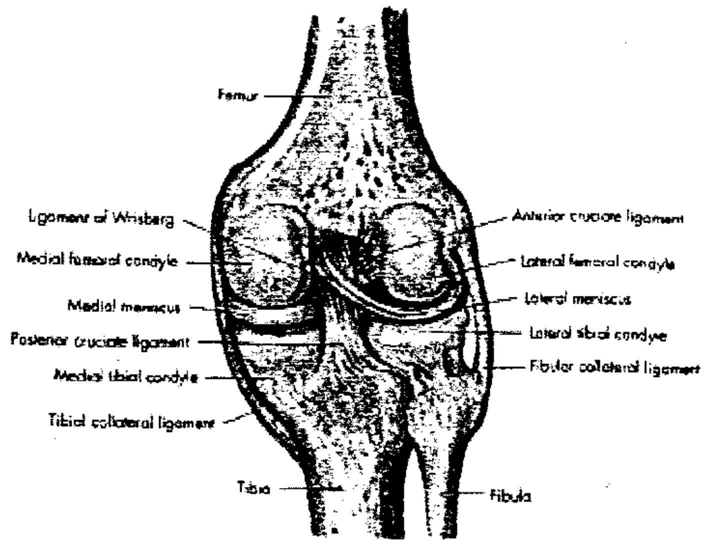


Figure 2: Posterior view of the knee joint

(Thompson & Floyd, 1998 p134)

The ligaments and joint capsule are the major static stabilisers of the joint. The anterior cruciate ligament is comprised of three twisted bands: anteromedial, intermediate and posterolateral bands. It runs superiorly and posteriorly from the attachment at the anterior region of the tibial plateau to the femoral insertion at the posterolateral region of the intercondylar notch. It prevents anterior translation of the tibia on the femur during weight bearing, and controls rotation of the tibia (Larson & Grana, 1993; Kakarlapudi & Bickerstaff, 2000; Brukner & Khan, 2002). The posterior cruciate ligament is the stronger of the two. It runs between the posterior region of the tibial plateau and the medial aspect of the intercondylar notch of the femur, and prevents forward translation of the femur and hyperextension of the knee. The medial collateral ligament provides medial stability to the knee. The ligament originates from the medial femoral epicondyle above the joint line and attaches to the anteromedial aspect of the tibia (Arnheim & Prentice, 2000; Kakarlapudi & Bickerstaff, 2000; Brukner & Khan, 2002). Some fibres merge into the deep posterior capsular ligament and semimembranosus muscle as well as the medial meniscus (Arnheim & Prentice, 2000; Kakarlapudi & Bickerstaff, 2000). It prevents lateral tilting of the tibia on the femur during valgus stress, and external rotary forces. The lateral collateral ligament provides lateral stability to the knee. It runs between the lateral epicondyle of the femur and the head of the fibula (Larson & Grana, 1993; Arnheim & Prentice, 2000; Brukner & Khan, 2002; Dugan, 2005). It prevents medial tilting of the tibia on the femur during varus stress (Arnheim & Prentice, 2000; Kakarlapudi & Bickerstaff, 2000).

The menisci are two oval fibrocartilages attached to the tibial plateau medially and laterally (Arnheim & Prentice, 2000; Brukner & Khan, 2002). The medial meniscus is C-shaped while the lateral meniscus is smaller and circular (Winkel et al., 1997; Arnheim & Prentice, 2000). They increase the concavity of the articular facets of the tibia resulting in increased stabilisation of the joint. They protect the joint by absorbing some of the forces passing through the joint as well as maintaining the spacing between the femoral condyles and tibial plateau (Larson & Grana, 1993; Arnheim & Prentice, 2000; Brukner & Khan, 2002; Dugan, 2005). The menisci reportedly transmit between thirty and fifty-five percent of the load transmitted through the knee (Winkel et al., 1997; Arnheim & Prentice, 2000). The menisci also serve to enlarge the contact area on the tibia and aid in joint lubrication (Larson & Grana, 1993; Winkel et al., 1997; Brukner & Khan, 2002). The joint capsule encloses the articular surfaces of the knee (Arnheim & Prentice, 2000). It is composed of a fibrous membrane and a synovial membrane (Winkel et al., 1997). It is divided into four regions, namely: posterolateral, posteromedial, anterolateral, and anteromedial (Arnheim & Prentice, 2000).

Dynamic muscle stabilisation provided predominantly by the quadriceps, hamstring and gastrocnemius muscles protects the knee joint, allowing the knee to withstand the considerable stresses and strains placed on the knee during locomotion and weight-bearing (Huston & Wojtys, 1996; Thompson & Floyd, 1998). The quadriceps mechanism is comprised of the rectus femoris, vastus medialis, vastus lateralis and vastus intermedius (Larson & Grana, 1993; Arnheim & Prentice, 2000). These muscles are the dynamic supporters of the patella, as well as being extensors of the knee (Woodall & Welsh, 1990; Larson & Grana, 1993; Thompson & Floyd, 1998). They are attached to the proximal pole of the patella by the quadriceps tendon (Woodall & Welsh, 1990; Larson & Grana, 1993). The vastus medialis is divided into the vastus medialis longus, which has longitudinally oriented fibres, and vastus medialis obliquus which has more obliquely oriented fibres. The vastus medialis obliquus is the primary patellar stabiliser, ensuring that the patella remains centralised within the sulcus during movement (Larson & Grana, 1993; Thompson & Floyd, 1998). The pes anserine group and biceps femoris are other dynamic structures which affect patella stability by controlling internal and external tibial rotation respectively, which has a notable effect on patella tracking (Malek & Mangine, 1981; Woodall & Welsh, 1990). The biceps femoris, along with the semimembranosus and semitendinosus make up the hamstring muscle group. The hamstrings and gastrocnemius are responsible for knee flexion (Thompson & Floyd, 1998; Arnheim & Prentice, 2000). The popliteus muscle is another internal rotator of the tibia and provides rotatory stability by opposing forward translation of the tibia on the femur during flexion (Larson & Grana, 1993; Thompson & Floyd, 1998; Arnheim & Prentice, 2000).

A number of physiological and arthrokinematic motions occur between the patella, femur and tibia. These include flexion, extension, rotation, rolling and gliding (Larson & Grana, 1993; Arnheim & Prentice, 2000). The tibiofemoral joint is classified as a ginglymus joint. This is as it functions like a hinge during flexion and extension. It is sometimes referred to as a trochoginglymus joint as a result of the internal and external rotation that can occur during flexion (Thompson & Floyd, 1998). The femoral condyles are curved such that the anterior section is oval-shaped and posterior section sphere-shaped. During knee flexion the anterior portions articulate with the tibia which is deepened by the menisci and basically functions as a modified ball-and-socket joint with limited rotatory motion (Larson & Grana, 1993). The patellofemoral joint is classified as an arthrodial joint due to the gliding motion of the patella on the femoral condyles (Thompson & Floyd, 1998; Walters, 2004). Normal knee range of motion includes 180 degrees extension to 140 degrees flexion, and about 30 degrees of internal rotation and 45 degrees external rotation when the knee is flexed to 30 degrees or more (Thompson & Floyd, 1998).

The patella and its articulation with the femur is called the patellofemoral joint (PFJ) (Malek & Mangine, 1981; Heng & Haw, 1996; Arnheim & Prentice, 2000). Anatomically the patellofemoral joint forms part of the knee joint complex, however, it is functionally distinct from the condylar tibio-femoral joint (Heng & Haw, 1996). The patella is the largest sesamoid bone in the body, and is embedded in the quadriceps tendon (Malek & Mangine, 1981; Heng & Haw, 1996; Arnheim & Prentice, 2000). Its longest axis is in the transverse plane and its superior surface is a convex dome while the articular surface is divided by a midline ridge into a medial facet which is usually convex, and a lateral facet which is usually concave (Heng & Haw, 1996).

The patellofemoral joint is placed under substantial compression and shear forces which are transmitted through continually changing points of contact during movement (Larson & Grana, 1993; Jackson, 1994). The magnitude of the compressive force on the patella, known as the patellofemoral joint reaction force, varies according to the activity being performed, and the resultant angle of flexion, quadriceps muscle tension and patella tendon tension (Woodall & Welsh, 1990; Larson & Grana, 1993; Powers et al., 1996; Powers, 1998; Erasmus, 2004). During an activity where there is minimal knee flexion such as ambulation, the largest reaction force exerted on the patellofemoral joint is approximately half of the body weight of the individual. During stair climbing with the knee flexed to 90 degrees, the reaction force can be up to three times the individual's body weight (Woodall & Welsh, 1990; Larson & Grana, 1993; Erasmus, 2004). Compressive forces decrease from thirty to zero degrees flexion (Woodall & Welsh, 1990). Contact areas stretch over both patellar facets and both trochlear condyles (Erasmus, 2004). These areas change according to the degree of flexion at the knee (Zappala et al., 1992; Powers, 1998; Erasmus, 2004). The contact areas increase with increased knee flexion, which results in the distribution of the increasing compressive force over a larger surface area, thus reducing the contact stress (Larson & Grana, 1993). The area of contact acts as a fulcrum, with a contact band sweeping along the patella from the inferior to superior aspect as the knee moves from full extension to 90 degrees flexion (Woodall & Welsh, 1990; Larson & Grana, 1993; Jackson, 1994).

Articulation occurs with the anterior aspect of the distal femur which is notched to accommodate the patella. During quadriceps contraction, patella tracking within the femoral groove depends on the pull of the quadriceps muscle and patella tendon, depth of femoral condyles and shape of the patella (Woodall & Welsh, 1990; Zappala et al., 1992; Larson & Grana, 1993; Holmes & Clancy, 1998; Arnheim & Prentice, 2000; Erasmus, 2004). The patella follows an S-curve as the knee moves from flexion to extension. With full flexion the patella is situated medially and it moves laterally with progressive extension, until the knee reaches terminal extension, where the patella moves slightly medially (Larson & Grana, 1993; Erasmus, 2004). Normal alignment and functioning of the patella is dependant on a balance of the medial and lateral forces exerted on the patella by the passive structures and active muscular forces (Karst & Jewett, 1993; Holmes & Clancy, 1998; Cowan et al., 2002). The neuromotor control systems also play a role in patellar tracking (Cowan et al., 2002).

The vastus medialis obliquus is the only dynamic medial stabiliser of the patella, and it prevents excessive lateral movement of the patella (Antich & Brewster, 1986; Arno, 1990; Hanten & Schulthies, 1990; Hilyard, 1990; Woodall & Welsh, 1990; Zappala et al., 1992; McConnell, 1993; Powers, 1998; Juhn, 1999). The oft cited work of Lieb and Perry (1968) showed that this is the only function of the vastus medialis obliquus, as it is not a knee extensor (Antich & Brewster, 1986; McConnell, 1993; Powers, 1998). The distal fibres of the vastus medialis are reported to be positioned at about 55 degrees to the longitudinal axis of the femur, making it ideally suited for opposing the lateral pull of the vastus lateralis (Antich & Brewster, 1986; Powers et al., 1996; Powers, 1998).

The function of the patella is to increase the efficiency of the quadriceps muscle during knee extension by increasing the distance of the patella tendon from the axis of knee extension, thus increasing the mechanical advantage of the levering mechanism (Malek & Mangine, 1981; Woodall & Welsh, 1990; Zappala et al., 1992; Heng & Haw, 1996; Thomee et al., 1999; Erasmus, 2004). It transmits quadriceps force to the tibia which places a large compressive force on the articular cartilage of the patella and femur. It also plays a protective role with respect to the anterior aspect of the knee joint (Malek & Mangine, 1981; Woodall & Welsh, 1990; Thomee et al., 1999).

ANTERIOR KNEE PAIN

There is a lack of consensus in the literature, especially in earlier studies, as to the exact definition of the term. Anterior knee pain, patellofemoral pain, chondromalacia patella and patellofemoral arthralgia were used interchangeably in the past. For a number of years chondromalacia patella was thought to be the leading cause of anterior knee pain and was thus the accepted clinical diagnosis for patients presenting with these symptoms (Malek & Mangine, 1981; Karlsson et al., 1996; Holmes & Clancy, 1998; Dye, 2004). The term has largely fallen into disuse except in cases where articular cartilage softening and fibrillation is identified during arthroscopy.

A clinical examination alone may not necessarily identify the source of pain, and costly, invasive procedures are not indicated for most patients. As a result, these non-specific terms listed above, have been used to describe the symptoms of this common clinical condition (Crossley et al., 2002). These terms are used synonymously in the literature. In this study, the term anterior knee pain was used to describe the symptom complex characterised by pain in the anterior region of the knee during activity and prolonged sitting in the absence of an identifiable pathologic condition. Patellofemoral dysfunction was taken to be a common cause of anterior knee pain. There are reportedly no reliable clinical measures of patellar tracking, and this is thought to be a major cause of patellofemoral pain (Crossley et al., 2002). Thus, as the pathogenesis is unknown, and there are no valid clinical tests to diagnose the condition, it was included in the umbrella term, anterior knee pain.

Regardless of the terminology, a number of stereotypical symptoms have been identified, namely: pain in the vicinity of the patella worsened by prolonged sitting, ascending or descending stairs, squatting and vigorous physical activity (Malek & Mangine, 1981; Carson et al., 1984; Sandow & Goodfellow, 1985; Jacobson & Flandry, 1989; Whitelaw et al., 1989; Arno, 1990; Hilyard, 1990; Woodall & Welsh, 1990; Tria et al., 1992; Zappala et al., 1992; Reid, 1993; Ruffin & Kinningham, 1993; Jackson, 1994; Kannus & Niittymaki, 1994; Heng & Haw, 1996; Cutbill et al., 1997; Nimon et al., 1998; Powers, 1998; Cesarelli et al., 1999; Juhn, 1999; Thomee et al., 1999; Witonski, 1999; Clark et al., 2000; Cowan et al., 2002; Crossley et al., 2002; Shea et al., 2003; Crossley et al., 2005).

The pain can usually be related to the anterior structures of the knee, but is often poorly localised (Carson et al., 1984; Sandow & Goodfellow, 1985; Hilyard, 1990; Souza & Gross, 1991; Tria et al., 1992; Ruffin & Kinningham, 1993; Stanitski, 1993; Powers, 1998). The onset of anterior knee pain is insidious, and tends to be bilateral (Hilyard, 1990; Ruffin & Kinningham, 1993; Stanitski, 1993; Powers, 1998; Lichota, 2003; Shea et al., 2003; Pollock, 2004). The condition is common among adolescents and young adults, especially females (Fairbank et al., 1984; Sandow & Goodfellow, 1985; Jacobson & Flandry, 1989; Tria et al., 1992; Stanitski, 1993; Galanty et al., 1994; Heng & Haw, 1996; Karlsson et al., 1996; Powers et al., 1996; Natri et al., 1998; Nimon et al., 1998; Cesarelli et al., 1999; Thomee et al., 1999; Clark et al., 2000; Price & Jones, 2000; Roush et al., 2000; Calmbach & Hutchens, 2003; Lichota, 2003; Shea et al., 2003; Dugan, 2005). The ratio may be as high as two to one in females versus males (Powers, 1998; Lichota, 2003). It is also widespread among physically active individuals and sportspeople, and makes up a large proportion of visits to sports clinics (O'Neill et al., 1992; Stanitski, 1993; Kannus & Niittymaki, 1994; Brody & Thein, 1998; Thomee et al., 1999; Crossley et al., 2005). It frequently interferes with exercise and sports participation and as a result, a large number of adolescents may be forced to limit their level of physical activity or perform sub-optimally on the sports field (Fairbank et al., 1984; Galanty et al., 1994; Thomee et al., 1999; Crossley et al., 2002).

The exact aetiology is unknown but a number of predisposing factors have been suggested as possible causes (Wilson, 1990; Heng & Haw, 1996; Powers, 1998; Wilk et al., 1998; Thomee et al., 1999). These include overuse, muscle imbalance, muscle tightness, trauma, overweight, genetic predisposition, valgus or varus knee, external tibial torsion, increased Q angle, abnormal mechanics of the foot and ankle, especially pronation, and generalised ligament laxity (Fairbank et al., 1984; Woodall & Welsh, 1990; O' Neill et al., 1992; Stanitski, 1993; Kannus & Niittymaki, 1994; Karlsson et al., 1996; Teitz, 1997; Post, 1998; Cesarelli et al., 1999; Juhn, 1999; Thomee et al., 1999; Roush et al., 2000; Pollock, 2004). It has also been suggested that growth-related factors unique to the adolescent population may be important contributing factors in the epidemiology of anterior knee pain (Teitz, 1997; Holmes & Clancy, 1998; Juhn, 1999; Stathopulu & Baildam, 2003). In many cases it appears that the onset of anterior knee pain coincides with the period of the adolescent growth spurt (Rogan, 1995). Malalignment between the patella and femur is the most commonly accepted mechanism for pain in the patellofemoral region (Powers et al., 1996; Holmes & Clancy, 1998; Thomee et al., 1999; Dye, 2004). Malalignment refers to insufficient action from the static and dynamic restraints of the patellofemoral joint to allow normal patellar tracking. This includes abnormal bony alignment of the lower limb, insufficient static soft tissue restraints and abnormal dynamic soft tissue restraints (Holmes & Clancy, 1998).

Muscle imbalance is a common finding, and appears to be associated with reduced strength possibly due to hypotrophy or inhibition. While reduced knee extensor strength is common, it is not known whether this is the cause or effect of anterior knee pain (Thomee, 1997; Powers, 1998; Thomee et al., 1999). Many studies report an abnormal relationship between vastus medialis obliquus and vastus lateralis activation patterns. The onset of vastus medialis obliquus activity is delayed in comparison with vastus lateralis (Hanten & Schulthies, 1990; Souza & Gross, 1991; Zappala et al., 1992; Heng & Haw, 1996; Powers et al., 1996; Post, 1998; Powers, 1998; Thomee et al., 1999; Roush et al., 2000; Cowan et al., 2002; Crossley et al., 2005). It is possible that this asynchronous muscle activity affects normal patella tracking, which would lead to areas of increased stress in the patellofemoral joint (Powers, 1998; Crossley et al., 2005). This issue is contentious as studies by Powers et al. (1996) and Karst and Willett (1995) dispute this vasti timing difference.

Having mentioned the difficulty in diagnosing this condition, many articles refer to disturbances of the patellofemoral mechanism as being a common abnormality involving the knee joint (Souza & Gross, 1991; Tria et al., 1992; Caylor et al., 1993; Powers, 1998). This joint is a major source of pain and dysfunction at the knee (Woodall & Welsh, 1990). Many authors have associated abnormal tracking of the patella in the femoral trochlear groove with the development of patellofemoral pain. This abnormal lateral tracking is thought to produce areas of increased stress on the patellofemoral joint (Powers, 1998; Cowan et al., 2002; Crossley et al., 2002). Crossley et al. (2002) went on to say that the management of patella tracking and alignment is difficult, and the relationship between patella tracking and patellofemoral pain is unclear.

Patellofemoral pain syndrome is reported to be the most common cause of anterior knee pain in adolescents (Tria et al., 1992; Nimon et al., 1998). It is found far more commonly in physically active adolescents (Patel & Nelson, 2000). Patellofemoral pain syndrome is a common cause of anterior knee pain in general, and is said to affect 20% of the general population, and an even greater percentage of the sporting population (Hilyard, 1990). Studies report that 2-30% of patients seen at sports medicine practices present with patellofemoral pain syndrome (Kannus & Niitymaki, 1994; Natri et al., 1998; Crossley et al., 2002).

Incidence of anterior knee pain

Ruffin and Kinningham (1993) reported that of 16 748 patients presenting to family doctors with musculoskeletal complaints as a result of a variety of sports, 11.3% had anterior knee pain, while Brody and Thein (1998) estimate that the condition accounts for 21-40% of all complaints within the clinical environment. The condition is said to affect 5 -10% of all patients presenting at sports injury clinics, and between 20% and 40% of all knee conditions seen at these sports injuries clinics (Price, 1987; Wilson, 1990; Kannus & Niittymaki, 1994; Heng & Haw, 1996; Johnson, 1997; Thomee et al., 1999; Roush et al., 2000; Bizzini et al., 2003).

While these figures refer to the general and sporting population, a study by Fairbank et al. (1984) found that 136 out of 446 randomly selected pupils from a school of 1850 had suffered knee pain in the previous year. This is a fairly high incidence, at 30.5%. Twenty-five subjects had stopped playing any form of sport due to their knee pain. This figure is supported by Harrison et al. (1995) who reported the prevalence within the adolescent population to be 30%. In another study on school children aged between 10 and 18 years, it was found that as many as 45% of the cross-section of adolescents had anterior knee pain on physical examination. The authors do acknowledge that it is likely that adolescents with the condition would be more likely to volunteer for the study than those without knee pain (Galanty et al., 1994). Thomee et al. (1999) cited a study done by Hording in the eighties, where anterior knee pain was the most common complaint reported by a subject group of 1990 pupils aged 10 to 19 years. In this study the incidence was only 3.3% of the group, with 10% falling within the 15 year old age group. Cutbill et al. (1997) found that of all reported general knee complaints the 10 to 19 year old group was the second highest, accounting for 19% of patients.

Clinical Findings

Generally, there is a lack of abnormal physical findings in patients with anterior knee pain (Sandow & Goodfellow, 1985). The physical examination should focus on the entire lower extremity, observing gait, malalignment of the lower extremity (increased femoral anteversion, inward squinting patella, tibial torsion and foot pronation), patella tracking (abnormal patella tilt, excessive lateral tracking and increased Q-angle), and crepitus (Malek & Mangine, 1981; Carson et al., 1984; Jacobson & Flandry, 1989; Cutbill et al., 1997; Holmes & Clancy, 1998; Post, 1998; Thomee et al., 1999; Lichota, 2003; Shea et al., 2003; Pollock, 2004). It should also include palpation of the joint, assessment of joint stability, location of pain sites and the presence of effusion (Malek & Mangine, 1981; Ruffin & Kinningham, 1993; Stanitski, 1993; Cutbill et al., 1997; Post, 1998; Lichota, 2003; Dye, 2004; Pollock, 2004). Muscle strength and co-ordination, flexibility, and range of motion of the lower limb should also be assessed (Malek & Mangine, 1981; Reid, 1993; Stanitski, 1993; Post, 1998). Assessment of dynamic stability is also important (Reid, 1993). Radiographs are necessary to rule out any other cause for the pain. In most cases the radiographs do not show anything remarkable (O' Neill et al., 1992; Heng & Haw, 1996; Nimon et al., 1998; Shea et al., 2003).

Studies report a variety of findings which indicate impaired muscle function of the lower limb in patients with anterior knee pain. Findings include reduced muscle strength, reduced EMG activity and reduced functional ability (Zappala et al., 1992; Thomee, 1997; Thomee et al., 1999; Cowan et al., 2002).

Studies report a 10-18% quadriceps strength deficit in patients with anterior knee pain (Kannus & Niitymaki, 1994; Thomee, 1997). Thomee (1997) found reduced vertical jump ability, decreased isometric, concentric and eccentric isokinetic knee extensor torque and reduced EMG activity in patients with anterior knee pain compared with an age- and gender-matched control group in the range close to full extension. There were also differences in EMG activity between vastus medialis and rectus femoris muscles (Souza & Gross, 1991; Zappala et al., 1992; Thomee, 1997). However, there are studies that refute these findings (Powers, 1998). Powers et al. (1996) reported decreased recruitment of the entire quadriceps muscle group during gait activities in patients with anterior knee pain. This reduction in recruitment was similar for all vasti, thus they did not find selective vastus medialis obliquus insufficiency.

Some patients complain of the knee giving way (Malek & Mangine, 1981; Fairbank et al., 1984; Arno, 1990; Shelton, 1992; Holmes & Clancy, 1998; Post, 1998; Powers, 1998; Thomee et al., 1999). This is reportedly due to the sudden relaxation of muscles due to pain-related inhibition of the quadriceps during loading of the patellofemoral joint (Holmes & Clancy, 1998; Post, 1998; Thomee et al., 1999). This occurs more frequently during standing, ascending stairs or walking downhill (Thomee et al., 1999).

Decreased flexibility is an important finding. Both hamstring and quadriceps tightness can result in increased patellofemoral joint reaction forces and increased stress on the patella tendon (Jacobson & Flandry, 1989; Shelton, 1992; Wilk et al., 1998). Tightness of the hamstrings can lead to reduced stride length and may cause the quadriceps to contract more powerfully in order to overcome the passive resistance of the tight hamstrings (Wilk et al., 1998). Tightness of the gastrocnemius-soleus complex can result in compensatory pronation of the foot which leads to increased tibial rotation and increased stress on the patellofemoral joint, while iliotibial band tightness can result in lateral tracking of the patella (Shelton, 1992; Zappala, 1992; Wilk et al., 1998).

Possible leg length discrepancy should be investigated, as this may have a significant effect on the lower limb mechanics and patellofemoral joint. Excessive pronation and flexed knee gait and stance may occur in compensation, and will directly affect the patellofemoral joint. Intrinsic imbalances of the foot may also affect lower extremity mechanics by resulting in excessive pronation. This leads to internal rotation of the tibia and lateral displacement of the patella (Wilk et al., 1998).

Galanty et al. (1994) found no relationship between any intrinsic variable and diagnosis of anterior knee pain.

Prognosis

In most cases anterior knee pain is self-limiting, but it can take up to 2 years to resolve (Patel & Nelson, 2000). The condition appears to have a benign natural history (Ruffin & Kinningham, 1993; Karlsson et al., 1996; Shea et al., 2003). Sandow & Goodfellow (1985) support this finding as they reported a high percentage of significant improvement over time in adolescents with untreated idiopathic anterior knee pain, with most patients' symptoms being completely resolved. Symptom reduction occurs with the reduction of rapid growth, and the natural history is one of improvement and resolution in most cases (Juhn, 1999; Shea et al., 2003). It does not appear to lead to premature arthrosis (Stanitski et al., 1993; Shea et al., 2003). Stathopulu & Baildam (2003) were not convinced, however, concluding that anterior knee pain in childhood may not be as benign as previously thought.

Conservative Treatment

Conservative treatment for anterior knee pain should always be the first approach (Malek & Mangine, 1981; Wilson, 1990; Shelton & Thigpen, 1991; Shelton, 1992; Cutbill et al., 1997; Holmes & Clancy, 1998; Wilk et al., 1998; Juhn, 1999; Crossley et al., 2002; Dye, 2004). Surgery is rarely indicated in this population group, especially as the pathological basis of the clinical syndrome is often unclear (Sandow & Goodfellow, 1985; Jackson, 1994; Thomee et al., 1999; Patel & Nelson, 2000). In fact, most authors reported better results with conservative treatment than surgical intervention (Shelton, 1992). A study by McConnell (1996) on individuals with patellofemoral pain syndrome reported that subjects who underwent surgery progressed at one-third of the rate of those who followed a physical therapy programme.

A comprehensive conservative rehabilitation programme comprises a number of components, namely: muscle strengthening, flexibility, proprioception, endurance and functional training (Shelton & Thigpen, 1991; Shelton, 1992; Thomee et al., 1999). Each component is essential for complete rehabilitation, but the greatest emphasis is placed on quadriceps strengthening (Arno, 1990; Shelton & Thigpen, 1991; Zappala et al., 1992; Kannus & Niittymaki, 1994; Powers, 1998). The aim is to address any possible abnormalities with stretching and strengthening exercises for the entire lower limb (Teitz, 1997). Muscle balance will result in the distribution of patellofemoral joint reaction forces over as large a surface area as possible (McConnell, 1993; Brody & Thein, 1998). The critical outcome of a rehabilitation programme is the reduction of pain and disability (Crossley et al., 2005).

Patients in the studies were encouraged to avoid or minimise symptom-producing activities and some were given non-steroidal anti-inflammatories (Shelton & Thigpen, 1991; O'Neill et al., 1992; Stanitski, 1993; Kannus & Niitymaki, 1994; Brody & Thein, 1998; Post, 1998; Wilk et al., 1998; Thomee et al., 1999; Shea et al., 2003; Dye, 2004; Pollock, 2004). This is to reduce the loading of the knee joint and to decrease pain, which is necessary for the rehabilitation exercises to be effective.

Rehabilitation programmes reported in the literature ran for between 6 and 12 weeks (Arno, 1990; Kannus & Niittymaki, 1994; Karlsson et al., 1996; Thomee et al., 1999; Crossley et al., 2002). Strength training of the muscles improves force production in the peripatellar musculature, resulting in increased stability in the knee (Brody & Thein, 1998). Much variation exists in the different quadriceps training protocols: open kinetic chain versus closed kinetic chain, eccentric work, isometrics, straight leg raises, short arc terminal extensions and isokinetic training (Malek & Mangine, 1981; Bennett & Stauber, 1986; Arno, 1990; Shelton & Thigpen, 1991; O'Neill et al., 1992; Tria et al., 1992; Stanitski, 1993; Galanty et al., 1994; Karlsson et al., 1996; Teitz, 1997; Thomee, 1997; Post, 1998; Thomee et al., 1999). A number of researchers advocate selective strengthening of the vastus medialis obliquus, especially if the apparent cause of pain is patellofemoral dysfunction (Arno, 1990; Hanten & Schulthies, 1990; Shelton, 1992; Zappala et al., 1992; Kannus & Niittymaki, 1994; Holmes & Clancy, 1998; Powers, 1998; Wilk et al., 1998). Rehabilitation programmes can either be followed with or without supervision of a therapist (Woodall & Welsh, 1990; Karlsson et al., 1996; Thomee, 1997). Progression is important to avoid exacerbating the condition (Hilyard, 1990; Shelton & Thigpen, 1991; Shelton, 1992; Thomee, 1997; Thomee et al., 1999). Functional training is an essential component of a complete rehabilitation programme, and refers to functionally oriented activities performed with good vastus medialis obliquus control. The traditional physical rehabilitation phases precede the functional phase, thus ensuring that normal joint motion, muscle strength and endurance is restored before progressing onto the functional phase (Lephart & Henry, 1995). It is a process of motor relearning, and progresses from basic to advanced activities (Shelton, 1992; Nyland et al., 1994).

A myriad studies report good results with primary conservative treatment. Malek and Mangine (1981) reported a 77% success rate which is supported by Karlsson et al. (1996) who reported an 80% remission in pain. Galanty et al. (1994) reported a 70-80% success rate. Tria (1992) and Cutbill et al. (1997) claim that as many as 95% of patients respond favourably. Bennett and Stauber (1986) employed a 4-week eccentric isokinetic programme, and reported significant strength gains in all 41 subjects. McMullen et al. (1990) reported significant functional improvements in their patients compared with the control group. This study showed no difference between a programme of isometric training and isokinetic training. Doucette and Goble (1992) reported an 84% success rate of pain-free patients with an 8-week comprehensive programme which included a progression from isometrics to concentric exercises, including both open- and closed kinetic chain exercises. Stiene et al. (1996) compared open- and closed kinetic chain exercises and concluded that both regimes showed a significant increase in knee extensor strength. Ingersoll and Knight (1991) reported favourable results by using EMG feedback to selectively strengthen the vastus medialis obliquus and thus correct faulty patella tracking. A study on sportsmen by DeHaven et al. (1979) concurs with this figure, reporting a 66% return to unrestricted sporting activities following conservative treatment.

Research indicates that these results are long-term in effect, as many subjects continued to experience improved function a number of months or even years after completion of rehabilitation. Thomee et al. (1999) cited a study by Hording which involved 34 patients between the ages of 8 and 19 years who were given a programme of isometric exercises to strengthen the quadriceps. At follow-up after 4 months, half the group was symptom-free. Karlsson et al. (1996) claimed an 85% success rate at an 11-year follow-up. Kannus and Niittymaki (1994) reported a 70% success rate following a 6-week conservative programme which included activity modification, non-steroidal anti-inflammatory drugs, isometric training and straight leg raises. Quadriceps strength gains remained stable at the 6 month follow-up. O'Neill et al. (1992) found an 80% improvement on a programme of isometrics and stretching at 12-16 month follow-up in a group comprised of adolescents and adults. Thomee (1997) investigated a 12-week conservative programme which involved pain monitoring and a progressive exercise programme. They reported a significant reduction in pain, increased muscle strength and level of physical activity. At the 12-month follow-up subjects still reported reduced pain, and 85% were involved in either competitive or recreational sporting activities.

Kannus and Niittymaki (1994) and Crossley et al. (2002) could not find a general or biomechanical factor which reliably predicted the success of non-operative treatment of anterior knee pain. Young age was the only variable that had a moderate relationship with success rate.

Proprioception and Dynamic Joint Stability

The term proprioception is not clearly defined in the literature. Nyland et al. (1994) state that in the 1940's a scientist by the name of Sherrington is said to have introduced the term "proprioception", describing the awareness of posture, movement, alterations in equilibrium and mechanical inertia that generate pressures and strains at the joints. Higgins (1991) used a much broader definition, referring to the assimilation of any information related to body position and movement. Seaman (1997) describes proprioception of the limb as an awareness of position and movement of the limb, while Sharma (1999) elaborates by referring to both a conscious and unconscious awareness of the position of the limb in space, joint position and joint movement. Two sub-modalities are described: joint position sense, or the awareness of the stationary position, and kinaesthesia, or the sense of limb movement (Seaman, 1997; Hiemstra et al., 2001).

The somatosensory system is often referred to as proprioception. It is responsible for detecting sensory stimuli such as pain, pressure and touch, and movements such as joint displacement. The somatosensory system receives input from mechanoreceptors in the skin, muscles, tendons, ligaments, capsules and joints (Lephart et al., 1997; Lephart et al., 1998; Fuchs et al., 1999; Sharma, 1999). These mechanoreceptors are also referred to as proprioceptors. They act as so-called biological transducers by converting the environmental stimuli they detect into action potentials within the associated afferent fibre (Seaman, 1997). These receptors signal changes in muscle length and tension, and joint position and motion. The most important contributors to joint proprioception are the peripheral articular and musculotendinous receptors. Specialised mechanoreceptors in the knee joint, specifically located in the joint capsule and ligaments, are sensitive to joint acceleration and deceleration. Receptors within the skeletal muscles detect changes in muscle length and tension. Together they contribute towards joint proprioception. This information is relayed to the central nervous system, which is primarily responsible for mediating the perception and execution of musculoskeletal control and movement (Lephart et al., 1997; Lephart et al., 1998; Sharma, 1999; Williams et al., 2001).

The central nervous system generates a motor response from the integrated input provided by the mechanoreceptors as well as the visual and vestibular receptors. These responses fall under three levels of motor control, namely: spinal reflexes, brainstem activity and cognitive programming. When the joint is placed under a mechanical load, spinal reflexes stimulate reflex muscular stabilisation (Lephart et al., 1997; Williams et al., 2001). Spinal reflexes form part of a neural network within the spinal cord that seems to result in the control of limb mechanics and rapid postural responses during movement (Williams et al., 2001). Cognitive programming involves the highest level of central nervous system function. It involves the motor cortex, basal ganglia and cerebellum, and refers to voluntary movements that are repeated and stored as central commands (Lephart et al., 1997). Thus, input provided by the afferent system via its spinal and cortical projections results in control of movement and joint stability via reflex and centrally driven muscle activity (Sharma, 1999). Proprioception is traditionally defined as the ability to determine the position of a joint in space at any given instant. It is usually tested using equipment that measures the threshold to detection of passive motion, passive and active limb repositioning and visual estimation of a passive angle change (Lephart et al., 1998; Fuchs et al., 1999; Rozzi et al., 1999; Sharma, 1999; Arnheim & Prentice, 2000; Roberts et al., 2000; Hiemstra et al., 2001; Williams et al., 2001). The focus of the present study, however, is on proprioception as it relates to neuromuscular control and articular function. The traditional methods are inappropriate for the present study as accurate measures of proprioception under dynamic conditions. It has yet to be proven how proprioceptive acuity, as measured by the traditional tests, gives an indication of joint position sensibility during activity, or neuromuscular joint protection (Sharma, 1999).

The central nervous system is the primary mediator of neuromuscular control and joint stability. Sensory information is received and processed by the brain and spinal cord, resulting in a conscious awareness of joint position and motion, unconscious joint stabilisation through protective spinal-mediated reflexes and the maintenance of posture and balance (Lephart et al., 1998). Proprioception and the accompanying neuromuscular feedback mechanisms are an important component in the establishment and maintenance of functional joint stability. Of particular importance are the receptors located in the articular and musculotendinous structures (Lephart et al., 1998). Solomonow and Krogsgaard (2001) describe joint stability as the harmonious functioning of the bones, joint capsule, muscles, and tendons as well as the sensory receptors and their spinal and cortical neural projections.

An integrated relationship exists between proprioception, neuromuscular control and dynamic joint stability (Lephart et al., 1997; Lephart et al., 1998; Sharma, 1999; Laskowski et al., 2000). Joint stability can be viewed as a continuum, with absolute stability on one end and severe instability on the other end. Proprioception, or the somatosensory system, and motor reaction determine the position of the knee joint on this continuum. Disrupted sensory control results in a shift towards the instability side. Pain causes inhibition of the stabilising muscles, which leads to joint instability, resulting in a cycle of pain and further inhibition. Any number of factors may affect this sensory control, including structural abnormalities, overuse, under use, injury, growth and muscle weakness (Lephart et al., 1997;

Lephart et al., 1998; Sharma, 1999). An essential part of a rehabilitation programme involves the training of the sensorimotor control system to generate adaptive neuromuscular activation patterns timeously in response to perturbations of normal joint motion. Strong muscles reacting quickly to correct abnormal joint movement serve to effectively stabilise the joint.

Barrett (1991) went so far as to suggest that proprioception is a greater contributor to normal limb function during activity than muscle strength. Proper knee function is integral to the integrity of the lower limb kinetic chain, hence proprioceptive deficits may have a significant effect on performance (Lephart et al., 1998). It may lead to alterations in joint stability and control of joint motion (Lattanzio et al., 1997).

Joint stability is essential to the proper functioning of the knee joint during movement. Dynamic joint stability refers to the ability of the knee joint to remain stable when subjected to rapidly changing loads during activity. This is brought about by the integrated contribution of articular form, soft tissue stabilisers and loads applied to the knee during weight-bearing and muscle action (Zatterstrom & Friden, 1994; Kakarlapudi & Bickerstaff, 2000; Williams et al., 2001). Proprioceptive input functions essentially in an adaptive role, enabling changes in motor strategy to be initiated based on information received upon changes in body, and hence joint position (Nyland et al., 1994). Proprioception acts as a protective mechanism in the knee joint, preventing excessive strain on the passive joint stabilisers during activity and as a means of preventing recurrent injury (Borsa et al., 1997). The role of the anterior cruciate ligament and other passive stabilisers in the knee joint in triggering muscular contractions in synergists as a protective reflex is well documented (Kennedy et al., 1982; Biedert et al., 1992; Zatterstrom & Friden, 1994). *Proprioception is essential for the maintenance of knee joint* stability under dynamic conditions. Afferent input results in controlled movement and joint stability through both reflex and centrally driven muscular activity (Sharma, 1999).

The restoration of proprioception and neuromuscular control is essential in a comprehensive conservative rehabilitation programme (Lephart et al., 1998). Rehabilitation programmes have previously tended to emphasize muscle strength, flexibility and endurance (Nyland et al., 1994). Disturbances in the afferent pathway of the somatosensory system may be a major contributing factor to the cycle of microtrauma and re-injury (Lephart et al., 1997; Lephart et al., 1998). The aim of a rehabilitation programme is the restoration of normal function so that the individual is able to participate in normal activities of daily living (Rutherford, 1988). If proprioceptive deficits are not ameliorated, the individual will not be completely rehabilitated and will thus be predisposed to re-injury because of deficiencies within the neuromuscular pathway. Kennedy et al. (1982) showed how ligament injury in the knee resulted in reduced mechanoreceptor function and reduced proprioception, which lead to reduced protective muscular stabilization, repetitive injury and progressive joint laxity.

→	→	Ligament injury	→
↑		↓	↓
Repetitive injury		Instability	Proprioceptive deficits
↑		↓	↓
←	Functional instability	←	↓ Neuromuscular control

(Lephart et al., 1998)

Thus, the programme needs to focus on the re-training of these pathways to improve the awareness of joint motion. Activities need to be aimed at all three levels of motor control: spine, brainstem and the higher centres, namely: the motor cortex, basal ganglia and cerebellum. The spinal level of control is responsible for reflex joint stabilisation. Enhancement of this neuromuscular mechanism probably occurs through dynamic joint stabilisation exercises of the lower limb. The brainstem is primarily responsible for the maintenance of posture and balance and is most likely trained by means of reactive neuromuscular activities. The higher control centres provide cognitive awareness of body position and movement where motor commands are initiated for voluntary movements. This mechanism is improved through kinaesthetic and proprioceptive training (Lephart et al., 1998).

The ultimate aim of the proprioceptive component is the promotion of dynamic joint and functional stability (Lephart et al., 1997).

Quadriceps Inhibition

Weakness of the quadriceps muscles is a common clinical finding in patients with anterior knee pain (Manal & Snyder-Mackler, 2000). There are a number of factors that may cause this quadriceps weakness. These include damage to the knee joint, muscle atrophy and reflex inhibition of the quadriceps (Stokes & Young, 1984). Reflex inhibition of the muscle, also referred to as arthrogenous muscle inhibition, is the inability to voluntarily contract the quadriceps muscle, and has been demonstrated in the presence of a painful knee, a knee in which there is chronic effusion, and a normal knee in which there is experimentally induced effusion (Antich & Brewster, 1986; Snyder-Mackler et al., 1994; Palmieri et al., 2003). Reflex inhibition is directly responsible for muscle weakness, and may also lead to muscle atrophy (Stokes & Young, 1984). General quadriceps weakness is often secondary to pain (Wild et al., 1982). Inhibition is difficult to measure, but measurement of maximal force output and EMG activity are indicators of the degree of inhibition (Wild et al., 1982; Antich & Brewster, 1986; Snyder-Mackler et al., 1994; Manal & Snyder-Mackler, 2000). Immobilisation, whether forced or voluntary, also leads to atrophy (Stokes & Young, 1984; Young, 1993). Muscle weakness predisposes the joint to further damage resulting in a vicious cycle of events (Wild et al., 1982; Stokes & Young, 1984; Young, 1993).

		Joint damage			
	↗	↓	↘		
Weakness	←	Reflex inhibition		←	Immobilisation
	↖	↓	↙		
		Muscle wasting			

(Young, 1993)

Afferent stimuli from the receptors located within and around the damaged knee joint inhibit activation of the alpha motor neurons found in the anterior horn of the spinal cord. The central pathway of the inhibitory stimuli is unknown.

The extensor strength deficits in patients with anterior knee pain, as detected by reduced muscle torque during isometric, concentric and eccentric contractions, may be due to reflex inhibition caused by afferent signals from the patellofemoral joint, possibly due to pain associated with the testing modality

(Thomee, 1997; Thomee et. al, 1999). The reduced torque was evidently more pronounced in the range close to full extension, and there was a difference in EMG activity between vastus medialis and rectus femoris muscles (Thomee, 1997).

Joint effusion is a major cause of inhibition. However, it is important to note that effusion is not always present in cases of inhibition. Research has shown that artificially induced effusion causes quadriceps inhibition (Kennedy et al., 1982; Wild et al., 1982; Stokes & Young, 1984; Young, 1993). In individuals presenting with effusion following menisectomy, it has been shown that aspiration of the effusion always reduces inhibition but does not completely eliminate it. Thus, it may be concluded that effusion is not the only cause of inhibition in those patients (Stokes & Young, 1984; Young, 1993). Even relatively small amounts of experimentally induced effusion result in substantial inhibition (Kennedy et al., 1982; Arno, 1990; Young, 1993). The effusion in normal knees was also shown to reduce the level of excitation of the quadriceps' anterior horn cells (Young, 1993). There are reports of bilateral quadriceps inhibition in patients with unilateral anterior cruciate ligament tears and patients with osteoarthritis. Palmieri et al. (2003) report that the neurophysiological mechanism resulting in this bilateral activation deficit remains unknown. They suggest that pain and inflammation activate a central response whereby general hyperexcitability in the spinal cord neurons occurs, as well as increased effectiveness of tonic descending inhibition which then counteracts the excitability of the spinal cord neurons.

If pain is present it may result in voluntary inhibition, whereby the patient is unwilling to maximally contract due to pain or the fear of pain (Stokes & Young, 1984; Rutherford, 1988; Powers et al., 1996). Reflex inhibition is a limiting factor in rehabilitation as it restricts full muscle activation, thus preventing restoration of muscle strength (Palmieri et al., 2003).

CHAPTER 3: METHODS AND PROCEDURES

Approval for the study was obtained from the University of Zululand's Faculty of Science and Agriculture Ethics Committee. All subjects and their parents completed an informed consent form prior to testing (Refer to Appendix 2).

SUBJECTS

A questionnaire was distributed to 9 local schools with permission from the headmaster of each school. Pupils between the ages of 10 and 17 years completed the questionnaire. Potential subjects for the intervention programme were recruited from an article that appeared in the local newspaper, referrals from doctors and from the results of the questionnaires completed by pupils at a number of local schools.

Skyline, lateral and antero-posterior view X-rays were taken of potential candidates. A physical examination by an orthopaedic surgeon determined patient eligibility. Subjects were between the ages of 10 and 17 years, 5 males and 18 females, with symptoms of non-traumatic anterior knee pain for more than one month. Subjects with the following conditions were excluded from the study: previously diagnosed ligamentous, meniscal, tendon, fat pad or bursae involvement; previous surgery; history of patella dislocation or subluxation; Osgood-Schlatter's disease; Sinding-Larsen-Johannsen disease.

RESEARCH GROUPS

Subjects were randomly allocated to either the control or experimental group. The control group (N=12) underwent a pre-testing and post-testing 21 days later, and were instructed to continue with normal everyday activity over the period. Refer to Appendix 7 for the testing proforma. The purpose of the control group was to determine whether any other factor besides the intervention programme could have been responsible for any changes observed in the parameters tested. Subjects were then offered the option of joining the intervention programme and thus forming part of the experimental group.

The experimental group (N=18) underwent a pre-testing, 18 day intervention programme, post-testing at 21 days and post-post testing 1 month post-intervention. All tests were carried out by the researcher and a trained research assistant.

The researcher collected the subjects after school and transported them to the testing laboratory at the University of Zululand. Subjects were instructed to wear a t-shirt, shorts and exercise shoes. Testing started at 14h30 and was completed by 16h00. Testing order followed that of the attached proforma (Appendix 7): history of knee pain; handedness; anthropometric measurements; flexibility; structural abnormalities; strength; proprioception; static stability and dynamic stability. The testing and intervention programme ran from June to December 2002.

ASSESSMENT PROTOCOL

A. Questionnaire

The questionnaire was designed based on information gleaned from a number of studies (Reider et al., 1981b; Galanty et al., 1994; Harrison et al., 1995). It contains 20 questions printed either in English or Afrikaans, aimed at discovering the level of physical activity, lower limb injury profile, and incidence, duration and severity of anterior knee pain. The age at onset of the pain is also included. (Refer to Appendix 1). The questionnaire was distributed to the various schools, and was completed under the guidance of either a researcher or the parents. All subjects who participated in the intervention programme also completed a questionnaire if they had not already done so.

B. Self-evaluation

1. Level of activity was measured using the Activity Rating Scale for Disorders of the Knee developed by Marx et al. (2001) (Refer to Appendix 3). The instrument is useful in assessing the general level of activity of the patient, not the most recent activity in the preceding days and weeks. Subjects were asked to indicate their peak level of activity in the past year to obtain a more accurate estimate of their baseline activity when actively participating in sport. Particular emphasis was placed on activities that are difficult for patients with knee conditions. The scale can be completed in a short time period and has demonstrated excellent construct validity (Marx et al., 2001).

2. Rating of disability using the Patient-Specific Functional Scale (PSFS) described by Chatman et al. (1997) (Refer to Appendix 4). The instrument aids clinicians in assessing the change in health or functional status of individual patients (Chatman et al., 1997; Westaway et al., 1998; Stratford et al., 2004). The PSFS should be administered at the initial assessment, prior to the assessment of any impairment measures. Patients were asked to identify up to five activities that they were experiencing difficulty with or were unable to perform because of their knee pain (Chatman et al., 1997; Westaway et al., 1998; Jolles et al., 2005). They were then asked to rate the current level of difficulty associated with each activity on an 11-point scale with the anchors, 0 (unable to perform activity) to 10 (able to perform activity at same level as before injury or problem) (Chatman et al., 1997; Westaway et al., 1998; Pietroban et al., 2002; Walker, 2004). The higher the score, the better the function (Westaway et al., 1998; Jolles et al., 2005). The scale was also used at re-assessments. As patients were asked to identify activities particular to their case, the PSFS is not a comprehensive measure of disability and was not designed to compare disabilities among patients. The scale is quick to administer and does not require special tools or training (Chatman et al., 1997; Jolles et al., 2005). Test-retest reliability is excellent, and it is a valid and responsive tool (Chatman et al., 1997; Pietroban et al., 2002; Walker, 2004; Jolles et al., 2005).

3. Rating of pain using a Visual Analogue Scale (VAS).
The VAS is a 10-cm horizontal line marked at 1-cm intervals, the ends of which define the minimum (no pain) and maximum (severe pain) of perceived pain (Thomee, 1997; Witvrouw et al., 2000; Crossley et al., 2002; Kane et al., 2005) (Refer to Appendix 5). Each subject indicated the intensity of their pain by making a mark on the line. Normal, least and worst pain experienced in the past week was measured (Harrison et al., 1995; Witvrouw et al., 2000; Crossley et al., 2002). The Visual Analogue Scale has been found to be a reliable and valid tool for measuring pain (Thomee et al., 1999; Kane et al., 2005). It has also been shown to be a valid indicator of pain changes in patients with anterior knee pain (Powers et al., 1996).

4. Overall improvement by the final session using the Scale for Change in Condition described by Harrison et al. (1995) (Refer to Appendix 6).
This 4-point scale was administered at the post-test and post-post-test, where patients indicated whether there was any change in their condition. The scale is useful for assessing the change in

functional status of individual patients (Harrison et al., 1995).

C. Handedness (Refer to Appendix 7)

The dominant hand and foot were recorded.

D. Anthropometric assessment (Refer to Appendix 7)

1. Height

   The stretch stature technique was used. The measurement was taken as the maximum distance from the floor to the vertex of the head with the head held in the Frankfort plane. The subject was barefoot and stood erect with heels together and arms hanging at the sides. The heels, buttocks, upper back and back of the head were in contact with the vertical wall. The subject was instructed to look ahead and take a deep breath. One tester ensured that the subject's heels were not elevated while the other applied a stretch force by cupping the subject's head and applying gentle traction alongside the mastoid processes. The first measurer then brought the headpiece firmly down and into contact with the vertex. The subject then stepped away from the wall, and the vertical distance from the floor to the headpiece was recorded (Gore, 2000).

2. Body Mass

   Taken on a beam-type balance and recorded to the nearest tenth of a kg.

3. Anthropometric measurement of leg length

   The distance between the trochanterion and external tibiale, and distance between external tibiale and lateral malleolus were measured to determine leg length (Steinkamp et al., 1993). Measurements were taken standing, to identify any functional limb length discrepancies (Holmes & Clancy, 1998). The landmarks were marked with the subject standing. Measurements were taken using large sliding calipers.

4. Anthropometric measurement of foot length

   The distance between the Acropodian and Pternion was measured on the standing subject using a sliding caliper. The caliper was held parallel to the long axis of the foot. The tester held the branch end of the caliper in the left hand and grasped the shaft with the second, third, and fourth digits of the right hand in opposition to the fifth digit while manipulating the cursor with the thumb. The sites were encompassed with minimal pressure (Gore, 2000).

E. Structural assessment (Refer to Appendix 7)

1. Flexibility

1.1 Hamstring: Straight Leg Hamstring Test

This test is commonly used to measure hamstring flexibility (SISA, 1998; Witvrouw et al., 2000). The subject lay supine on the plinth with one leg secured to the plinth to prevent hip flexion. The other leg was passively rotated about the hip joint as far as possible with the knee in full extension by the research assistant. The tester placed one hand anteriorly just below the knee and the other at the base of the ankle, keeping the knee fully extended. The researcher then measured the angle of hip flexion using a goniometer. The fulcrum of the goniometer was held over the greater trochanter, and the mobile arm was aligned with the midline of the femur using the lateral epicondyle as a reference point. The stationary arm of the goniometer was then aligned with the lateral midline of the pelvis. The angle measured was the angle of displacement from the horizontal. The procedure was repeated for both legs (SISA, 1998).

1.2 Quadriceps: Modified Thomas Test

This test was used to measure flexibility of the quadriceps muscles. The subject sat on the end of the plinth, and rolled back pulling both knees to the chest. This ensured that the pelvis was in posterior rotation and that the lumbar spine was flat on the plinth. The subject then lowered one leg towards the floor whilst holding the contralateral limb in maximum flexion with the arms. The angle of knee flexion was measured to determine the length of the quadriceps. The fulcrum of the goniometer was placed over the lateral epicondyle of the femur, the stationary arm of the goniometer was aligned with the lateral midline of the thigh using the greater trochanter as the reference point, and the mobile arm was aligned with the lateral midline of the fibula using the lateral malleolus as the reference point (SISA, 1998; Harvey, 1998).

1.3 Gastrocnemius: Straight Leg Gastrocnemius test

The patient was instructed to place the tested leg on a mark 0.6 meters from the plinth and to lean forward. The other leg was placed closer to the plinth for balance, and was bent. The tested leg was kept extended and the subject was instructed to maximally flex the tested ankle while keeping the heel on the ground (Witvrouw et al., 2000). The fulcrum of the goniometer was placed over the lateral malleolus, the fixed arm of the goniometer was aligned with the foot, and the mobile arm was aligned with the lateral midline of the fibula, using the lateral epicondyle of the femur as the reference point.

1.4 Iliotibial band: Ober's Test

The subject lay on the side with the hip and knee of the bottom leg flexed to flatten any lumbar lordosis and stabilise the pelvis (Kendall et al., 1993; Ruffin & Kinningham, 1993; Post, 1998). The knee of the top leg was held at a right angle and the hip was flexed to 90 degrees while fully abducted, brought into extension and allowed to adduct. The knee of the top leg should fall into adduction when released (Kendall et al., 1993; Ruffin & Kinningham, 1993). For normal length, the thigh drops approximately 10 degrees (Kendall et al., 1993). A tight iliotibial band prevents this from happening, causing the knee to remain abducted (Kendall et al., 1993; Ruffin & Kinningham, 1993; Post, 1998).

2. Q-angle

The subject stood with the feet together, knees extended and quadriceps muscle group relaxed (Livingston & Mandigo, 1998). Lines were drawn connecting the anterior superior iliac spine and the centre of the tibial tubercle with the geometric centre of the patella (Reider et al., 1981a; Holmes & Clancy, 1998; Arnheim & Prentice, 2000). A transparent, flexible plastic full circle goniometer was used to measure the Q-angle. The centre of the goniometer was placed at the midpoint of the patella. One arm of the goniometer was aligned with the line leading to the anterior superior iliac spine, and the other arm was aligned with the tibial tubercle (Caylor et al., 1993).

3. Valgus and varus stress tests

Valgus and varus stress tests reveal laxity of the medial and lateral collateral ligaments. The tests were performed with the subject supine, and the knee in 0 degrees and 30 degrees flexion. When testing the medial collateral ligament, the examiner's hand supported at the ankle, and the opposite hand applied a valgus force to the lateral aspect of the knee. The examiner assessed for the onset of pain, extent of valgus movement, and the end point. When testing the lateral collateral ligament, the tester's hands were reversed, and a varus force was applied to the medial aspect of the knee (Arnheim & Prentice, 2000; Brukner & Khan, 2002).

4. Test for the presence of crepitus

   Crepitus was felt for during passive knee flexion and extension.

5. Assessment of the lower leg and foot. The presence of the following was recorded:

   5.1 Genu valgum

   5.2 Genu varum

   5.3 Genu recurvatum

   5.4 Pes cavus/ planus

   5.5 Pronation/ Supination

F. Functional assessment (Refer to Appendix 7)

1. Strength

   1.1 Quadriceps

   1.2 Hamstring

   Measurements of maximal muscle strength were recorded using a hydraulically-braked closed kinetic chain knee flexion/extension machine attached to a static dynamometer. The Akron which was to be used to test isokinetic quadriceps and hamstring strength broke down beyond repair just prior to the commencement of testing. The closest testing device was 2 hours drive away, hence it was decided to modify a closed kinetic chain piece of rehabilitation equipment into a muscle strength testing device. The machine was tested on healthy subjects and the pilot study to determine test-retest reliability.

   Subjects were strapped into the seat and positioned by means of a goniometer to record the force generated during knee flexion and extension with the knee positioned at 90 degrees flexion. Subjects were given one practice trial, and then the highest value of three attempts was recorded. Subjects were given a 30-second rest break between attempts.

Figure 3: The testing of muscle strength

2. Proprioception: Measured on the Willknox wobbleboard placed on a flat wooden surface. Time spent unbalanced during a two minute period was recorded.

Figure 4: Testing proprioception on the Willknox wobbleboard

3. Static balance: The Stork Stand as described by Bosco & Gustafson (1983).

The subject stood on the dominant leg, placing the other foot flat on the medial aspect of the supporting knee, with the hands on the hips. At the signal to begin, the subject raised the heel of the supporting leg and attempted to maintain balance for as long as possible without moving the ball of the supporting foot or letting its heel touch the ground. Time, in seconds, was recorded from the time the heel was raised to the time the balance was lost or the hands were removed from the hips. Three trials were given, and the highest of three scores was recorded to the nearest second. A test-retest reliability coefficient of 0.87 was reported for the best of three trials given on different days (Bosco & Gustafson, 1983).

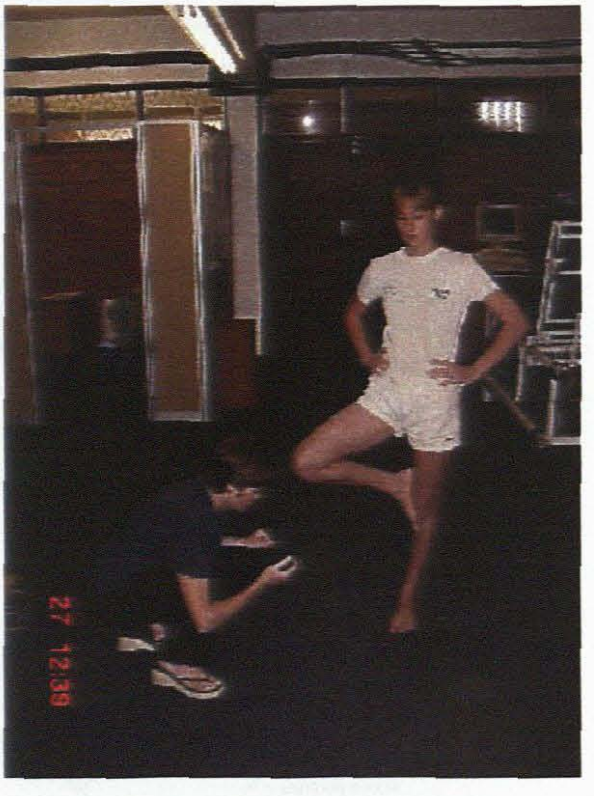


Figure 5: The Stork stand

4. Dynamic balance: Bass Test of Dynamic Balance as described by Bosco & Gustafson (1983). The subject stood with the right foot in the starting circle and leapt into the first circle with the left foot, then leapt from circle to circle, alternating feet (Refer to Figure 6). The subject must land on the ball of the foot, and not allow the heel to touch the ground. Errors were counted: each error counted as a penalty point every time it occurred. Errors included the following: 1) the heel touching the ground; 2) moving or hopping on the supporting foot while in the circle; 3) touching the floor outside a circle with the supporting foot; and 4) touching the floor with the free foot or any other part

of the body. The timer counted the seconds (up to five seconds) out loud, beginning the count as the subject landed in the circle. Counting was restarted if the performer leapt to the next circle in less than five seconds. If the subject spent more than five seconds in the circle, the extra time was deducted from the total time. Errors were counted silently and cumulatively by the tester who followed the subject closely. A total of five trials were given, three of which were practice runs. The score of the better of the last two trials was the recorded score. The final score was the total time plus 50, minus three times the total errors. The greater the time taken and the fewer the errors, the better the score. A reliability coefficient of 0.95 was obtained with female college students as subjects. The test is easy to administer and is applicable to both sexes and various age groups (Bosco & Gustafson, 1983).

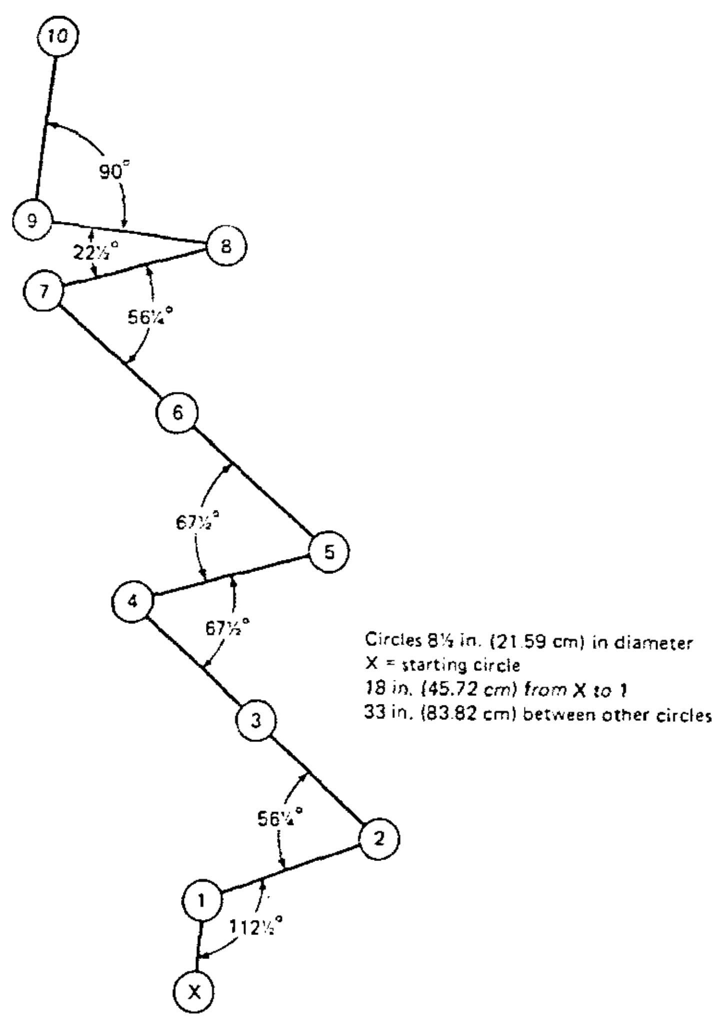


Figure 6: Layout for Bass Test for assessing dynamic stability

(Bosco and Gustafson, 1983 p122)

INTERVENTION PROGRAMME

The programme included muscle strength training, proprioceptive work and dynamic stability training (Refer to Appendix 8). Knee flexion and extension exercises to strengthen the quadriceps and hamstring muscles were performed on a seated flexion-extension machine designed on isokinetic principles. The exercise was performed at 5 different resistance settings. Three sets of repetitions were performed at each resistance, with a 20-second rest between each set. The repetitions performed at the lowest resistance setting served as the warm-up. Subjects also performed wobbleboard exercises and a routine on the mini-trampoline. From the third session, subjects were progressively introduced to a functional jumping routine.

A home programme was given in the second contact session, and included flexibility and strength training exercises for the lower limb, which subjects were to follow concurrently with the rehabilitation programme (Refer to Appendix 9). The home programme was aimed at stretching and strengthening the lower limb as a whole, and included proprioception exercises. Flexibility training focused on static stretching of the calf, hamstring and hip flexor muscles. The muscle strengthening portion consisted of closed kinetic chain hip, knee and ankle exercises (step-ups; calf raises; toe raises; pelvic lift; leg curls), while the proprioceptive exercises involved maintaining balance on an unstable surface, such as a narrow plank. An exercise log was kept by subjects to enhance compliance (Refer to Appendix 10).

Subjects in general attended 5 contact sessions of approximately 45 minutes over the 21 day period. They were encouraged to continue with the home programme on their own on completion of the programme.

CHAPTER 4: RESULTS AND DISCUSSION

SECTION 1

THE INCIDENCE OF ANTERIOR KNEE PAIN AMONG ADOLESCENTS

1. Incidence of anterior knee pain

A total of 2414 questionnaires were distributed to nine local junior and high schools, of which 1870 were returned. The return rate was thus 77.5%. Thirty-four questionnaires were spoilt or completed by children younger than 10 years of age. 475 subjects were excluded as they had a history of traumatic knee injury, and an additional 147 were excluded as their answers on the questionnaire were inconclusive.

1.1 Percentage of total population affected and incidence in males versus females

Table 1. Number and percentage of subjects per category and per gender (N=1210)

Category	Number of subjects	Percentage of total subjects	Male		Female	
			N	%	N	%
Positive AKP	331.0	27.4	142.0	42.9	189.0	57.1
No knee pain	879.0	72.6	338.0	38.5	541.0	61.5

Results from the questionnaires indicate that 27.4% of adolescents who participated in the study had experienced non-traumatic anterior knee pain at some time between the ages of 10 and 17 years. This is comparable to the 20-40% reported in the literature for this age group (Kannus & Niittymaki, 1994; Heng & Haw, 1996; Johnson, 1997; Roush et al., 2000). Of this group, 42.9% was male and 57.1% was female. While this does indicate that more females than males were affected, the ratio is lower than that reflected in the literature. In some studies the ratio was reported to be as high as two to one in females versus males (Powers, 1998; Lichota, 2003).

1.2 Incidence of anterior knee pain according to age group

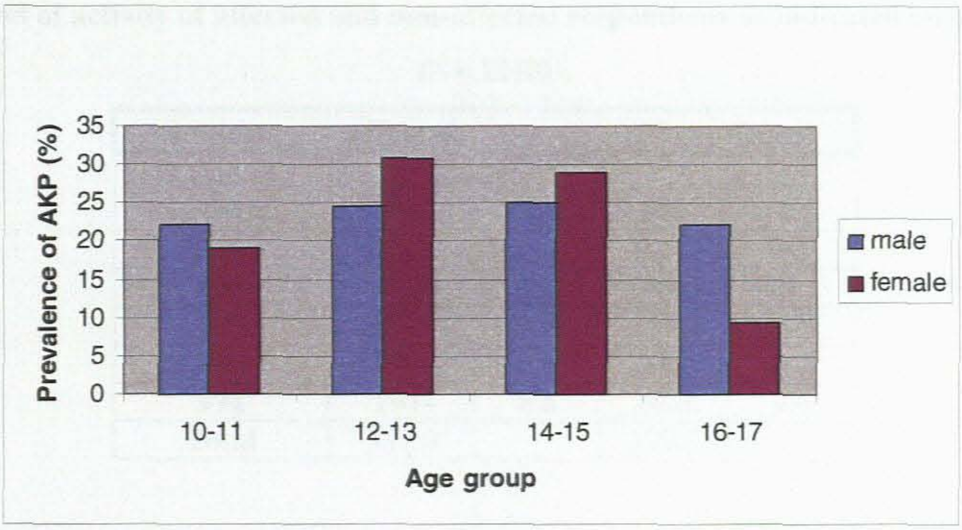


Figure 7: The prevalence of anterior knee pain per age group, represented as a percentage of all the respondents, as indicated on the knee pain questionnaire

The highest incidence of anterior knee pain in girls was at 13 years of age while in boys it was at 14 years of age. While the girls showed a definite peak in the incidence of anterior knee pain around 12 to 13 years, it was less defined for the boys. The highest incidence of anterior knee pain reported for 12 to 13 year old girls and 14 to 15 year old boys correlates with the period of the adolescent growth spurt. The growth spurt begins at roughly 10.5 to 11 years in girls, and 12.5 to 13 years in boys, and lasts for approximately 2 years. However, there is wide variation, and the spurt may occur anywhere between 10.5 and 16 years of age (Sinclair, 1989).

1.3 Knee affected by condition

Of the subjects that reported anterior knee pain, 21% experienced it in the left knee only, 34% in the right knee only and 45% bilaterally. The literature supports this finding, stating that the condition tends to be bilateral (Powers, 1998; Lichota, 2003; Shea et al., 2003; Pollock, 2004).

1.4 Medical treatment sought

31% of subjects had visited a medical doctor because of their knee pain. 37% of the subjects had visited a Physiotherapist or Biokineticist, 43% of which reported that the intervention they received was successful.

2. Level of activity of respondents

Table 2: Level of activity of affected and non-affected respondents as indicated on questionnaire (N= 1210)

Subjects	Affected		Non-affected	
Level of activity	No.	%	No.	%
Never	20.0	6.1	141.0	16.0
<3x	169.0	51.1	484.0	55.1
3-4x	82.0	24.7	155.0	17.6
5-7x	31.0	9.4	59.0	6.7
>7x	29.0	8.8	40.0	4.6
Total	331.0		879.0	

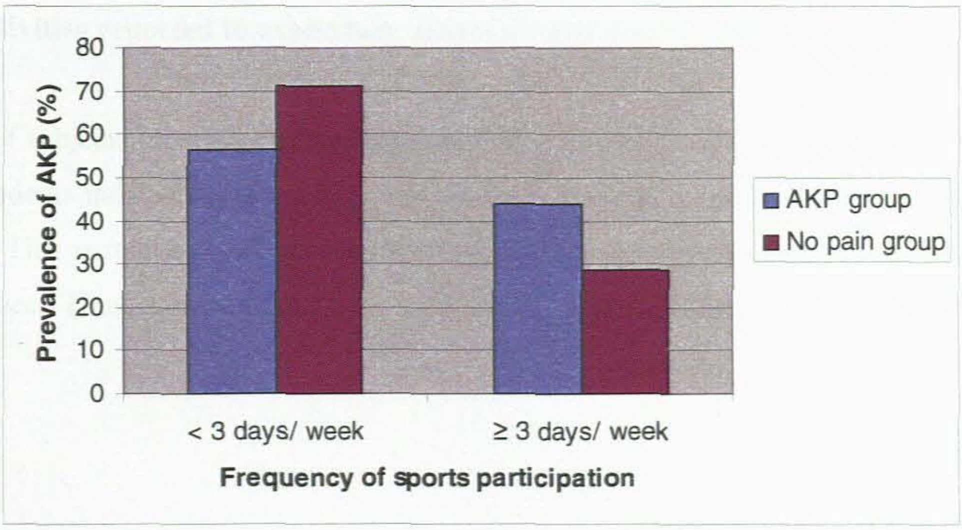


Figure 8: The prevalence of anterior knee pain compared with level of activity as indicated on the questionnaire

57.2% of the affected group and 71.1% of the non-affected group participated in sport less than 3 times per week. 42.9% of the affected group and 28.9% of the non-affected group participated in sport 3 or more times per week. Thus, while most respondents participated less then 3 times per week, those that participated more then 3 times per week appear more likely to experience anterior knee pain. Thus, a greater percentage of respondents with anterior knee pain than those without were active at least 3 times per week for at least 30 minutes per session.

3. Activities exacerbating condition

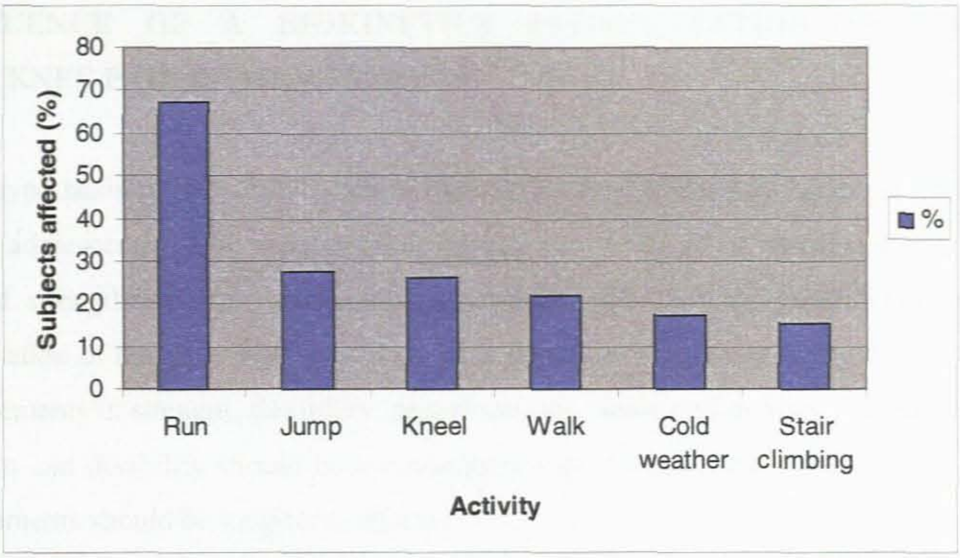


Figure 9: Activities reported to exacerbate anterior knee pain as indicated on the questionnaire

82% of subjects reported that the pain interfered with their sport participation. The majority of respondents indicated that running, followed by jumping, was a major source of increased knee pain. This is relevant as both running and jumping are essential components of most sporting activities. Thus, alleviating the knee pain would result in greater sports participation.

SECTION 2

THE INFLUENCE OF A BIOKINETICS REHABILITATION PROGRAMME ON ANTERIOR KNEE PAIN IN ADOLESCENTS

The general hypothesis of this study is that a biokinetics rehabilitation programme alleviates anterior knee pain in adolescents. The rehabilitation programme is aimed at stabilising the knee joint by stretching and strengthening the involved musculature, and improving proprioception of the lower limb. Stabilisation of the knee joint should result in decreased subjective rating of pain and disability. Thus, improvements in strength, flexibility, proprioception, static and dynamic balance, and subjective ratings of pain and disability should be a consequence of the biokinetics programme. Furthermore, these improvements should be long-term effects.

1. Baseline Descriptive Data and Characteristics of the Subjects of the Experimental and Control groups.

1.1 Age, height, weight and level of body fat

Table 3: Descriptive data of the control (N=12) and experimental (N=18) groups

		Age (yrs)	**Height (m)**	**Weight (kg)**	**Body fat (%)**
Control	Mean	14.6	1.7	63.6	19.5
	SD	1.9	0.1	16.4	7.3
Experimental	Mean	14.0	1.6	57.9	19.9
	SD	1.4	0.1	12.2	7.0
Difference (%)		-4.1**	-5.9**	-9.0**	2.1**

(**= p>0.05)

There is a strong similarity between the control and experimental groups. While the control group was slightly older, taller and heavier, these differences were not significant ($p>0.05$).

1.2 Duration of anterior knee pain

Table 4: Mean duration of anterior knee pain as reported by the control (N=12) and experimental (N=18) groups

		Duration of pain (months)
Control	Mean	15.6
	SD	14.5
Experimental	Mean	16.2
	SD	13.6

Both groups had a mean duration of anterior knee pain in excess of 1 year prior to commencing with the rehabilitation programme. The literature reports that the condition can take up to 2 years to resolve, with symptoms improving with the reduction of rapid growth (Juhn, 1999; Patel & Nelson, 2000; Shea et al., 2003).

1.3 Dominant knee versus non-dominant knee

Table 5: Injured knees in control (N=12) and experimental (N=18) groups

	Bilateral	Right	Left
Control	5	3	4
Experimental	7	6	5

There was no difference of injury in the dominant or non-dominant knee, as 11 of the control subjects and 16 of the experimental subjects claimed to be right-footed.

1.4 Q-angle

Table 6: Q-angles of the control (N=12) and experimental groups (N=18)

		Q-angle (R) (degrees)	**Q-angle (L) (degrees)**
Control	Mean	15.5	16.0
	SD	4.0	4.1
	Min	8.0	8.0
	Max	22.0	21.0
Experimental	Mean	14.6	14.7
	SD	4.4	4.3
	Min	7.0	8.0
	Max	22.0	21.0

The normal range for Q-angles is 10 to 20 degrees (Reider et al., 1981a; Livingston & Mandigo, 1998; Arnheim & Prentice, 2000). As the minimum and maximum values for the control and experimental groups indicate, not all subjects fell within this range. According to the literature this is an indication of patella maltracking, which can cause symptoms of anterior knee pain (Arnheim & Prentice, 2000).

1.5 Level of activity

Table 7: Mean activity levels according to the Activity Rating Scale (Marx et al., 2001) of the control (N=12) and experimental (N=18) groups

		Activity Level (Total)	Activity Level (Females)	Activity Level (Males)
Control	Mean	12.4	12.2	13.0
	SD	2.0	2.2	1.7
Experimental	Mean	13.1	13.0	13.3
	SD	2.2	2.4	1.5

The above table indicates the average level of activity for the control and experimental groups according to the Activity Rating Scale designed by Marx et al. (2001). The scores indicate that on average both groups participated in activities involving twisting, cutting and decelerating three times per week. There is a strong similarity between the groups.

1.6 Activities exacerbating anterior knee pain

Table 8: Activities most-commonly reported by subjects to cause pain on the Patient-Specific Functional Scale (Chatman et al., 1997)

Activity	Experimental (N=18)	Control (N=12)
Run	94.4%	91.7%
Jump	55.6%	66.7%
Stairclimbing	55.6%	41.7%
Sit	38.9%	41.7%
Sit cross-legged	22.8%	25.0%
Twist	16.7%	16.7%

Running was the most commonly cited activity exacerbating knee pain in both the control and experimental groups. Both running and jumping are integral components of most sports codes. Improved ability to perform these activities results in improved ability to perform sporting and everyday activities.

2. Subjective Ratings of Pain and Disability of the Control and Experimental Groups in the Pre-, Post- and Post-post Tests

Pain in the anterior region of the knee is the symptom common amongst all subjects. The pain results in decreased ability, and/or reluctance to perform certain activities. Thus, a real measure of improvement in condition as experienced by the subjects would be decreased pain and an associated improvement in function.

2.1 Subjective Ratings of Pain

Table 9: Baseline values of pain as indicated on a Visual Analogue Scale (VAS) for the control (N=12) and experimental (N=18) groups

	Pain	Worst	Least	Normal
Control	Mean	6.6	2.5	4.6
	SD	0.9	0.9	1.4
Experimental	Mean	7.1	3.3	5.4
	SD	1.2	1.8	1.9
Difference (%)		7.6**	32.0**	17.4**

(**= p>0.05)

The groups are similar in their ratings of pain as there is no significant difference between the two groups ($p>0.05$). It would appear that there is a large difference in the reported 'Least

Pain', but it is not significant and is probably due to the low values reported. The experimental group did report higher levels of pain than the control group in all three categories.

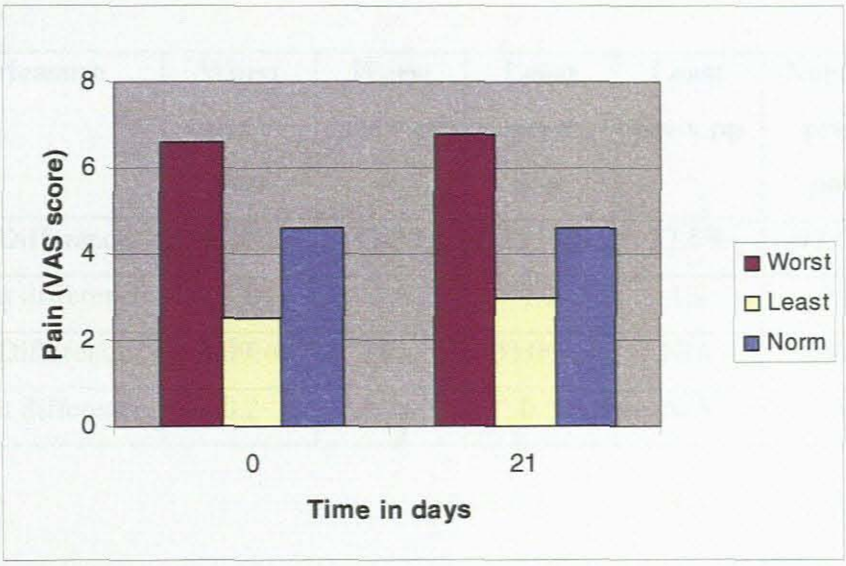
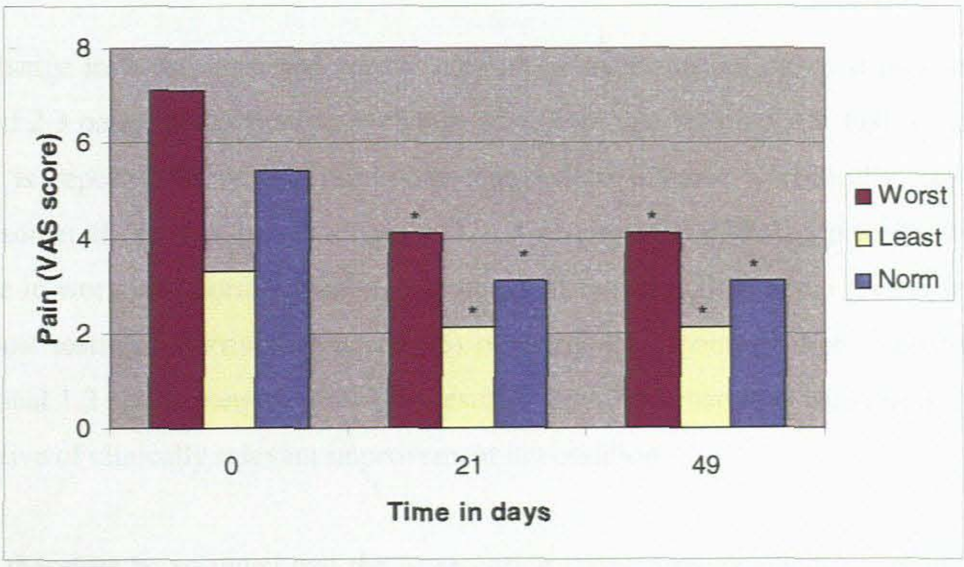


Figure 10: The control group's mean ratings of worst, least and normal pain as indicated on a visual analogue scale at the pre- and post-testing (N=12)



(*=p<0.01)

Figure 11: The experimental group's mean ratings of worst, least and normal pain as indicated on a visual analogue scale at the pre, post- and post-post testing (N=18)

Table 10: Percentage change and change in scores of mean ratings of worst, least and normal pain as indicated on a VAS at the post- and post-post testing, for the control (N=12) and experimental (N=18) groups

Group	Measure	Worst pre v post	Worst pre v pp	Least pre v post	Least pre v pp	Normal pre v post	Normal pre v pp
Exp	% Difference	-43.0%*	-42.8%*	-35.3%*	-37.5%*	-42.0%*	-41.6%*
	Point difference	3.0	3.0	1.2	1.2	2.3	2.3
Control	% Difference	3.0%**	N/A	20.0%**	N/A	0%**	N/A
	Point difference	0.2	N/A	0.5	N/A	0	N/A

(*= p<0.01)

(**= p>0.01)

There was a significant improvement in worst, least and normal pain ratings of the experimental group at the post-testing, and this was maintained at the post-post testing ($p<0.01$). There was no significant change in the control group, however the worst and least pain did increase at the post-test ($p>0.01$).

The change in worst, least and normal pain in the experimental group at post-testing was 3.0, 1.2 and 2.3 points respectively. A change of 1.0cm on a 10-cm VAS, that is a difference of 1 point, is reported to be the minimum required to indicate a clinically important change (Harrison et al., 1995; Crossley et al., 2002). Crossley et al. (2002) reported a 4- and 3.5 point change in worst and normal pain after 6 weeks of rehabilitation, and a greater improvement at post-post testing. Harrison et al. (1995) reported a 1.1 point change at post-testing and an additional 1.2 point change at post-post testing. Thus, the change in pain ratings in this study is indicative of clinically relevant improvement in condition.

It can therefore be assumed that the intervention programme resulted in a reduction in pain in the subjects, which was maintained after completion of the programme.

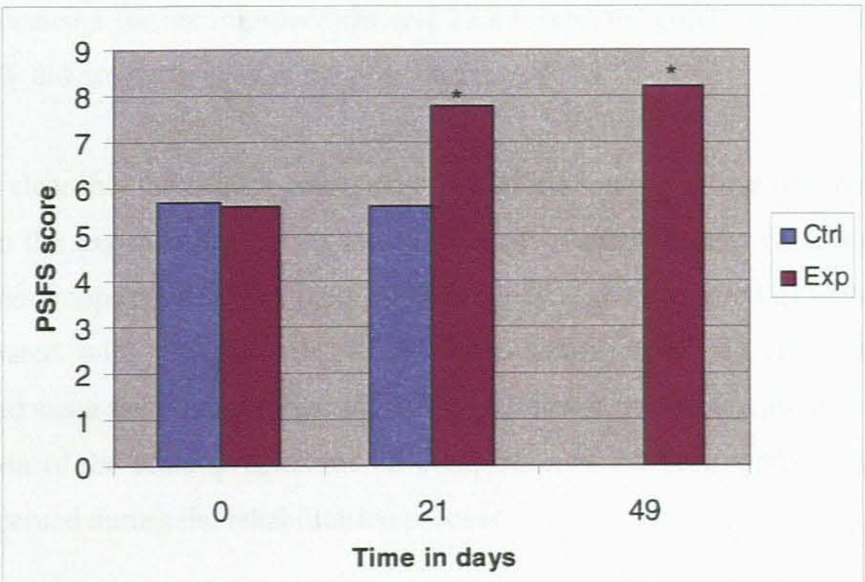
2.2 Subjective Ratings of Disability

Table 11: Baseline values of disability as indicated on the Patient-Specific Functional Scale (Chatman et al., 1997)

		PSFS
Control	Mean	5.7
	SD	1.2
Experimental	Mean	5.6
	SD	1.4
Difference(%)		1.8**

(**= p>0.05)

At the pre-test the control and experimental groups were very similar with respect to levels of disability experienced due to knee pain. There was no significant difference between the groups (p>0.05).



(* = p<0.01)

Figure 12: Mean ratings of ability to perform various activities as indicated on the Patient-Specific Functional Scale (Chatman et al., 1997) at the pre, post- and post-post testing of the control (N=12) and experimental (N=18) groups

The intervention programme resulted in a significant improvement in the ability of the subjects from the experimental group to perform activities indicated by individual subjects on the Patient-Specific Functional Scale ($p<0.01$). No such change occurred in the control group ($p>0.01$). Subjects indicated particular activities which they were experiencing difficulty with due to their knee pain. On completion of the intervention programme, subjects reported a greatly improved ability to perform these same activities. This reduced disability was maintained at the post-post testing ($p<0.01$). Thus, it would appear that participation in the intervention programme resulted in decreased disability due to anterior knee pain, which was maintained in the long-term.

3. Change in condition

75 % of the control group indicated that there was no change in their condition at the post-test, while 25% indicated that their condition was worse than at the pre-test. 66.7% of the experimental group indicated that their condition was improved at the post-test, and 33.3% indicated that their condition was greatly improved. At the post-post test 16.7% indicated that their condition had deteriorated since the post-test, 11.1% reported no change in condition, 27.8% indicated a further improvement and 27.8% reported good improvement since the post-test. 16.7% did not participate in the post-post test.

Thus, it is clear that the control group experienced the same or worse pain over the period. All subjects in the experimental group indicated improvement in their condition at the post-test. Most of the group reported that their condition was at least as good or better at the post-post test compared with the post-test. A small percentage indicated that their condition had deteriorated since the post-test, but was still much better than at the pre-test. This supports the continuation of the home programme on completion of the programme so as to maintain the benefits accrued during the rehabilitation process.

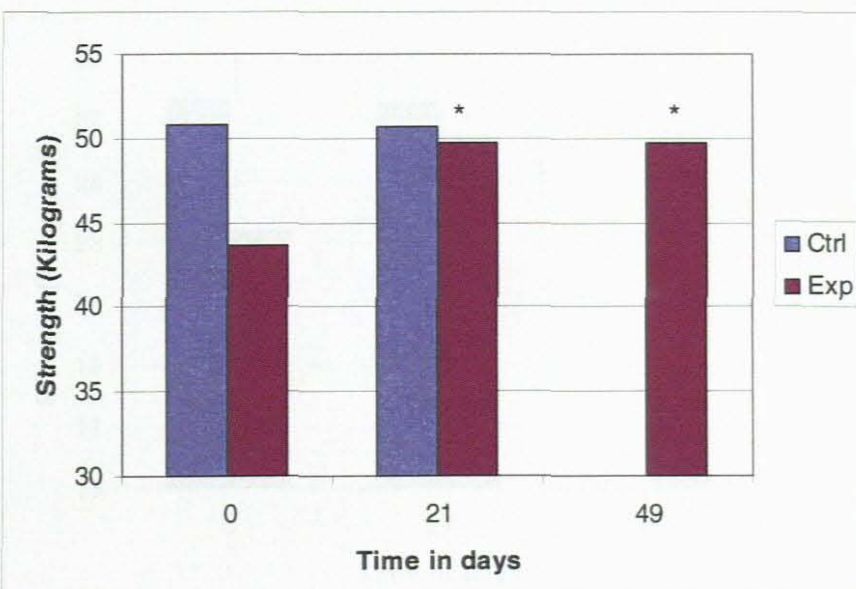
4. Structural and Functional Variables Measured

The following structural and functional variables were measured during testing. Changes in these variables were assumed to account for the change in condition.

4.1 Muscle strength

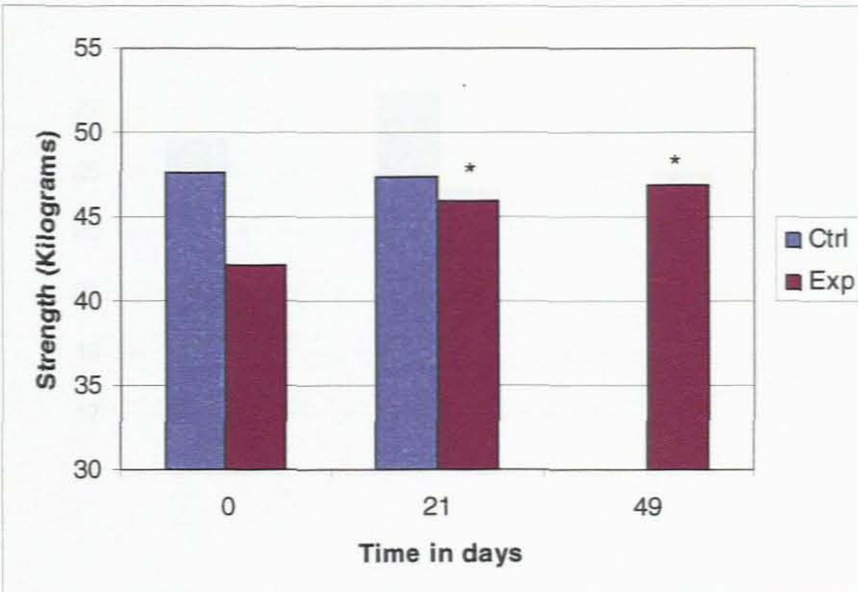
Table 12: Baseline values of mean muscle strength and percentage difference of the control (N=12) and experimental (N=18) groups

		R Quads pre (kg)	L Quads pre (kg)	R Hams pre (kg)	L Hams pre (kg)
Control	Mean	50.8	47.6	27.7	26.0
	SD	18.1	14.1	9.6	10.1
Experimental	Mean	43.6	42.1	23.4	21.2
	SD	10.8	9.8	4.9	4.5
Difference (%)		-14.2	-11.6	-15.5	-18.5



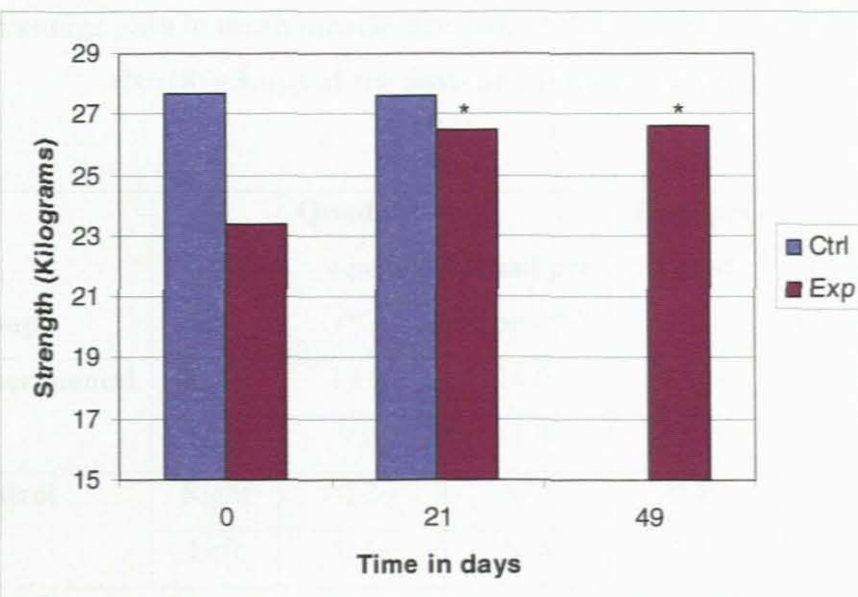
(* = p<0.01)

Figure 13: Mean values of right quadriceps strength of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing



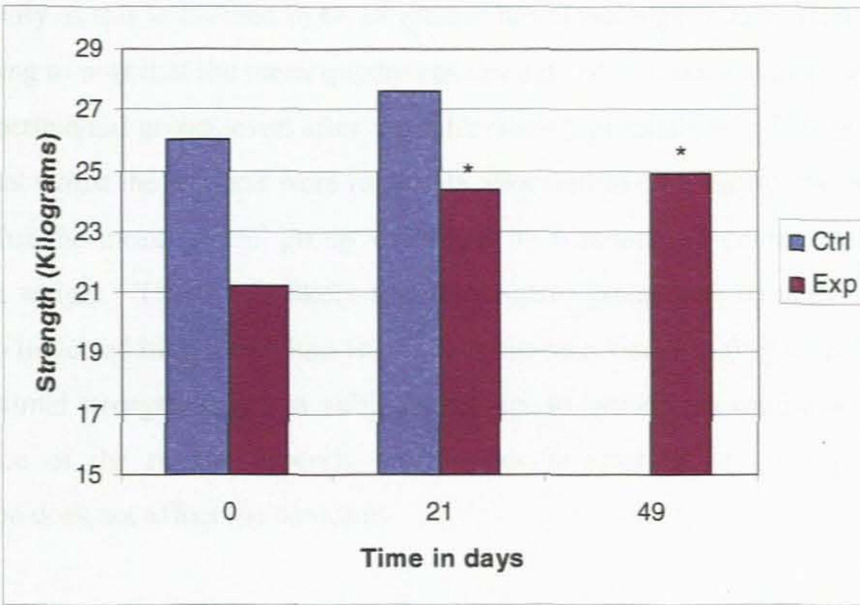
(* = p<0.01)

Figure 14: Mean values of left quadriceps strength of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing



(* = p<0.01)

Figure 15: Mean values of right hamstring strength of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing



(* = p<0.01)

Figure 16: Mean values of left hamstring strength of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing

Table 13: Percentage gain in mean muscle strength of the control (N=12) and experimental (N=18) groups at the post- and post-post testing

Group	Side	Quad pre v post (%)	Quad pre v pp (%)	Ham pre v post (%)	Ham pre v pp (%)
Experimental	Right	14.0*	14.0*	13.2*	13.7*
	Left	9.0*	11.4*	15.1*	17.5*
Control	Right	-0.2**	N/A	-0.4**	N/A
	Left	-0.4**	N/A	-2.7**	N/A

(* = p<0.01)
(**= p>0.01)

There was a significant gain in muscle strength in both the quadriceps and hamstring muscle groups at the post- and post-post testing of the experimental group (p<0.01). There was no significant change in the control group (p>0.01). Strength testing was performed as a closed chain activity as this is deemed to be of greater functional significance (Roush et al., 2000). It is interesting to note that the mean quadriceps strength of the control group was higher than that of the experimental group, even after the intervention programme. This is most likely due to the fact that whilst the subjects were randomly allocated to each group, the descriptive statistics indicate that the mean control group was older by 6 months, 4 centimetres taller and 3.5 kg heavier in weight. Thus, it is likely that the control group was stronger. The experimental group also indicated higher baseline values for pain on a visual analogue scale, which can result in submaximal strength scores as subjects attempt to avoid pain during testing. Because the significance of the results depends on changes in strength and not initial strength, this observation does not affect the outcome.

The right quadriceps and hamstring muscle groups were stronger for both the control and experimental groups. This reflects right-sided dominance as 11 out of 12 and 16 out of 18 subjects in the control and experimental groups respectively indicated that they were right-footed. The percentage increase in muscle strength of the experimental group ranged between 9.0 and 17.5%. While there is a dearth of literature with actual strength figures, this value does concur with other studies. A number of studies measured changes in isometric strength following a training or rehabilitation programme. Changes in strength ranged from 10.0 to 37% after 8 to 12 weeks, depending on the training regimen (Rutherford, 1988; Thomee, 1997; Clark et al., 2000; Smith & Bruce-Low, 2004). The aforementioned studies ran for a much longer time period than the current study, however, Rutherford (1988) reported a 5% improvement in isometric quadriceps strength after 2 weeks of strength training, while Maitland et al. (1993) reported 10.0 to 16% improvement after 25 days of training. Thomee (1997) noted continued strength improvement by an additional 7.0% at a 6 month follow-up. While the actual results of this study cannot be compared with the aforementioned studies due to different testing procedures, the percentage gain in muscle strength can be compared.

In the current study concentric muscle strength was measured. Again, the strength improvements obtained with the Biokinetics programme concur with the literature. Smith & Bruce-Low (2004) cited a study where the 1-repetition maximum was measured, and reported a 5.5 – 11.6% increase after 10 weeks of training. Thomee (1997) reported a 12.0% increase in concentric muscle strength at 3 months follow-up and 17.0% increase at 12 months. Colak et al. (1998) reported improvements in quadriceps and hamstring concentric strength of 13.5 and 7.4% respectively after 4 weeks of training. Witvrouw et al. (2000) reported a 11.7% and 8.0% improvement in quadriceps strength and 16.7% and 14.0% improvement in hamstring strength at 5 weeks and 3 months respectively, after following an open kinetic chain rehabilitation programme for 5 weeks.

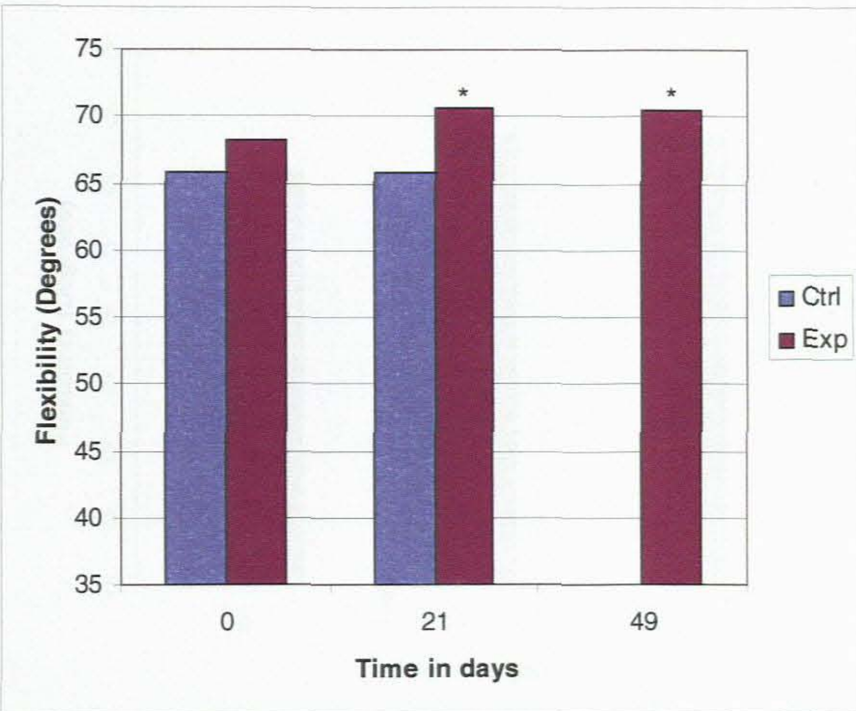
Initially the increase in strength is due to more efficient activation of the muscle. Thus, the changes are the result of improvements in the neuromuscular system, especially within the first 4 weeks of training, rather than muscle hypertrophy (BASES, 2002; Deschenes & Kraemer, 2002; Singh, 2002). Singh (2002) reported improvements of 20.0 to 40.0% in strength during the first few weeks of training without a significant improvement in muscle size. After 4 to 6 weeks of resistance training significant muscle fibre hypertrophy becomes evident (Deschenes & Kraemer, 2002). A study on prepubertal boys undergoing 10 weeks of training indicated increased motor unit activation of the elbow flexors by 9.0% and knee extensors of 12.0% (Benjamin & Glow, 2003).

During the initial testing, in order to avoid pain, subjects may not have given a maximal attempt which would truly reflect their strength. This fact coupled with improvements in the neuromuscular system and decreased inhibition would have accounted for the reasonably large improvement in muscle strength over a short time period. The above studies refer predominantly to adult improvements, which would be slightly different to values for adolescents. Due to the special circumstances of the strength test, actual values cannot be compared, but percentage improvement in strength can be compared. The rehabilitation programme nonetheless resulted in significant improvement in muscle strength values.

4.2 Muscle flexibility

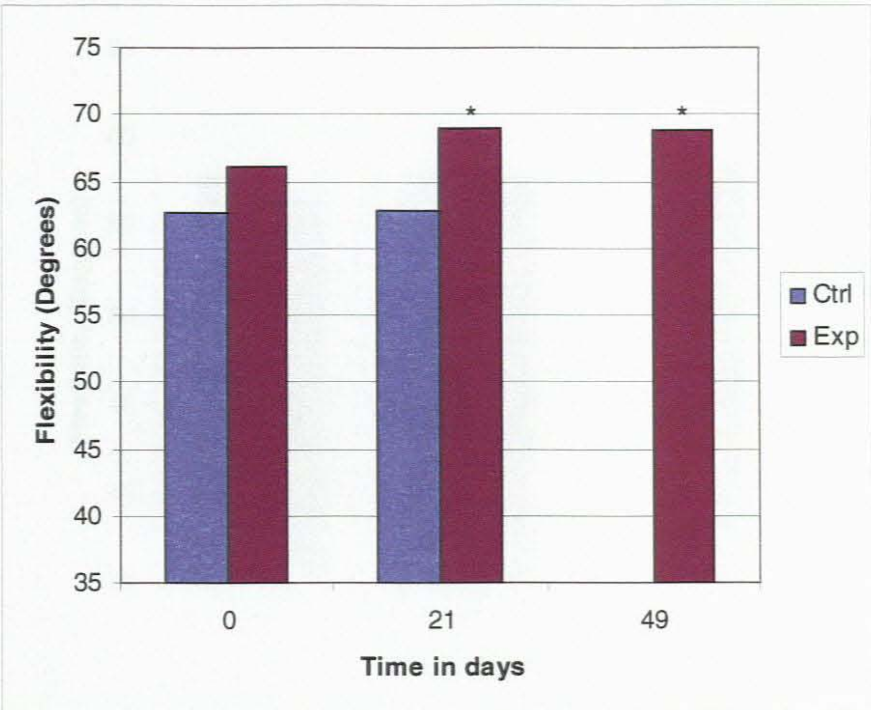
Table 14: Baseline mean muscle flexibility values and percentage difference of the control (N=12) and experimental (N=18) groups

Side	Group		Quads pre (°)	Hams pre (°)	Gastroc pre (°)
Right	Control	Mean	65.9	57.4	67.8
		SD	9.6	7.7	4.8
	Experimental	Mean	68.2	57.7	66.7
		SD	12.1	8.3	3.8
	Difference (%)		3.5	0.5	-1.6
Left	Control	Mean	62.6	58.0	69.6
		SD	10.3	5.5	6.2
	Experimental	Mean	66.1	56.5	66.8
		SD	10.8	8.0	6.0
	Difference (%)		5.6	-2.6	-4.0



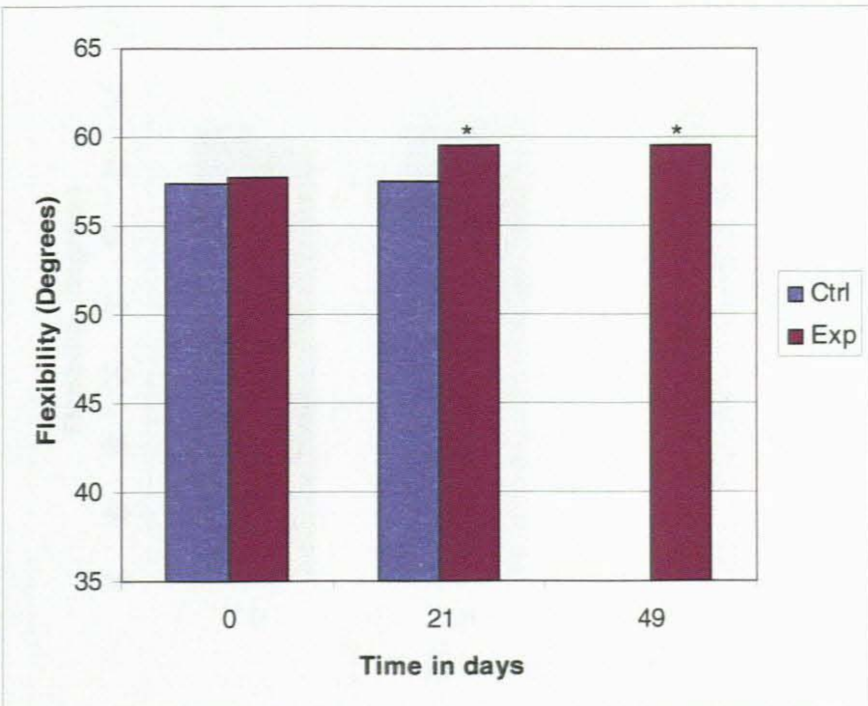
(*= p < 0.01)

Figure 17: Mean values of right quadriceps flexibility of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing



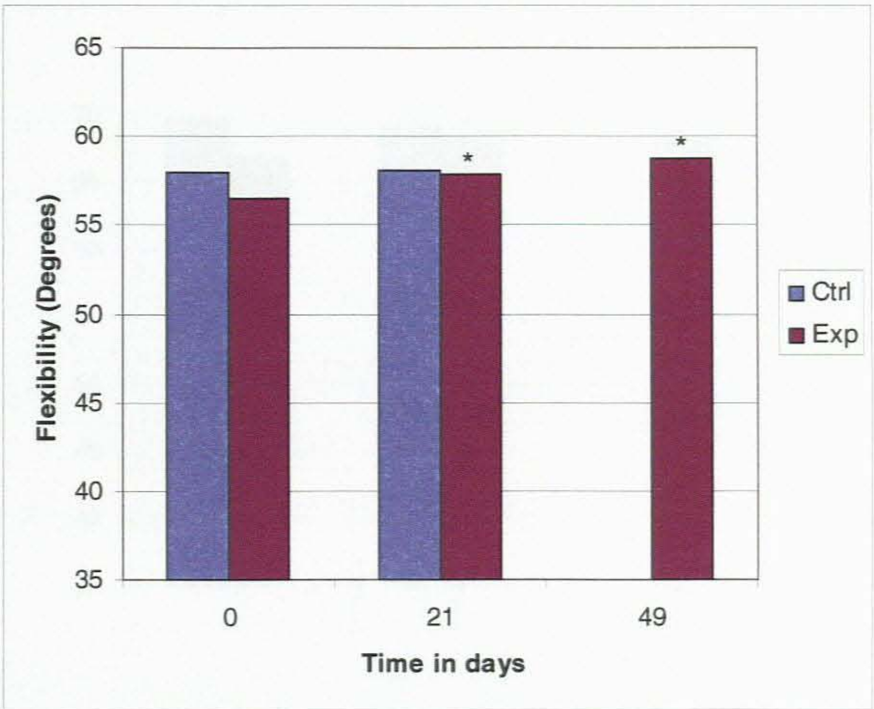
($* = p < 0.01$)

Figure 18: Mean values of left quadriceps flexibility of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing



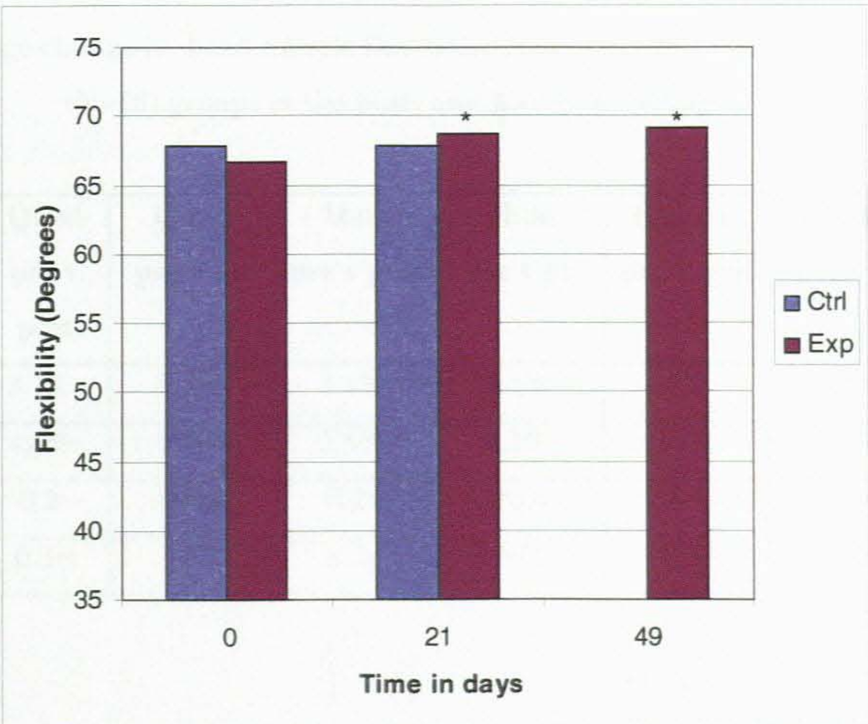
($* = p < 0.01$)

Figure 19: Mean values of right hamstring flexibility of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing



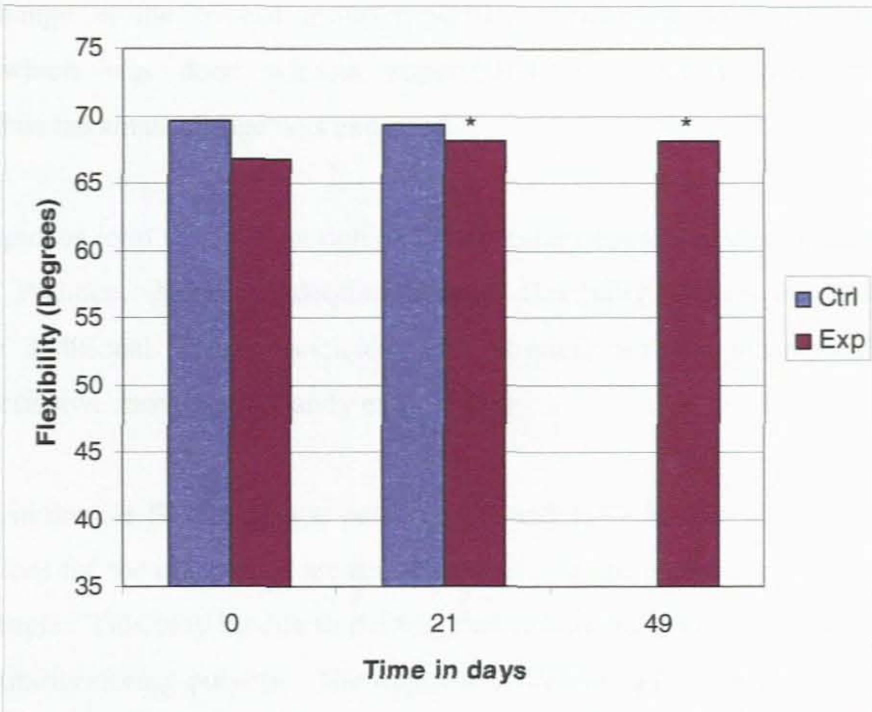
(*= $p < 0.01$)

Figure 20: Mean values of left hamstring flexibility of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing



(*= $p < 0.01$)

Figure 21: Mean values of right gastrocnemius flexibility of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing



(*= p < 0.01)

Figure 22: Mean values of left gastrocnemius flexibility of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing

Table 15: Percentage change in mean muscle flexibility of the control (N=12) and experimental (N=18) groups at the post- and post-post testing

Group	Side	Quad pre v post	Quad pre v pp	Ham pre v post	Ham pre v pp	Gastroc pre v post	Gastroc pre v pp
Exp	Right	3.7%*	3.4%*	3.1%*	3.1%*	3.0%*	3.7%*
	Left	4.4%*	4.1%*	2.5%*	4.1%*	2.2%*	2.2%*
Control	Right	-0.2**	N/A	0.2**	N/A	0**	N/A
	Left	0.3**	N/A	0.2**	N/A	-0.3**	N/A

(*= p < 0.01)

(**= p>0.01)

There was a small but significant improvement in quadriceps, hamstring and gastrocnemius flexibility of the experimental group at the post- and post-post testing (p<0.01). There was no significant change in the control group ($p>0.01$). Stretching formed part of the home programme which was done without supervision, concurrently with the intervention programme, thus the small change was expected.

Stretching improves joint range of motion and is necessary for successful physical performance (Arnheim & Prentice, 2000). Adequate muscle flexibility allows the muscle tissue to accommodate additional stress associated with physical activity more easily and allows efficient and effective movement (Bandy et al., 1998).

Improvement in muscle flexibility was between 2.2 and 4.4% for the different muscle groups. The actual values for the quadriceps are much greater than those reported by Harvey (1998) for adult sportspeople. This may be due to the fact that female adolescents go through a period of increased flexibility during puberty. The opposite is true for adolescent males, but they made up a small portion of the study (Chandy & Grana, 1985; Kibler & Chandler, 2003). The hamstring flexibility values are lower than those reported for junior athletes which were between 76.0 and 80.0° (Chandler et al., 1990). This is most likely as junior athletes follow a regular complete stretching programme for any number of months or years, while these subjects only stretched for a few weeks.

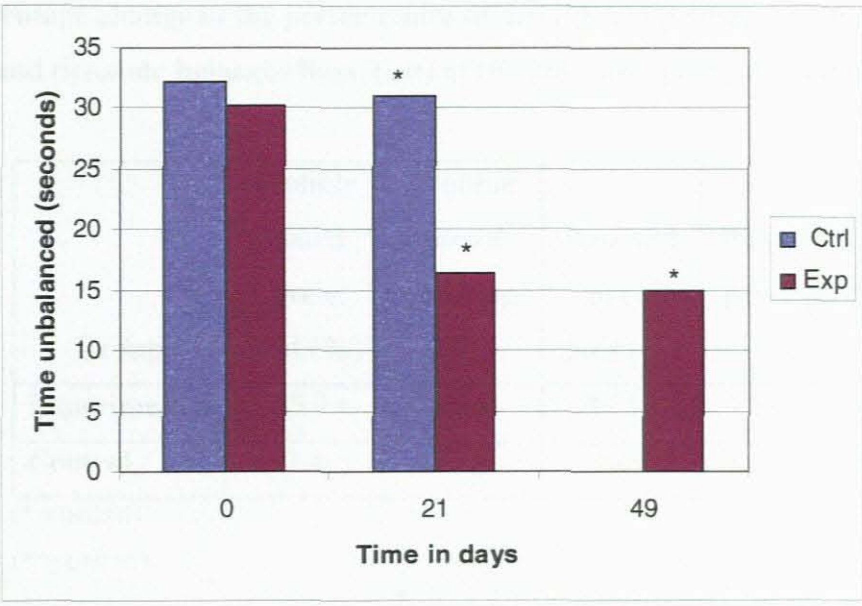
Piva (2005) reported the following improvements in flexibility in adults after 3 months: Quadriceps: 2.3%; Hamstrings: 3.7%; Gastrocnemius: 1.9%. Bandy et al. (1998) reported an 11.0% improvement in hamstring flexibility after 6 weeks of static stretching. Witvrouw et al. (2000) reported improvements of between 5.1% and 8.8% for quadriceps, hamstrings and gastrocnemius at 5 weeks post-testing and between 6.7% and 18.8% at 3 months post-post testing. Studies report varying changes in muscle flexibility in children of between 5.0 and 12.0% (BASES, 2002). Kibler and Chandler (2003) concur. Their findings in junior tennis players indicated an average 7.3% improvement in hamstring flexibility at 1 year follow up with subjects following the stretching programme twice per week. Bandy et al. (1998) reported greater increases after 6 weeks of varying protocols for static hamstring stretching, in the range of 23.8 to 26.9%. These improvements in flexibility are dynamic and reversible, and therefore the exercises need to be continued over an extended period of time to maintain the gains (Kibler & Chandler, 2003).

None of the studies available were run for as short a time period as the current study, but the results do appear to follow the trend evident in the literature. Thus, as there was no change in the control group, it can be stated that the rehabilitation programme resulted in improved flexibility of the quadriceps, hamstrings and gastrocnemius muscle groups. These improvements were maintained or improved further at the 1 month follow up.

4.3 Measures of Proprioception, Dynamic Balance and Static Balance

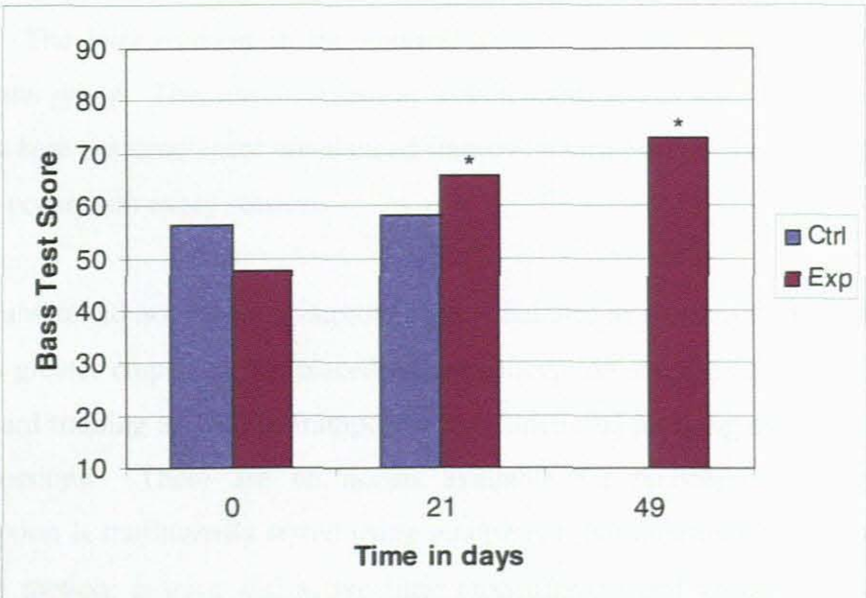
Table 16: Baseline values of proprioception as measured on the Willknox Wobbleboard, dynamic balance as measured using the Bass Test (Bosco & Gustafson, 1983), and static balance as measured with the Stork Stand (Bosco & Gustafson, 1983) of the control (N=12) and experimental (N=18) groups and the percentage difference between the groups

		Wobble board (sec)	Bass test	Stork stand R (sec)	Stork stand L (sec)
Control	Mean	32.2	56.4	10.7	7.2
	SD	13.4	15.1	6.5	4.0
Experimental	Mean	30.3	47.7	9.5	6.3
	SD	13.5	17.1	7.0	3.6
Difference (%)		-5.9	-15.4	-11.2	-12.5



(*= p < 0.01)

Figure 23: Mean wobbleboard scores of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing, as measured by recording time in seconds unbalanced on the Willknox Wobbleboard



(*= p < 0.01)

Figure 24: Mean Bass Test scores of the control (N=12) and experimental (N=18) groups at pre-, post- and post-post testing as measured by the Bass Test (Bosco & Gustafson, 1983)

Table 17: Percentage change in the performance of activities of proprioception (wobbleboard) and dynamic balance (Bass Test) at the post- and post-post testing

Group	Wobble board pre v post (%)	Wobble board pre v pp (%)	Bass test pre v post (%)	Bass test pre v pp (%)
Experimental	-45.9 *	-50.8*	37.5 *	53.2*
Control	-3.4*	N/A	3.4**	N/A

(* = p<0.01)

(**= p>0.01)

There was a large significant improvement in both proprioception and dynamic balance of the experimental group at the post- and post-post testing (p<0.01). While there was an overall improvement in performance of the Stork Stand at the post- and post-post testing, it was not significant (p>0.01). There was no significant change in the bass test and stork stand in the control group (p>0.01), but there was a very small significant change in the wobbleboard scores (p<0.01). The improvement in the control group was much smaller than that seen in the experimental group. This improvement in wobbleboard scores after just one session is seen in practice, where the time spent unbalanced improves with every session. A degree of learning must thus occur with every session.

The programme did not result in improved static balance as measured by the Stork Stand. This may be as greater emphasis was placed on proprioception and dynamic stability in the form of wobbleboard training as well as trampoline and functional jumping exercises in the supervised contact sessions. There are no norms available for wobbleboard scores. This is as proprioception is traditionally tested using equipment that measures the threshold to detection of passive motion, passive and active limb repositioning and visual estimation of a passive angle change (Lephart et al., 1998; Fuchs et al., 1999; Rozzi et al., 1999; Sharma, 1999; Arnheim & Prentice, 2000; Roberts et al., 2000; Hiemstra et al., 2001; Williams et al., 2001). These tests were not considered to give meaningful results within the spectrum of dynamic knee function as was the focus of this study. The noteworthy improvement in proprioception and dynamic balance is indicative of improved stability of the knee joint complex. These components are important for pain-free sport participation and the execution of activities of daily living. It is interesting to note that both these factors improved to an even greater extent at the post-post testing. This may be due to the fact that once the pain is reduced, subjects are able to return to sporting activities fully which further improves function.

It can thus be reasonably assumed that the rehabilitation programme resulted in improved proprioception, as measured on a wobbleboard, and dynamic stability, and continued improvement at the follow up testing.

There was 100% subject compliance with respect to the intervention programme and post-testing. Unfortunately there was a small drop-out of 16.7% of subjects in the experimental group who did not participate in the post-post test. This high compliancy is probably due to the fairly rapid results attained and the short duration of the intervention programme.

CHAPTER 5: CONCLUSION

The general hypothesis of this study, that a Biokinetics rehabilitation programme alleviates anterior knee pain in adolescents, can be accepted. The programme resulted in significantly reduced subjective ratings of pain and disability. There was an improvement in condition following completion of the programme. This improvement in condition can be attributed to the increase in strength, flexibility, proprioception and dynamic balance components tested. These variables improved as a consequence of the Biokinetics rehabilitation programme. Furthermore, the improvements were long-term effects.

There was a significant improvement in worst, least and normal pain ratings of the experimental group at the post-testing, and this was maintained at the post-post testing ($p<0.01$). The decrease in pain was in the range of 35.3 – 43.0% at the post- and post-post testing in comparison with the initial pain ratings. There was no significant change in the control group, however the worst and least pain did increase at the post-test ($p>0.01$). There was a significant improvement in the ability to perform activities indicated by individual subjects on the Patient-Specific Functional Scale ($p<0.01$). No such change occurred in the control group ($p>0.01$). On completion of the intervention programme subjects reported a greatly improved ability to perform the particular activities that they were previously experiencing difficulty with due to their knee pain. This reduced disability was maintained at the post-post testing ($p<0.01$). Thus, it would appear that participation in the intervention programme resulted in decreased pain and disability due to anterior knee pain, which was maintained in the long-term.

The control group indicated that there was either no change in their condition or that the condition was worse at the post-test. Thus, it is clear that the control group experienced the same or worse pain over the period. All subjects in the experimental group indicated improvement in their condition at the post-test. Most of the group reported that their condition was at least as good or better at the post-post test compared with the post-test. A small percentage indicated that their condition had deteriorated since the post-test, but was still much better than at the pre-test. This supports the continuation of the home programme on completion of the programme so as to maintain the benefits accrued during the rehabilitation process.

There was a significant gain in muscle strength in both the quadriceps and hamstring muscle groups at the post- and post-post testing of the experimental group ($p<0.01$). The percentage increase ranged between 9.0 and 17.5%. There was no significant change in the control group ($p>0.01$). The right quadriceps and hamstring muscle groups were stronger for both the control and experimental groups. This reflects right-sided dominance as 11 out of 12 and 16 out of 18 subjects in the control and experimental groups respectively indicated that they were right-footed.

There was a small but significant improvement in quadriceps, hamstring and gastrocnemius flexibility of the experimental group at the post- and post-post testing ($p<0.01$). There was no significant change in the control group ($p>0.01$). Improvement in muscle flexibility was between 2.2 and 4.4% for the different muscle groups. These improvements were maintained or improved further at the 1 month follow up.

There was a large significant improvement in both proprioception and dynamic balance of the experimental group at the post- and post-post testing ($p<0.01$). While there was an overall improvement in performance of the Stork Stand at the post-and post-post testing, it was not significant ($p>0.01$). There was no significant change in the Bass Test and stork stand in the control group ($p>0.01$), but there was a very small significant change in the wobbleboard scores ($p<0.01$). The improvement in the control group was much smaller than that seen in the experimental group. This improvement in wobbleboard scores after just one session is seen in practice, where the time spent unbalanced improves with every session. A degree of learning must thus occur with every session. The noteworthy improvement in proprioception and dynamic balance is indicative of improved stability of the knee joint complex. These components are important for pain-free sport participation and the execution of activities of daily living. Both these factors improved to an even greater extent at the post-post testing. This may be due to the fact that once the pain is reduced, subjects are able to return to sporting activities fully which further improves function. It can thus be reasonably assumed that the rehabilitation programme resulted in improved proprioception as measured on a wobbleboard, and dynamic stability, and continued improvement at the follow up testing.

Results from the questionnaires indicate that 27.4% of children in the study had experienced non-traumatic anterior knee pain at some time between the ages of 10 and 17 years. Of this group, 42.9% was male, 57.1% was female. In the experimental group, 5 subjects were male while 13 subjects were female. Thus, it seems that this study concurs with the literature, and that anterior knee pain is more prevalent among adolescent females than males.

According to the questionnaire results, a greater percentage of respondents with anterior knee pain than those without were physically active 3 times per week or more. 42.9% of the affected group participated in physical activity at least 3 times per week, compared with only 28.9% of the non-affected group. Thus, adolescents who are more physically active appear to be more affected by anterior knee pain.

No subjects withdrew from the study during the intervention programme. The high rate of improvement in pain and disability, and relatively short duration most likely account for this. Thus, it can be concluded that conservative treatment in the form of stretching, strengthening, proprioceptive and dynamic balance training, is a beneficial strategy for this common and often debilitating condition. In the context of South African health care, a structured biokinetics rehabilitation programme based on sound clinical and scientific principles has the potential to endear positive outcomes in the treatment of anterior knee pain.

REFERENCES

ANTICH, T.J. & BREWSTER, C.E. (1986). Modification of quadriceps femoris muscle exercises during knee rehabilitation. *Physical Therapy*, 66(8):1246-1251

ARNHEIM, D.D. & PRENTICE, W.E. (2000). *Principles of athletic training (10th ed.)*. Boston: McGraw-Hill.

ARNO, S. (1990). The A Angle: a quantitative measurement of patella alignment and realignment. *The Journal of Orthopaedic and Sports Physical Therapy*, 12(6):237-242

BANDY, W.D.; IRION, J.M. & BRIGGLER, M. (1998). The effect of static stretch and dynamic range of motion training on the flexibility of the hamstring muscles. *The Journal of Orthopaedic and Sports Physical Therapy*, 27(4):295-300

BARRETT, D.S. (1991). Proprioception and function after anterior cruciate ligament reconstruction. *Journal of Bone and Joint Surgery (Br)*, 73:833-837

BENJAMIN, H.J., & GLOW, K.M. (2003). Strength training for children and adolescents: what can physicians recommend? *The Physician and Sports Medicine*, 31: 19

BENNETT, J.G. & STAUBER, W.T. (1986). Evaluation and treatment of anterior knee pain using eccentric exercise. *Medicine and Science in Sports and Exercise*, 18:526-530

BIEDERT, R.M.; STAUFFER, E. & FRIEDERICH, N.F. (1992). Occurrence of free nerve endings in the soft tissue of the knee joint: A histologic investigation. *The American Journal of Sports Medicine*, 20(4):430-433

BIZZINI, M.; CHILDS, J.D.; PIVA, S.R. & DELITTO, A. (2003). Systematic review of the quality of randomized controlled trials for patellofemoral pain syndrome. *The Journal of Orthopaedic and Sports Physical Therapy*, 33(1):4-20

BORSA, P.A.; LEPHART, S.M.; IRRGANG, J.J; SAFRAN, M.R. & FU, F.H. (1997). The effects of joint position and direction of joint motion on proprioceptive sensibility in anterior cruciate ligament-deficient athletes. *The American Journal of Sports Medicine*, 25(3):336-340

BOSCO, J.S. & GUSTAFSON, W.F. (1983). *Measurement and evaluation in physical education, fitness, and sports*. New Jersey: Prentice-Hall

BRITISH ASSOCIATION OF SPORT AND EXERCISE SCIENCES (BASES) (2002). *Guidelines for Resistance Exercise in Young People*. Liverpool: REACH Group

BRODY, L.T. & THEIN, J.M. (1998). Nonoperative treatment for patellofemoral pain. *The Journal of Orthopaedic and Sports Physical Therapy*, 28(5):336-344

BRUKNER, P. & KHAN, K. (2002). *Clinical Sports Medicine (Revised 2nd ed.)*. Sydney: McGraw-Hills Co. Inc.

CALMBACH, W.L. & HUTCHENS, M. (2003). Evaluation of patients presenting with knee pain: Part II. Differential Diagnosis. *American Family Physician*, 68(5):907-912

CARSON, W.G.; JAMES, S.L.; LARSON, R.L.; SINGER, K.M. & WINTERNITZ, W.W. (1984). Patellofemoral disorders: Physical and radiographic evaluation. Part 1: Physical examination. *Clinical Orthopaedics and Related Research*, 185:165-177

CAYLOR, D.; FRITES, R. & WORRELL, T.W. (1993). The relationship between quadriceps angle and anterior knee pain syndrome. *The Journal of Orthopaedic and Sports Physical Therapy*, 17(1):11-16

CESARELLI, M.; BIFULCO, P. & BRACALE, M. (1999). Quadriceps muscles activation in anterior knee pain during isokinetic exercise. *Medical Engineering and Physics*, 21:469-478

CHANDLER, T.J.; KIBLER, W.B.; UHL, T.L.; WOOTEN, B.; KISER, A. & STONE, E. (1990). Flexibility comparisons of junior elite tennis players to other athletes. *The American Journal of Sports*

Medicine, 18(2):134-136

CHANDY, T.A. & GRANA, W.A. (1985). Secondary school athletic injury in boys and girls: A three year comparison. *The Physician and Sports Medicine*, 13(3):106-111

CHATMAN, A.B.; HYAMS, S.P.; NEEL, J.M.; BINKLEY, J.M.; STRATFORD, P.W.; SCHOMBERG, A. & STABLER, M. (1997). The Patient-Specific Functional Scale: Measurement properties in patients with knee dysfunction. *Physical Therapy,* 77(8):820-829

CLARK, D.I.; DOWNING, N.; MITCHELL, J.; COULSON, L.; SYZPRYT, E.P. & DOHERTY, M. (2000). Physiotherapy for anterior knee pain: a randomised controlled trial. *Annals of the Rheumatic Diseases*, 59:700-704

COLAK, S.; DJURDJEVIC, S. & RUDNJANIN, S. (1998). Isokinetic muscular training of pilots of combat aviation. *Physical Education*, 1(5):29-32

COWAN, S.M.; BENNELL, K.L.; CROSSLEY, K.M.; HODGES, P.W. & McCONNELL, J. (2002). Physical therapy alters recruitment of the vasti in patellofemoral pain syndrome. *Medicine & Science in Sports & Exercise*, 34(12):1879-1885

CROSSLEY, K.; BENNELL, K.; GREEN, S.; COWAN, S. & McCONNELL, J. (2002). Physical therapy for patellofemoral pain: A randomized, double-blinded, placebo-controlled trial. *The American Journal of Sports Medicine*, 30(6): 857-865

CROSSLEY, K.; COWAN, S.; McCONNELL, J. & BENNELL, K. (2005). Physical therapy improves knee flexion during stair ambulation in patellofemoral pain. *Medicine and Science in Sports and Exercise*, 37(2):176-183

CUTBILL, J.W.; LADLY, K.O.; BRAY, R.C.; THORNE, P. & VERHOEF, M. (1997). Anterior knee pain: A review. *Clinical Journal of Sports Medicine*, 7:40-45

DeHAVEN, K.E.; DOLAN, W.A. & MAYER, P.J. (1979). Chondromalacia patellae in athletes. *American Journal of Sports Medicine*, 7:5-11

DESCHENES, M.R. & KRAEMER, W.J. (2002). Performance and physiologic adaptations to resistance training. *American Journal of Physical Medicine and Rehabilitation*, 81(Suppl):S3-S16

DIFIORI, J.P. (1999). Overuse injuries in children and adolescents. *The Physician and Sports Medicine*, 27(1):75-89

DOUCETTE, S.A. & GOBLE, E.M. (1992). The effect of exercise on patellar tracking in lateral patellar compression syndrome. *American Journal of Sports Medicine*, 20: 434-440

DUGAN, S.A. (2005). Sports-related knee injuries in female athletes. What gives? *American Journal of Physical Medicine and Rehabilitation*, 84(2):122-129

DYE, S.F. (1996). The knee as a biologic transmission with an envelope of function: A theory. *Clinical Orthopaedics and Related Research*, 323: 10-18

DYE, S.F. (2004). Patello-femoral pain: A mosaic of pathophysiology. *SA Orthopaedic Journal*, 3(4):30-38

ERASMUS, P.J. (2004). Patello-femoral biomechanics. *SA Orthopaedic Journal*, 3(4):12-15

FAIRBANK, J.C.; PYNSENT, P.B. & PHILLIPS, H. (1984). Quantitative measurements of joint mobility in adolescents. *Annals of the Rheumatic Diseases*, 43:288-294

FUCHS, S.; THORWESTERN, L. & NIEWERTH, S. (1999). Proprioceptive function in knees with and without total knee arthroplasty. *American Journal of Physical Medicine and Rehabilitation*, 78(1):39-45

GALANTY, H.L.; MATTHEWS, C. & HERGENROEDER, A.C. (1994). Anterior knee pain in adolescents. *Clinical Journal of Sports Medicine*, 4:176-181

GORE, J.C. (2000). *Physiological Tests for Elite Athletes.* Champaign: Human Kinetics

HANTEN, W.P. & SCHULTHIES, S.S. (1990). Exercise effect on electromyographic activity of the vastus medialis oblique and vastus lateralis muscles. *Physical Therapy*, 70(9):561-565

HARRISON, E.; QUINNEY, H.; MAGEE, D.; SHEPPARD, M.S. & McQUARRIE, A. (1995). Analysis of outcome measures used in the study of patellofemoral pain syndrome. *Physiotherapy Canada*, 47(4):264-272

HARVEY, D. (1998). Assessment of the flexibility of elite athletes using the modified Thomas test. *British Journal of Sports Medicine*, 32:68-70

HENG, R.C. & HAW, C.S. (1996). Patello-femoral pain syndrome: Diagnosis and management from an anatomical and biomechanical perspective. *Current Orthopaedics,* 10:256-266

HIEMSTRA, L.A.; LO, I.K. & FOWLER, P.J. (2001). Effects of fatigue on knee proprioception: Implications for dynamic stabilization. *The Journal of Orthopaedic and Sports Physical Therapy*, 31(10):598-605

HIGGINS, S. (1991). Motor skill acquisition. *Physical Therapy*, 71(2):123-139

HILYARD, A. (1990). Recent advances in the management of patellofemoral pain: the McConnell programme. *Physiotherapy*, 76:559-565

HOLMES, S.W. & CLANCY, W.G. (1998). Clinical classification of patellofemoral pain and dysfunction. *The Journal of Orthopaedic and Sports Physical Therapy*, 28(5):299-306

HUSTON, L.J. & WOJTYS, E.M. (1996). Neuromuscular performance characteristics in elite female athletes. *The American Journal of Sports Medicine*, 24(4):427-436

INGERSOLL, C.D. & KNIGHT, K.L. (1991). Patellar location changes following EMG biofeedback or progressive resistive exercises. *Medicine and Science in Sports and Exercise*, 23:1122-1127

JACKSON, A.M. (1994). Mini-symposium: Lower limb problems in children. *Current Orthopaedics*, 8:83-93

JACOBSON, K.E. & FLANDRY, F.C. (1989). Diagnosis of anterior knee pain. *Clinics in Sports Medicine*, 8:179-195

JOHNSON, R.P. (1997). Anterior knee pain in adolescents and young adults. *Current Opinion in Rheumatology*, 9:159-164

JOLLES, B.M.; BUCHBINDER, R. & BEATON, D.E. (2005). A study compared nine patient-specific indices for musculoskeletal disorders. *Journal of Clinical Epidemiology*, 58: 791-801

JUHN, M.S. (1999). Patellofemoral pain syndrome: A review and guidelines for treatment. *American Family Physician*, 60(7):2012-2022

KAKARLAPUDI, T.K. & BICKERSTAFF, D.R. (2000). Knee instability: isolated and complex. *British Journal of Sports Medicine*, 34: 395-400

KANE, R.L.; BERSHADSKY, B.; ROCKWOOD, T.; SALEH, K. & ISLAM, N.C. (2005). Visual analog scale reporting was standardized. *Journal of Clinical Epidemiology*, 58: 618-623

KANNUS, P. & NIITTYMAKI, S. (1994). Which factors predict outcome in non-operative treatment of patellofemoral pain syndrome? A prospective follow-up study. *Medicine and Science in Sports and Exercise*, 26:289-296

KARLSSON, J.; THOMEE, R. & SWARD, L. (1996). Eleven year follow-up of patello-femoral pain syndrome. *Clinical Journal of Sports Medicine*, 6:22-26

KARST, G.M. & JEWETT, P.D. (1993). Electromyographic analysis of exercises proposed for differential activation of medial and lateral quadriceps femoris muscle components. *Physical Therapy*, 73(5):286-295

KARST, G.M. & WILLETT, G.M. (1995). Onset timing of electromyographic activity in the vastus medialis oblique and vastus lateralis muscles in subjects with and without patellofemoral pain. *Physical Therapy*, 75:813-823

KENDALL, F.P.; McCREARY, E.K. & PROVANCE, P.G. (1993). *Muscles: Testing and Function (4th ed.)*. Baltimore: Williams & Wilkins

KENNEDY, J.C.; ALEXANDER, I.J. & HAYES, K.C. (1982). Nerve supply of the human knee and its functional importance. *The American Journal of Sports Medicine*, 10(6):329-335

KIBLER, W.B. & CHANDLER, T.J. (2003). Range of motion in junior tennis players participating in an injury risk modification program. *Journal of Science and Medicine in Sport*, 6(1):51-62

LARSON, R.L. & GRANA, W.A. (1993). *The Knee: Form, Function, Pathology & Treatment.* Philadelphia: W.B. Saunders Co.

LASKOWSKI, E.R.; NEWCOMER-ANEY, K. & SMITH, J. (2000). Proprioception. *Physical Medicine and Rehabilitation Clinics of North America*, 11(2):323-340

LATTANZIO, P.J.; PETRELLA, R.J.; SPROULE, J.R. & FOWLER, P.J. (1997). Effects of fatigue on knee proprioception. *Clinical Journal of Sport Medicine*, 7:22-27

LEPHART, S.M. & HENRY, T.J. (1995). Functional rehabilitation for the upper and lower extremity. *The Orthopedic Clinics of North America*, 26(3):579-592

LEPHART, S.M.; PINCIVERO, D.M. & ROZZI, S.L. (1998). Proprioception of the ankle and knee. *Sports Medicine*, 25(3):149-155

LEPHART, S.M.; PINCIVERO, D.M.; GIRALDO, J.L. & FU, F.H. (1997). The role of proprioception in the management and rehabilitation of athletic injuries. *The American Journal of Sports Medicine*, 25(1):130-137

LICHOTA, D.K. (2003). Anterior knee pain: symptom or syndrome? *Current Women's Health Reports,* 3:81-86

LIEB, F.J. & PERRY, J. (1968). Quadriceps Function. An anatomical and mechanical study using amputated limbs. *Journal of Bone and Joint Surgery*, 50A:1535-1548

LIVINGSTON, L.A. & MANDIGO, J.L. (1998). Bilateral Q angle asymmetry and anterior knee pain syndrome. *Clinical Biomechanics*, 14:7-13

MAITLAND, M.E.; LOWE, R.; STEWART, S.; FUNG, T. & BELL, G.D. (1993). Does Cybex testing increase knee laxity after anterior cruciate ligament reconstructions? *The American Journal of Sports Medicine,* 21(5):690-695

MALEK, M.M. & MANGINE, R.E. (1981). Patellofemoral pain syndromes: a comprehensive and conservative approach. *The Journal of Orthopaedic and Sports Physical Therapy*, 2(3):108-116

MANAL, T.J. & SNYDER-MACKLER, L. (2000). Failure of voluntary activation of the quadriceps femoris muscle after patellar contusion. *Journal of Orthopaedic & Sports Physical Therapy*, 30(11):654-663

MARX, R.G.; STUMP, T.J.; JONES, E.C.; WICKIEWICZ, T.L. & WARREN, R.F. (2001). Development and evaluation of an activity rating scale for disorders of the knee. *The American Journal of Sports Medicine*, 29(2):213-218

McCONNELL, J. (1993). Commentary. *Physical Therapy*, 73(5):295-297

McCONNELL, J. (1996). Management of patellofemoral problems. *Manipulation Therapy*, 1:60-66

McMULLEN, W.; RONCARATI, A. & KOVAL, P. (1990). Static and isokinetic treatments of chondromalacia patellae: a comparative investigation. *The Journal of Orthopaedic and Sports Physical Therapy*, 12:256-266

NATRI, A.; KANNUS, P. & JARVINEN, M. (1998). Which factors predict the long-term outcome in chronic patellofemoral pain syndrome? A 7-year prospective follow-up study. *Medicine and Science in Sports and Exercise*, 30:1572-1577

NIMON, G.; MURRAY, D.; SANDOW, M. & GOODFELLOW, J. (1998). Natural history of anterior knee pain: A 14- to 20-year follow-up of non-operative management. *Journal of Pediatric Orthopedics*, 18(1):118-122

NYLAND, J.; BROSKY, T.; CURRIER, D.; NITZ, A. & CABORN, D. (1994). Review of the afferent neural system of the knee and its contribution to motor learning. *The Journal of Orthopaedic and Sports Physical Therapy*, 19(1):2-11

O' NEILL, D.B.; MICHELI, L.J. & WARNER, J.P. (1992). Patellofemoral stress: a prospective analysis of exercise treatment in adolescents and adults. *The American Journal of Sports Medicine*, 20(2):151-156

PALMIERI, R.M.; INGERSOLL, C.D.; EDWARDS, J.E.; HOFFMAN, M.A.; STONE, M.B.; BABINGTON, J.P.; CORDOVA, M.L. & KRAUSE, B.A. (2003). Arthrogenic muscle inhibition is not present in the limb contralateral to a simulated knee joint effusion. *American Journal of Physical Medicine & Rehabilitation*, 82(12):910-916

PATEL, D.R. & NELSON, T.L. (2000). Sports injuries in adolescents. *Medical Clinics of North America*, 84(4):983-1005

PIETROBAN, R.; COEYTAUX, R.R.; CAREY, T.S.; RICHARDSON, W.J. & DeVELLIS, R.F. (2002). Standard scales for measurement of functional outcome for cervical pain or dysfunction: A systematic review. *Spine*, 27(5): 515-522

PIVA, S.R. (2005). Association between impairments and function in individuals with patellofemoral syndrome. Unpublished PhD dissertation. Pittsburgh: University of Pittsburgh

POLLOCK, D. (2004). Clinical examination of the patello-femoral joint. *SA Orthopaedic Journal*, 3(4):8-10

POST, W.R. (1998). Patellofemoral pain: Let the physical exam define the treatment. *The Physician and Sports Medicine*, 26(1):68-79

POWERS, C.M. (1998). Rehabilitation of patellofemoral joint disorders: a critical review. *Journal of Orthopaedic and Sports Physical Therapy*, 28(5):345-354

POWERS, C.M.; LANDEL, R. & PERRY, J. (1996). Timing and intensity of vastus muscle activity during functional activities in subjects with and without patellofemoral pain. *Physical Therapy*, 76(9):946-967

PRICE, A. & JONES, J.J. (2000). Chronic traumatic anterior knee pain. *Injury*, 31(5):373-378

PRICE, D.J. (1987). Anterior knee pain in athletes. *Medical News Tribune*, 4(20):24-26

REID, D.C. (1993). The myth, mystic and frustration of anterior knee pain. *Clinical Journal of Sports Medicine*, 3:139-143

REIDER, B.; MARSHALL, J.L. & RING, B. (1981a). Patellar tracking. *Clinical Orthopaedics and Related Research*, 157:143-148

REIDER, B.; MARSHALL, J.L. & WARREN, R.F. (1981b). Clinical characteristics of patellar disorders in young athletes. *The American Journal of Sports Medicine*, 9:270

ROBERTS, D.; FRIDEN, T.; STOMBERG, A.; LINDSTRAND, A. & MORITZ, U. (2000). Bilateral proprioceptive defects in patients with a unilateral anterior cruciate ligament reconstruction: A comparison between patients and healthy individuals. *Journal of Orthopaedic Research*, 18(4):565-571

ROGAN, I.M. (1995). Anterior knee pain in the sporting population: Forum. *SA Bone and Joint Surgery*, 5(2):28-30

ROUSH, M.B.; SEVIER, T.L.; WILSON, J.K.; JENKINSON, D.M.; HELFST, R.H.; GEHLSEN, G.M. & BASEY, A.L. (2000). Anterior knee pain: a clinical comparison of rehabilitation methods. *Clinical Journal of Sports Medicine*, 10(1):22-28

ROZZI, S.L.; LEPHART, S.M.; GEAR, W.S. & FU, F.H. (1999). Knee joint laxity and neuromuscular characteristics of male and female soccer and basketball players. *The American Journal of Sports Medicine*, 27(3):312-319

RUFFIN, M.T. & KININGHAM, R.B. (1993). Anterior knee pain: the challenge of patellofemoral syndrome. *American Family Physician*, 47(1):185-194

RUTHERFORD, O.M. (1988). Muscular coordination and strength training. Implications for injury rehabilitation. *Sports Medicine*, 5:196-202

SANDOW, M.J. & GOODFELLOW, J.W. (1985). Natural history of anterior knee pain in adolescents. *Journal of Bone and Joint Surgery*, 67(1):36-38

SEAMAN, D.R. (1997). Proprioceptor: an obsolete, inaccurate word. *Journal of Manipulative and Physiological Therapeutics*, 20(4):279-284

SHARMA, L. (1999). Proprioceptive impairment in knee osteoarthritis. *Rheumatic Disease Clinics of North America*, 25(2):299-314

SHEA, K.G.; PFEIFFER, R. & CURTIN, M. (2003). Idiopathic anterior knee pain in adolescents. *Orthopedic Clinics of North America*, 34(3):377-383

SHELTON, G.L. (1992). Conservative management of patellofemoral dysfunction. *Primary Care*, 19(2):331-350

SHELTON, G.L. & THIGPEN, L.K. (1991). Rehabilitation of patellofemoral dysfunction: a review of literature. *The Journal of Orthopaedic and Sports Physical Therapy*, 14(6):243-249

SINCLAIR, D. (1989). *Human Growth after Birth (5^{th} ed.).* Oxford: Oxford University Press

SINGH, R. (2002). The importance of exercise as a therapeutic agent. *Malaysian Journal of Medical Sciences*, 9(2):7-16

SMITH, D. & BRUCE-LOW, S. (2004). Strength training methods and the work of Arthur Jones. *Journal of Exercise Physiology*, 7(6):52-68

SNYDER-MACKLER, L.; DE LUCA, P.F.; WILLIAMS, P.R.; EASTLACK, M.M. & BARTOLOZZI, A.R. (1994). Reflex inhibition of the quadriceps femoris muscle after injury or reconstruction of the anterior cruciate ligament. *The Journal of Bone and Joint Surgery*, 76(4):555-560

SOLOMONOW, M. & KROGSGAARD, M. (2001). Sensorimotor control of knee stability. A review. *Scandinavian Journal of Medicine and Science in Sports*, 11(2):64-80

SOUZA, D.R. & GROSS, M.T. (1991). Comparison of vastus medialis obliquus: vastus lateralis muscle integrated electromyographic ratios between healthy subjects and patients with patellofemoral pain. *Physical Therapy*, 71(4):310-320

SPORTS INSTITUTE OF SOUTH AFRICA (SISA)(1998). *Hockey Manual.*

STANITSKI, C.L. (1993). Anterior knee pain syndromes in the adolescent. *Journal of Bone and Joint Surgery*, 75(9):1407-1416

STATHOPULU, E. & BAILDAM, E. (2003). Anterior knee pain: a long-term follow-up. *Rheumatology*, 42(2):380-382

STEINKAMP, L.A.; DILLINGHAM, M.F. & MARKEL, M.D. (1993). Biomechanical considerations in patellofemoral joint rehabilitation. *The American Journal of Sports Medicine*, 21(3):438-444

STIENE, H.A.; BROSKY, T.; REINKING, M.F.; NYLAND, J. & MASON, M.B. (1996). A comparison of closed kinetic chain and isokinetic joint isolation exercise in patients with patellofemoral dysfunction. *The Journal of Orthopaedic and Sports Physical Therapy*, 24(3):136-141

STOKES, M. & YOUNG, A. (1984). Investigation of quadriceps inhibition: Implication for clinical practice. *Physiotherapy*, 70(11):425-428

STRATFORD, P.W.; KENNEDY, D.M. & HANNA, S.E. (2004). Condition-specific Western Ontario McMaster Osteoarthritis Index was not superior to region-specific Lower Extremity Functional Scale in detecting change. *Journal of Clinical Epidemiology*, 57: 1025-1032

TEITZ, C.C. (1997). The female athlete. *Journal of the American Academy of Orthopaedic Surgeons*, 5(2):89-94

THOMEE, R. (1997). A comprehensive treatment approach for patellofemoral pain syndrome in young women. *Physical Therapy*, 77(12):1690-1703

THOMEE, R.; AUGUSTSSON, J. & KARLSSON, J. (1999). Patellofemoral pain syndrome: A review of current issues. *Sports Medicine*, 28(4):245-262

THOMPSON, C.W. & FLOYD, R.T. (1998). *Manual of Structural Kinesiology (13^{th} ed.)*. Singapore: McGraw-Hill

TRIA, A.J.; PALUMBO, R.C. & ALICEA, J.A. (1992). Conservative care for patellofemoral care. *Orthopedic Clinics of North America*, 23(4):545-554

WALKER, M.J. (2004). Manual physical therapy examination and intervention of a patient with radial wrist pain: A case report. *Journal of Orthopaedic & Sports Physical Therapy*, 34(12):761-769

WALTERS, J. (2004). A rational approach to the management of patello-femoral malarticulation. *SA Orthopaedic Journal*, 3(4):16-18

WESTAWAY, M.D.; STRATFORD, P.W. & BINKLEY, J.M. (1998). The Patient-Specific Functional Scale: Validation of its use in persons with neck dysfunction. *Journal of Orthopaedic & Sports Physical Therapy*, 27(5): 331-338

WHITELAW, G.P. Jr; RULLO, D.J.; MARKOWITZ, H.D.; MARANDOLA, M.S. & DEWAELE, M.J. (1989). A conservative approach to anterior knee pain. *Clinical Orthopaedics and Related Research*, 246:234-237

WILD, J.J.; FRANKLIN, T.D. & WOODS, G.W. (1982). Patellar pain and quadriceps rehabilitation: an EMG study. *The American Journal of Sports Medicine*, 10(1):12-15

WILK, K.E.; ROMANIELLO, W.T.; SOSCIA, S.M.; ARRIGO, C.A. & ANDREWS, J.R. (1998). The relationship between subjective knee scores, isokinetic testing, and functional testing in the ACL-reconstructed knee. *Journal of Orthopaedic and Sports Physical Therapy*, 20(2):60-73

WILLIAMS, G.N.; CHMIELEWSKI, T.; RUDOLPH, K.S.; BUCHANAN, T.S. & SNYDER-MACKLER, L. (2001). Dynamic knee stability: Current theory and implications for clinicians and scientists. *Journal of Orthopaedic and Sports Physical Therapy*, 31(10):546-566

WILSON, T. (1990). Anterior knee pain: a new technique for examination and treatment. *Physiotherapy*, 76(7):371-376

WINKEL, D.; MATTHIJS, O. & PHELPS, V. (1997). *Diagnosis and Treatment of the Lower Extremities*. Maryland: Aspen Publishers Inc.

WITONSKI, B. (1999). Anterior knee pain syndrome. *International Orthopaedics*, 23:341-344

WITVROUW, E.; LYSENS, R.; BELLEMANS, J.; PEERS, K. & VANDERSTRAETEN, G. (2000). Open versus closed kinetic chain exercises for patellofemoral pain. *The American Journal of Sports Medicine*, 28(5):687-694

WOODALL, W. & WELSH, J. (1990). A biomechanical basis for rehabilitation programs involving the patellofemoral joint. *Journal of Orthopaedic and Sports Physical Therapy*, 11(11):535-542

YOUNG, A. (1993). Current issues in arthrogenous inhibition. *Annals of the Rheumatic Diseases*, 52:829-834

ZAPPALA, F.G.; TAFFEL, C.B. & SCUDERI, G.R. (1992). Rehabilitation of patellofemoral joint disorders. *Orthopedic Clinics of North America*, 23(4):555-566

ZATTERSTROM, R. & FRIDEN, T. (1994). The effect of physiotherapy on standing balance in chror anterior cruciate ligament insufficiency. *The American Journal of Sports Medicine*, 22(4):531-536

APPENDICES

APPENDIX 1

Knee pain questionnaire completed by scholars between the ages of 10 and 17 years of age

Knee Pain Questionnaire

Name:________________________ Telephone no.:_______________
Address:____
Date of birth:_____________________ Today's date:_______________

Please circle the correct answer

Gender:	Male Female
Do you like playing sport?	Yes No
How many times a week do you play sport for at least 30 minutes?	Never 1-3 times 3-5 times 5-7 times More than 7 times
What type of sport do you play?	Hockey Rugby Soccer Tennis Netball Squash Cricket Dancing Athletics Swimming Gymnastics Other:____________________
Have you ever injured any of the following?	Hip Knee Ankle Foot Thigh Lower leg

Please briefly describe the injury/injuries

____

____

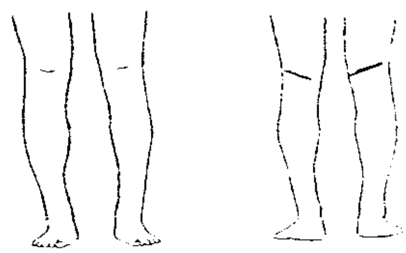
____

Have you ever had sore knees?   Yes   No

If you answered No to the above question, then please hand in the questionnaire.
If you answered Yes to the above question, then please continue.

Which knee is/was sore?   Right   Left   Both

Please give an approximate date when the pain started _______________

Where did you feel the pain in your knees? (Please mark with a **cross** (×) on the diagram)	Front R L Back L R 
How long were your knees sore for?	Less than 1 month 1-3 months 3-6 months 6-9 months 9-12 months more than 1 year
How often are/were your knees sore?	Often Sometimes Hardly ever
How bad is/was the pain?	Severe Moderate Mild
Which of these activities make/made your knees sore?	Cold weather Running Standing Walking Jumping Kneeling Sitting Going downstairs Going upstairs Other__________________
Does/Did the knee pain interfere with sport?	Often Sometimes Never
Have you got sore knees today?	Yes No
Have you ever been to the doctor about your knee pain?	Yes No
When did you go?	____________________
How many times did you go?	____________________
Have you ever taken medication for your knee pain?	Often Sometimes Never
Have you had any other treatment for your knees?	None Surgery Physiotherapy Biokinetics Podiatry Other ____________________
If you have had other treatment, was it successful?	Yes No Other____________________

APPENDIX 2

Informed consent and subject assent forms completed by the parents and subjects respectively.

INFORMED CONSENT FORM

I, ___________________________, having been fully informed of the research project entitled *The Role of a Biokinetics Rehabilitation Programme in Alleviating Anterior Knee Pain in Adolescents*, do hereby give consent for my child ____________________ to participate in the aforementioned project.

I have been fully informed of the procedures involved, as well as the potential risks and benefits associated with the study, as explained to me verbally and in writing. In agreeing to my child's participation in this study, I waive any legal recourse against the researchers or the University of Zululand, from any and all claims resulting from personal injuries sustained.

I realise that it is my child's responsibility to promptly report to the researcher any signs or symptoms indicative of an abnormality, pain or distress.

I am aware that part of the programme may involve training without supervision from the researcher, and undertake to ensure my child's compliance.

I am aware that my child can withdraw from participation in the study at any time. I am aware that my child's anonymity will be assured at all times, and agree that the information collected may be used and published for statistical or scientific purposes.

I have read this form, and understand the procedures. I have had an opportunity to ask questions, and these have been answered to my satisfaction.

____________________	________________	___________
(Parent/Guardian of subject)	Signature	Date
____________________	________________	___________
Tester	Signature	Date

SUBJECT ASSENT FORM

I, ____________________________, understand that my parent/guardian has given permission for me to participate in the research project entitled *The Role of a Biokinetics Rehabilitation Programme in Alleviating Anterior Knee Pain in Adolescents.*

The procedures involved have been explained to me verbally and in writing. All questions have been answered satisfactorily.

I understand that I must promptly report any signs or symptoms indicating an abnormality, pain or distress to the researcher.

I am taking part of my own free will, and understand that I can withdraw at any time.

____________________________ _______________

Signature Date

____________________________ _______________

Tester Date

APPENDIX 3

Scale to determine subject's level of activity

Activity Rating Scale

Please indicate how often you performed each activity in your healthiest and most active state, in the past year.

	< once a month	Once a month	Once a week	2/3 times a week	4+ times a week
Running: while playing a sport or jogging					
Cutting: changing directions while running					
Decelerating: coming to a quick stop while running					
Pivoting: turning your body with your foot planted while playing a sport (Eg. Kicking, throwing, hitting a ball)					

(Marx et al., 2001)

APPENDIX 4

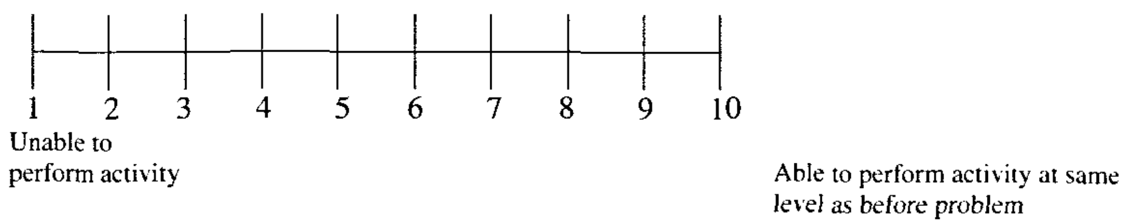
Patient-Specific Functional Scale

Tester to read and fill in below: Complete at the end of the history and prior to the physical assessment.

Initial assessment:
I am going to ask you to identify up to 3 important activities that you are unable to do or are having difficulty with as a result of your knee pain. Today, are there any activities that you are unable to do or having difficulty with because of your knee pain. (Tester shows scale to subject and has subject rate each activity).

Final assessment:
When I assessed you on ___________________ (previous date), you told me you had difficulty with (read all activities from list). Today, do you still have difficulty with: (read and have patient score each item on the list)?

PATIENT-SPECIFIC ACTIVITY SCORING SCHEME (Point to one number)



Activity	initial		final
1.			
2.			
3.			
4.			
5.			
Other			

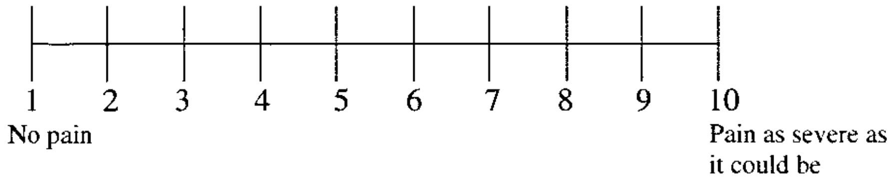
(Chatman et al., 1997)

APPENDIX 5

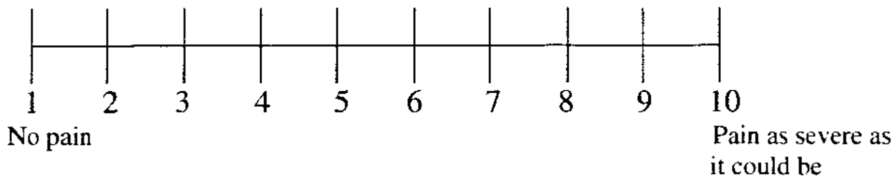
Visual Analogue Scales for Pain Ratings

Mark the point on the line that best indicates your pain level relative to the pain definers at the end of the line.

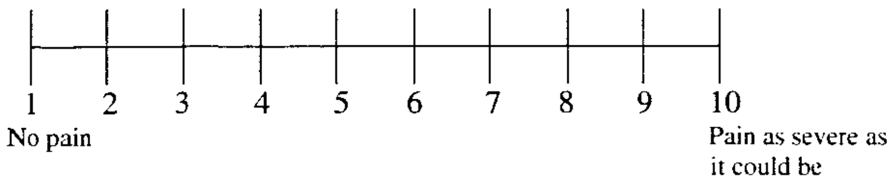
Rate your pain at its **worst:**



Rate your pain at its **least**:



Rate your pain as it is **usually felt**:



(Harrison et al., 1995)

APPENDIX 6

Scale for change in condition

1. Significant improvement noted
2. Some improvement noted
3. No improvement noted
4. Condition worse

(Harrison et al., 1995)

APPENDIX 7

Testing proforma

ASSESSMENT FORM

Name: Date:

History:			
Weight:	Height:	Handedness	Hand:
			Foot:

STRUCTURAL	RIGHT	LEFT
Trochanterion – Ext. tib.		
Ext. tib – Lat malleolus		
Foot length		
Q-Angle		
Flexibility		
Hamstring		
Quadriceps		
Abductors		
Gastrocnemius		
Crepitus	None/Slight/ Moderate/ Severe	None/Slight/ Moderate/ Severe
Valgus stress test	None/Slight/ Moderate/ Severe	None/Slight/ Moderate/ Severe
Varus stress test	None/Slight/ Moderate/ Severe	None/Slight/ Moderate/ Severe
Anterior drawer (ACL)	None/Slight/ Moderate/ Severe	None/Slight/ Moderate/ Severe
Genu varum	None/Slight/ Moderate/ Severe	None/Slight/ Moderate/ Severe
Genu valgum	None/Slight/ Moderate/ Severe	None/Slight/ Moderate/ Severe
Genu recurvatum	None/Slight/ Moderate/ Severe	None/Slight/ Moderate/ Severe
Pes cavus/planus		
Tibial Int/Ext rotation		
Pronation/Supination		

FUNCTIONAL	Right		Left	
Peak torque Quads:	1.	2.	1.	2.
Peak torque Hams:	1.	2.	1.	2.
Willknox Wobbleboard	Front:	Back:	Left:	Right:
Stork stand	1. 2. 3.		1. 2. 3.	
Bass test	T1.		T2	
	E1		E2	

APPENDIX 8

Intervention programme followed during contact sessions

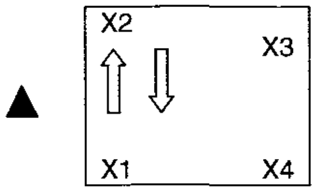
EXERCISE		**LEVEL**	**SETS**	**REPS**	**REST**
WARM UP		1	3	15	20sec
STRENGTHENING					
		2	2	12	20sec
		3	2	8	20sec
		4	2	6	20sec
		5	2	4	20sec
WOBBLEBOARD			2 min		
MINI-TRAMPOLINE					
	Jog		30 sec		
	2 bounce/leg		30sec		
	3 bounce/leg		30sec		
	1 leg only bounce		2x15 sec		
	2 leg bounce		30sec		
	Twist		30sec		
	1 leg twist		2x15 sec		
JUMP ROUTINE					
(See diagram)	1. Forward - Back		3-5 x		
	2. Side - side		3-5 x		
	3. Clockwise		3-5 x		
	4. Anti-clockwise		3-5 x		
	5. Cross forwards		3-5 x		
	6. Cross backwards		3-5 x		

Jump Routine

Key: Each diagram represents 4 crosses (0.4x0.4m) drawn on a gym mat

►/▲ represent the direction the head and body are facing throughout the jump

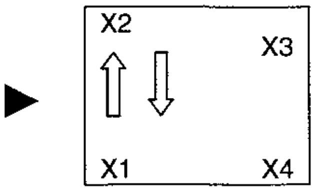
1



Jump 1: Forward-Back

X1→X2→X1→X2

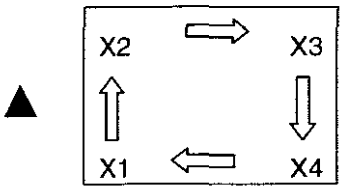
2



Jump 2: Side-Side

X1→X2→X1→X2

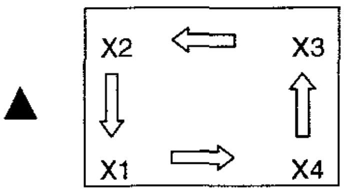
3



Jump 3: Clockwise

X1→X2→X3→X4→X1

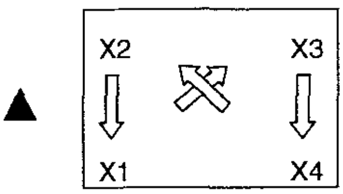
4



Jump 4: Anti-clockwise

X1→X4→X3→X2→X1

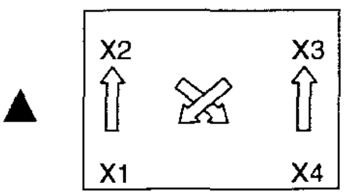
5



Jump 5: Cross-forwards

X1→X3→X4→X2→X1

6



Jump 6: Cross-backwards

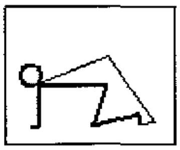
X1→X2→X4→X3→X1

APPENDIX 9

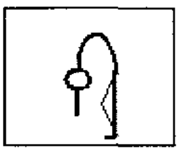
HOME PROGRAMME
Lower limb

Stretching: (Hold each stretch for 30sec, repeat 3 times)

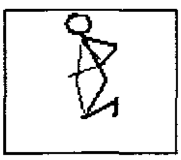
1. Calf
   Stand on the hands and knees with the toes pointed forward. Lift the knees off the floor so that the legs are straight. Push the heels down towards the ground.



2. Hamstrings
   Stand with the feet 50cm apart. Bend over forward, relaxing the upper body and keeping the legs straight. Bend knees after each stretch, then straighten again.

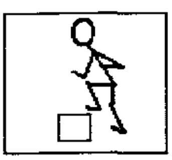


3. Hip flexors
   Kneel on the mat and perform a posterior pelvic tilt. The stretch will be felt in the thigh muscles.

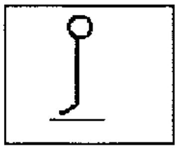


Strengthening:

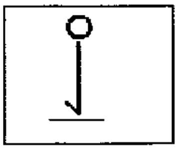
1. Step ups
   Step up and down on a step of about 30cm high. Lead with the right foot for 30 seconds, then repeat on the left side. Keep alternating legs for 5-8 minutes



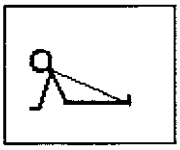
2. Calf raises (1 x 15-20)
   Lift up onto the toes, with the weight centred first onto the little toe, then the centre of the foot, then the big toe.



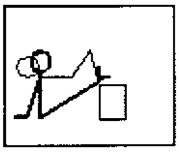
3. Toe raises (1 x 15-20)
   Whilst standing upright, raise the fore foot off the ground. First lift and tilt the soles inwards, then straight up, then outwards.



4. Pelvic lift (1 x 15-20)
   Sit on the mat with the legs straight and hands supporting behind the hips. Lift the hips off the ground until the body is straight. Lower and repeat.



5. Leg curls (1 x 15-20)
   Sit on the ground with the heels resting on a chair/bench. Support the body by placing the hands next to the hips. Lift the body up from the heels, bending the knees. The hips should lift higher than the level of the feet.



Proprioception:

6. Stork stand
   Balance barefoot on one leg on a 2.5cm wide plank for one minute

APPENDIX 10

Exercise Log

Name:										
Date	Str	Ex 1	Ex 2	Ex 3	Ex 4	Ex 5	Ex 6	Ex 7	Ex 8	Comment