The effect of Kinesio® tape on Quadriceps muscle power output, length/tension, and hip and knee range of motion in asymptomatic cyclists

By

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I, Dani Nelson, do declare that this dissertation is representative of my own work in both conception and execution.

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DEDICATION

To my mom and dad, Bev and Dan Nelson, thank you for affording me the privilege of an education and for supporting me every step of the way. Thank you for all of your encouragement, generosity and love.

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ABSTRACT

Background:

As Kinesio® tape may increase range of motion, facilitate muscle function, enhance circulation, and normalize muscle length/tension ratios creating optimal force, use of this athletic tape has gained popularity in various sporting disciplines. Cycling is a highly competitive sport that continually seeks ways of improving performance. There are, however, no controlled, published studies examining the effects of Kinesio® tape on a cyclist's performance.

Objectives:

To determine the participants' power output, bicycle speed, and cadence, quadriceps length/tension, and hip and knee flexion and extension range of motion in terms of the objective findings without the use of Kinesio® tape and then following the application of Kinesio® tape to the quadriceps muscles. To determine the participants' perception of a change in their power output, speed, and cadence post- intervention.

Method:

Forty asymptomatic trained amateur cyclists performed two 1.5 km time trials pre- and post-Kinesio® tape application. The pre- and post- intervention range of motion measurements and the average and maximum power output (watts), cadence (rpm), and speed (km/h) were measured using a universal goniometer and cycle ergometer respectively. The participants' perception of a change in power, cadence, and speed following the application of Kinesio® tape was also recorded. SPSS version 18 (SPSS Inc.) was used to analyse the data.

Results:

There was a significant decrease in maximum power ($p = 0.007$) post- intervention, but no significant differences in the average power, or average and maximum speed and cadence measurements. Range of motion measurements post- intervention showed a significant flexion ($p < 0.021$). The majority of the participants (60%) perceived an increase in power and speed post- intervention.

Conclusions:

There was a visual trend showing an increase in most of the power, speed, and cadence parameters assessed. The range of motion parameters revealed conflicting results and warrant further research

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LIST OF ABBREVIATIONS

ANOVA: analysis of variance

ATP: adenosine triphosphate

BMI: body mass index

cm: centimeters

CP: creatine phosphate

kg: kilograms

km: kilometers

km/h: kilometers per hour

m: meters

min: minutes

MTB: mountain bicycle

***n*:** sample size

***p*:** probability

ROM: range of motion

rpm: revolutions per minute

s: seconds

SD: standard deviation

Tacx: Tacx Fortius Virtual Reality Trainer

TDC: top dead centre

TT1: time trial one

TT2: time trial two

VO2: oxygen uptake

W: watts

GLOSSARY OF TERMS

Aerodynamics: The science which deals with air in motion and the reactions of a body moving in air (Beneke *et al*., 1989).

Bottom bracket: Consists of a shell through which the axle passes (Beneke *et al*., 1989).

Bicycle setup: Adjustment of the bicycle to ensure proper positioning of the cyclist on the bicycle, allowing the cyclist to be efficient, comfortable, and injury free (Burke, 2003).

Cadence: The speed at which the pedals are turned, reported in revolutions per minute (Green, Johnson, and Maloney, 1999).

Chain: Series of links pinned together extending from the chainring to the cogs on the back wheel, allowing propulsion of the bicycle by pedaling (Downs, 2010).

Cogset: A cluster of cogs that fit onto a cassette, allowing for a range of gears to be chosen by the cyclist (Beneke *et al*., 1989; Downs, 2010).

Competitive cyclist: One who rides a bicycle based on competition, with the desire to be more successful than others (http://www.merriam-webster.com/dictionary/competitive)

Crankset: Serves as the point where leg power is transferred from the pedals to the chain and ultimately the rear wheel, composed of two crank arms, a bottom bracket, and one or more chain rings of a bicycle (Downs, 2010).

Cycling efficiency: The ratio of work accomplished to energy expended, determined by the amount of power that can be produced for a given oxygen and energy expenditure (Hopker *et al*., 2010).

Derailleur: Mechanism mounted to the seat tube that pushes the chain off one cog and onto another, composed of levers, cables, and front and rear end derailleurs (Beneke *et al*., 1989; Downs, 2010).

Drivetrain: Consists of the pedals, crankset, cogset, chain and derailleurs of a bicycle, forming the system through which human power is translated into forward motion (Beneke *et al*., 1989; Downs, 2010).

Frame geometry: Determined by the angles and lengths of the frame tubes (Beneke *et al*., 1989). It is also dependent on the use for which the bicycle is designed (Downs, 2010).

Hub: Occupies the center of the wheel and is the foundation of the wheelset, housing the axle and bearings on which the wheels spin, and anchoring the spokes that hold the rims (Downs, 2010).

Mountain bicycle: A bicycle designed for off road use with an upright handlebar, sturdy tyres, and wide range gearing (Downs, 2010).

Patella Tracking: Occurs during knee flexion and extension as the patella “tracks” along the femoral trochlea, this movement should be smooth from beginning to end (Magee, 2008).

Pedal cycle/stroke: One complete circular movement of the pedals around the bottom bracket (Asplund and St Pierre, 2004).

Power: The rate of doing work expressed in watts (Powers and Howley, 1997). Power represents the quantity of energy delivered to the pedals by the cyclist per unit of time (Burke, 2003).

Road bicycle: A lightweight, multispeed bicycle characterized by a drop handlebar (Downs, 2010).

Rolling resistance: Inherent resistance dependant on the area of contact between the tyre and the road, directly proportional to the weight that a wheel supports (Beneke *et al*., 1989).

Seat tube: Tube that runs from the seat down to the bottom bracket (Downs, 2010)

Speed: The distance travelled per unit of time (http://physics.about.com/o/glossary/g/speed.htm).

Spoke: One of several wires attaching the rim to the hub (Beneke *et al*., 1989; Downs, 2010).

Time Trial: An event ridden individually where cyclists ride against the clock to achieve the best possible time, distances vary from one kilometer to fourty kilometers (Beneke *et al*., 1989).

Wheelbase length: Distance between the front and rear wheel axles (Beneke *et al*., 1989).

Wheelset: Consists of the tyre, rim, spokes and hub (Beneke *et al*., 1989).

CHAPTER 1

INTRODUCTION

1.1 Introduction to the Study

Millions of bicycles are used daily for transportation, recreational or competitive cycling (Hug and Dorel, 2009). According to Cycling South Africa, there are a total of 25 836 registered cyclists within South Africa (Engelbrecht, 2011). This membership base is collectively made up of 14 355 road cyclists and 11 481 off road cyclists (mountain bikers), although many cyclists actively participate in both road cycling and off road cycling (mountain biking) (Engelbrecht, 2011). In Kwa-Zulu Natal there are a total of 3 977 registered cyclists. The Kwa-Zulu Natal members of Cycling South Africa are comprised of 2 901 registered road cyclists, and 3 365 registered mountain bikers, with many members participating in both road and MTB cycling (Engelbrecht, 2011). According to Engelbrecht (2011), of the total number of cyclists throughout South Africa only a portion are competitive cyclists. Throughout South Africa, the competitive cyclists total 4 018, divided into 2 271 road cyclists and 1 747 mountain bikers. In Kwa-Zulu Natal there are a total of 636 competitive cyclists, comprised of 308 road cyclists and 328 mountain bikers (Engelbrecht, 2011).

Cyclists are in constant pursuit of improving their performance and finding the edge over their competitors (Beneke *et al*., 1989; Burke, 2003). In the book ‘Every Second Counts’, Lance Armstrong (2004) writes of how after three weeks of racing the Tour de France, it is often won by a margin of less than a minute, and the cyclists had to examine every small part of their bodies and bicycles to reduce the race completion time, even something as small as a fraction of a second in the sleeves of the jerseys worn during racing. The body mass of a cyclist, combined with the weight of their bicycle, is a force working against them that directly influences rolling resistance, requiring more leg power to resist gravitational forces (Beneke *et al*., 1989; Burke, 2003). Lighter bicycles are, therefore, faster than heavier bicycles (Burke, 2003) and cyclists constantly look to lighten the weight of their bicycle, right down to the smallest component (Beneke *et al*., 1989; Burke, 2003;

Downs, 2010). Reducing wheel weight is one way to reduce the bicycles overall weight (Beneke *et al*., 1989). As the weight of the wheels is magnified several times when they spin, a reduction of 500 grams off the wheels, could improve performance as much as if 1 kg had been taken off the frame or any other non-moving part of the bicycle (Beneke *et al*., 1989). Most of a cyclist's effort when riding goes into overcoming aerodynamic forces caused by wind and the bicycles motion through the air (Beneke *et al*., 1989; Burke, 2003). The following table illustrates the valuable seconds saved as a result of aerodynamic changes made to the bicycle equipment. Although the time saving is relatively small per item, it could mean the difference between first and second place. In the Tour de France of 2000, Lance Armstrong, one of the cycling greats, was beaten by only two seconds in the prologue stage, showing how only two seconds is enough to classify cyclists as a winner and a runner-up (Armstrong, 2004).

Table 1.1 Time saved in a 40 km time trial resulting from aerodynamic item modifications

Item modification	**Time saving (seconds)**
Bicycle frame	42
Spoked wheels	39
Handlebars	29
Front disk wheels	14
Rear disk wheels	14
Two disk wheels	67
Cranks and cogs	6
Pedals	9
Helmet	14
Clothing	14
Water bottle	14

(Table abridged from Beneke *et al*., 1989)

Tight fitting clothing is one effective way of streamlining a cyclist's apparel with the intension to improve aerodynamics by reducing wind resistance (Beneke *et al*., 1989). Clothing, such as compression garments, however, can also improve muscle efficiency (Doan *et al*., 2003; Higgins, Naughton, and Burgess, 2009; Kemmler *et al*., 2009; Troynikov *et al*., 2010). Compression garments are said to enhance blood flow, improve muscle oxygenation, reduce fatigue, and reduce muscle oscillation (Doan *et al*., 2003; Troynikov *et al*., 2010). The degree of pressure produced by the compression garment is determined by the interrelation of the garment fit, physical properties, materials, and the nature of the sporting activity (Troynikov *et al*., 2010). Compression garments have also been shown to increase skin temperature allowing for increased muscle temperature and performance (Doan *et al*., 2003). An elastic tape, such as Kinesio®

tape, may be proposed to act like a compression garment, in the sense that pressure is applied to the skin, increasing skin temperature and aiding blood flow (Halseth *et al*., 2004).

The leg muscles power the pedalling motion, but the knee extensor muscle group is the prime source of force generating energy to the crank in the downstroke or propulsive phase of cycling. Many cyclists emphasize muscle training on the knee extensor muscles for performance enhancement (Raymond, Joseph, and Gabriel, 2005). During the pedalling motion muscles couple adjacent joint motions, acting to complement the joints' actions. Pedal strokes vary among cyclists, depending on their body types, riding positions, cadence selection, and which type of riding (mountain bicycle, road bicycle) they are doing (Lopes and McCormack, 2006). As cycling is repetitive in nature, restrictions in range of movement may occur (Burke, 2003). By improving muscle function it would be advantageous to the cyclists' performance in helping to correct the efficiency of the quadriceps contractions (Burke, 2003). Improving muscle function may occur by way of removing restrictions or reducing muscular fatigue by normalizing length/tension ratios (Burke, 2003).

The majority of a cyclist's pedal power is generated from driving the pedals downward powered primarily by the quadriceps muscles. The quadriceps muscle group and the gluteus maximus muscles power the pedal stroke from 0° at the top of the pedal stroke, until the pedal approaches 180° (Asplund and St Pierre, 2004; Lopes and McCormack, 2006). The quadriceps muscle involvement is greatest from 60-90°, and the gluteus maximus muscle involvement greatest from 70-150° (Asplund and St Pierre, 2004; Lopes and McCormack, 2006). The hamstrings muscle group becomes active in sweeping the pedal up to the 270° position (Umberger, Gerritsen, and Martin, 2006). The final pull to reach the top of the stroke involves the action of the iliopsoas muscles from 270° to return to 0° at the top of the pedal stroke (Lopes and McCormack, 2006).

Chiropractic practise is not solely comprised of manipulative procedures but can include the provision of ergonomic and exercise services (Duenas, 2002). This includes therapeutic taping and strapping procedures. Kinesio® taping is a technique that was established in the 1970's by Dr. Kenzo Kase, also a chiropractor (Garcia-Muro *et al.*, 2010). The technique claims several main effects: to normalize muscular function, to diminish pain, to increase lymphatic and blood flow, to aid in the correction of possible articular malalignments and to protect against muscle fatigue and injury (Kase *et al*., 1996, as cited by Garcia-Muro *et al.*, 2010). Of the reported effects of Kinesio® tape on the muscle, increasing range of motion (ROM); and reducing fatigue by normalizing length/tension ratios which creates optimal forces as well as tissue recovery (Kase, 2008), are more pertinent to this study. The elasticity of Kinesio® tape is its most important feature in attaining these effects, by subcutaneously lifting the skin to improve fluid movement and produce positive results for the top layers of fascia, as well as the much deeper layers. According to Kase, Wallis, and Kase (2003), a muscle may be facilitated and its function enhanced when taped from origin to insertion at 15%-50% tape tension. However, there is paucity in the literature regarding this statement.

Kinesio® tape received Lance Armstrong's endorsement in his book 'Every Second Counts' (Armstrong, 2004; Kase, 2008). In the Tour de France of 2002 the US Postal Team, led by Lance Armstrong, had Kinesio® tape applied to different parts of their bodies every morning by their team Chiropractor (Armstrong, 2004). Lance Armstrong (2004) said; "Something that was better than any laser, bandage, or electric massager was the tape, that seemed to have magical powers and could just fix things, it really worked."

It is, therefore, important to test these proposed changes and theories in a sport such as cycling, in which the cyclists may improve their performance from the proposed changes in muscle strength and joint ROM and to do it in such a way that the specific action of the sport may be reproduced. It is evident that athletes are in constant pursuit of improving performance and gaining those valuable seconds, and sometimes milliseconds, which may help them to triumph over their rivals. The outcome of this study may help enhance the cyclists' performances in the form of an externally applied intervention, Kinesio® tape, to facilitate the natural physiological actions of the body.

1.2 Aims

The aim of this study was to determine the effect of the application of Kinesio® tape to the quadriceps on cycling power output, cycling cadence, cycling speed, quadriceps length/tension, and hip and knee range of motion (flexion and extension) in trained amateur cyclists, and to determine the participants' perception.

1.3 Objectives

The objectives of the study were:

1) To determine the participants' power output, bicycle speed and cadence, quadriceps length/tension, and hip and knee ROM (flexion and extension), in terms of objective findings, without the use of Kinesio® tape.

2) To determine the participants' power output, bicycle speed and cadence, quadriceps length/tension, and hip and knee ROM (flexion and extension), in terms of objective findings, following the application of Kinesio® tape to the quadriceps muscles.

3) To determine the participants' perception of a change in their power output, speed and cadence post- intervention.

4) To compare outcome measures of the control to the intervention.

1.4 Hypotheses of the Study

Hypothesis One: It was hypothesised that Kinesio® tape applied to the quadriceps muscles would result in no significant difference in the participants' power, speed, and cadence.

Hypothesis Two: It was hypothesised that Kinesio® tape applied to the quadriceps muscles would result in no significant difference in the hip and knee joint ROM (flexion and extension).

Hypothesis Three: It was hypothesised that Kinesio® tape applied to the quadriceps muscles would result in no significant difference in the quadriceps length/tension.

Hypothesis Four: It was hypothesised that Kinesio® tape applied to the quadriceps muscles would result in no significant difference in the participants' perception of their power, speed, and cadence.

In the remaining chapters, the researcher will review the literature on the lower limb anatomy, effects of Kinesio® tape, and literature on cycling (Chapter 2); describe in detail the methodology of the study (Chapter 3); and present the statistics (Chapter 4); the results (Chapter 5); and the subsequent recommendations and conclusions (Chapter 6).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This literature review aims to inform the reader of the relevant anatomy of the lower limb, as well as the relationship between the lower limb and the cycling stroke. The importance of the various outcome measures in cycling will be discussed and the relevant effects of Kinesio® tape reviewed.

2.2 Anatomy

2.2.1 Lower Limb Bony Anatomy

2.2.1.1 Hip Joint

The hip joint is a multiaxial ball and socket synovial joint (Moore and Dalley, 1999; Marieb, 2004). The round head of the femur articulates with the cup-like acetabulum on the lateral aspect of the hip bone (Moore and Dalley, 1999; Marieb, 2004). The head of the femur forms approximately two thirds of a sphere that articulates with the hemispherical hollow of the acetabulum (Moore and Dalley, 1999; Marieb, 2004). The heavy, prominent rim of the acetabulum consists of a semilunar articular part covered with articular cartilage, the lunate surface of the acetabulum (Moore and Dalley, 1999; Marieb, 2004). The lunate surface and acetabular rim form three quarters of a circle, with the acetabular notch being the missing inferior segment of the circle (Moore and Dalley, 1999; Marieb, 2004). As a result of the height of the acetabular rim and labrum, more than half of the femoral head fits within the acetabulum (Moore and Dalley, 1999; Marieb, 2004). The acetabulum is formed by the three primary bones forming the hip bone, namely; the ilium, ischium, and pubis (Moore and Dalley, 1999; Marieb, 2004). Centrally, the acetabular fossa, a deep non-articular part of the hip bone, is formed mainly by the ischium, the ilium contributes to the superior part of the acetabulum, and the pubis forms the anterior part of the acetabulum. The acetabulum is directed inferiorly, laterally, and anteriorly in humans (Moore and Dalley, 1999; Marieb, 2004). The hip joint is the most stable joint, owing to depth of the socket and the ball and socket construction, the strength of its capsule, and the attachments of muscles crossing the joint (Moore and Dalley, 1999; Marieb, 2004).

2.2.1.2 Knee Joint

The knee joint is primarily a hinge type of synovial joint (Moore and Dalley, 1999; Marieb, 2004). The articular surfaces of the knee joint are characterized by their large size and incongruent shapes (Moore and Dalley, 1999; Marieb, 2004). The knee joint consists of three articulations; two tibiofemoral articulations between the lateral and medial femoral and tibial condyles, and one intermediate patellofemoral articulation between the patella and the femur (Moore and Dalley, 1999). The tibiofemoral joint is the largest joint in the body (Moore and Dalley, 1999; Magee, 2008). The articular surfaces of the tibia and femur are not congruent, the two bones approach congruency only in full extension (Magee, 2008). The lateral femoral condyle projects anteriorly more than the medial femoral condyle to help prevent lateral dislocation of the patella (Magee, 2008). The space between the femur and tibia is partially filled by two menisci that are attached to the tibia to add congruency, both menisci are thicker along the periphery and thinner along the inner margin (Moore and Dalley, 1999; Magee, 2008). The medial meniscus is “C” shaped and is thicker anteriorly than posteriorly (Moore and Dalley, 1999; Magee, 2008). The lateral meniscus is “O” shaped and is generally of equal thickness throughout (Moore and Dalley, 1999; Magee, 2008). The patellofemoral joint is a modified plane joint, with the lateral articular surface of the patella being wider (Magee, 2008). The patella is a sesamoid bone within the patella tendon, possessing five facets, or ridges: superior, inferior, medial, lateral and odd (Magee, 2008).

2.2.2 Neurovascular Structures in the Anterior Thigh

In the anteromedial thigh, the femoral triangle is a subfascial space bound by the inguinal ligament superiorly, adductor longus medially, and the sartorius laterally (Moore and Dalley, 1999; Marieb, 2004). The contents of the femoral triangle include the femoral nerve, and the femoral sheath containing the femoral artery and several branches, femoral vein and proximal tributaries, and the deep inguinal lymph nodes and associated lymphatic vessels (Moore and Dalley, 1999; Marieb, 2004). The femoral nerve (L2, L3, L4) is the largest branch of the lumbar plexus, after passing through the femoral triangle it divides into several branches that innervate the anterior thigh muscles, including the quadriceps muscle group (Moore and Dalley, 1999). The femoral nerve also supplies articular branches to the hip and knee joints (Moore and Dalley, 1999). The femoral nerves terminal branch is the saphenous nerve that runs anteriorly and inferiorly to supply the skin and fascia on the anteromedial aspects of the knee, leg, and foot (Moore and Dalley, 1999). The femoral artery is a continuation of the external iliac artery and gives rise to several branches that supply the anterior and anteromedial aspects of the thigh (Moore and Dalley, 1999). Cutaneous branches of the femoral artery extend to the anteromedial aspect of the thigh. The femoral artery is the main artery supplying the lower limb, occupying a relatively superficial position at its origin, deep to the fascia lata (Moore and Dalley, 1999). The deep artery of the thigh is the largest branch of the femoral artery and supplies muscles of all three fascial compartments; hamstrings, vastus lateralis, and adductor magnus, making it the chief artery to the thigh (Moore and Dalley, 1999). The circumflex femoral arteries supply the thigh muscles, including the quadriceps muscle group, and the hip joint (Moore and Dalley, 1999). The femoral vein lies posterior to the femoral artery as it ascends the thigh as a continuation of the popliteal vein and terminates in the external iliac vein (Moore and Dalley, 1999). The fascial tube known as the femoral sheath that surrounds the femoral artery and femoral vein, allows for the vessels to glide deep to the inguinal ligament during movements of the hip joint (Moore and Dalley, 1999; Marieb, 2004).

2.2.3 Lower Limb Musculature

There is a well defined muscle recruitment pattern in cycling, with single-joint and multi-joint muscles serving different purposes at different phases of cycling, but all muscles work together in a coordinated way to maximise efficiency (Raymond, Joseph, and Gabriel, 2005). The anatomy of the most important muscles will be outlined in this section, with the biomechanics of cycling and cycling efficiency relating to these muscles discussed later in this chapter.

Table 2.1 Attachments, Innervation and Action of Quadriceps Femoris Components

Muscle	Proximal Attachment	Distal Attachment	Innervation	Action
Rectus Femoris	Anterior inferior iliac spine and ilium superior to acetabulum	Via a common tendinous insertion to the base of patella; indirectly via patellar ligament to tibial tuberosity	Femoral Nerve (L2,L3,L4)	Extend leg at knee joint; rectus femoris also steadies hip joint and helps iliopsoas muscle flex the thigh
Vastus Lateralis	Greater trochanter an lateral lip of linea aspera of femur			
Vastus Medialis	Intertrochanteric line and medial lip of linea aspera of femur			
Vastus Intermedius	Anterior and lateral surfaces of shaft of femur			

(Table abridged from Moore and Dalley, 1999)

Martin and Brown (2009) stated that the ankle, knee, and hip joints are extended for greater than half of the pedalling cycle. The hamstring muscles span and act on two joints allowing for extension at the hip joint, and flexion at the knee joint. The hamstrings demonstrate most activity when they are eccentrically contracting, resisting hip flexion and knee extension (Moore and Dalley, 1999; Marieb, 2004).

Table 2.2 Attachments, Innervation and Action of Hamstrings Components

Muscle	Proximal Attachment	Distal Attachment	Innervation	Action
Semitendinosus	Ischial tuberosity	Superior part of tibia on medial surface	Tibial division of sciatic nerve (L5, S1, S2)	Extend thigh; flex leg and rotate it medially when knee is flexed
Semimembranosus	Ischial tuberosity	Posterior part of tibia on medial condyle		

Muscle	Proximal Attachment	Distal Attachment	Innervation	Action
Biceps Femoris	Long head: ischial tuberosity Short head: linea aspera and lateral supracondylar line of femur	Fibula on lateral side of head	Long head: Tibial division of sciatic nerve (L5, S1, S2) Short head: Common fibular division of sciatic nerve (L5, S1, S2)	Extend thigh; flex leg and rotate it laterally when knee is flexed

(Table abridged from Moore and Dalley, 1999)

The gluteal muscles share a common compartment but are organized into two layers, the superficial and deep layers. The superficial layer consists of the three large glutei; maximus, medius, and minimus, these muscles are all mainly extensors of the thigh (Moore and Dalley, 1999; Marieb, 2004).

Table 2.3 Attachments, Innervation and Action of Gluteal Muscles

Muscle	Proximal Attachment	Distal Attachment	Innervation	Action
Gluteus Maximus	Dorsal surface of sacrum and coccyx, ilium posterior to posterior gluteal line	Some fibers insert on gluteal tuberosity, most fibers end in iliotibial tract and insert on lateral condyle of tibia	Inferior gluteal nerve (L5, S1, S2)	Extends thigh, especially from flexed position; assists in lateral rotation of thigh
Gluteus Medius	External surface of ilium between anterior and posterior gluteal lines	Lateral surface of greater trochanter of femur	Superior gluteal nerve (L5, S1)	Abduct and medially rotate thigh
Gluteus Minimus	External surface of ilium between anterior and inferior gluteal lines	Anterior surface of greater trochanter of femur		

(Table abridged from Moore and Dalley, 1999)

The iliopsoas muscle is the chief flexor of the thigh, being the most powerful of the hip flexors with the longest range. The iliopsoas muscle is formed of: the iliacus, its broad lateral part; and the psoas major, its long medial part (Moore and Dalley, 1999; Marieb, 2004).

Table 2.4 Attachments, Innervation and Action of Iliopsoas Components

Muscle	Proximal Attachment	Distal Attachment	Innervation	Action
Psoas major	Sides of T12-L5 vertebrae and discs between them; transverse process of all lumbar vertebrae	Lesser trochanter of femur	Anterior rami of lumbar nerves (L1, L2, L3)	Act conjointly in flexing the thigh at the hip joint and in stabilizing the hip joint
Psoas minor	Sides of T12-L1 vertebrae and intervertebral disc	Pectineal line	Anterior rami of lumbar nerves (L2, L3)	
Iliacus	Iliac fossa, iliac crest; ala of sacrum, anterior sacroiliac ligaments	Tendon of psoas major, lesser trochanter, an femur distal to it	Femoral nerve (L2, L3)	

(Table abridged from Moore and Dalley, 1999)

2.2.4 Lower Limb Biomechanics

The movements of the hip joint are flexion-extension, abduction-adduction, medial-lateral rotation and circumduction (Moore and Dalley, 1999; Marieb, 2004; Magee, 2008). The movements of hip flexion and hip extension were measured in this study and will be discussed further. The degree of flexion and extension at the hip joint depends on the position of the knee, if the knee is flexed, the thigh can be actively flexed until it reaches the anterior abdominal wall (Magee, 2008). Hip range of motion normally ranges between 110° – 120° during flexion, and 10° - 15° during extension (Magee, 2008). Knee range of motion normally ranges between 0° – 135° during flexion, and 0° – 15° during extension (Magee, 2008).

The movements of the knee joint are mainly flexion-extension, with some rotation occurring when the knee is flexed (Moore and Dalley, 1999; Magee, 2008). The knee joint is relatively weak mechanically because of the incongruence of its articular surfaces (Magee, 2008). The stability of the knee joint, therefore, depends on the strength and actions of the surrounding muscles and their tendons, and the ligaments that connect the femur and tibia (Magee, 2008). The anterior muscles are the most important of these supports (Magee, 2008). The most important muscle in stabilizing the knee joint is the quadriceps femoris muscle (Moore and Dalley, 1999).

During the pedalling motion muscles couple adjacent joint motions, acting to complement the joints' actions (Burke, 2003). The leg muscles power the pedalling motion but, the knee extensor muscle group is the prime source to generate energy to the crank in the downstroke or propulsive phase of cycling (Raymond, Joseph, and Gabriel, 2005). The quadriceps muscle has been identified as the most important muscle in cycling with the vastus lateralis, vastus medialis, and rectus femoris, having more than 50% of their respective maximum activity during the first half of the propulsive phase of the pedal movement (0˚-90˚) (Raymond, Joseph, and Gabriel, 2005). Martin and Brown (2009) stated that the ankle, knee, and hip joints extended for greater than half of the pedalling cycle. This illustrates the predominant role of the quadriceps muscle, or knee extensor muscle group, in cycling. Many serious cyclists emphasize muscle training on the knee extensor muscles for performance enhancement (Raymond, Joseph, and Gabriel, 2005).

The quadriceps femoris muscle is capable of producing action at both the hip and the knee, and it is seen as the great extensor of the leg (Moore and Dalley, 1999). The rectus femoris division of the quadriceps femoris muscle acts to flex the hip, along with the iliopsoas (Moore and Dalley, 1999; Marieb, 2004). The ability of the rectus femoris to extend the knee is compromised when the hip is flexed, but it does contribute to the extension force when the thigh is extended (Moore and Dalley, 1999). The three vastus muscles, vastus intermedius, vastus medialis and vastus lateralis, form the primary extensor muscle group of the knee (Moore and Dalley, 1999, Magee, 2008). The ability of the quadriceps femoris muscle group to produce knee extension is most effective when the hip joint is extended (Moore and Dalley, 1999).

The hamstrings muscle group produces extension at the hip and flexion at the knee (Moore and Dalley, 1999; Marieb, 2004). These two actions of the hamstrings cannot be performed maximally at the same time, as full flexion of the knee requires so much shortening that the hamstrings cannot provide the additional contraction needed for full extension of the hip, and vice versa (Moore and Dalley, 1999). The hamstrings, however, demonstrate most activity when they are eccentrically contracting to resist hip flexion and knee extension (Moore and Dalley, 1999).

2.2.5 Muscle Length/Tension Ratios

The active and passive mechanical performance of muscles depends on muscle architecture and morphology (Fry *et al.,* 2003). The isometric relationship between muscle length and force is a fundamental property of skeletal muscle (Gollapudi and Lin, 2009). The optimal resting length for muscle fibres is that length at which they can generate maximum force (Marieb, 2004). The ideal length tension relationship occurs when a muscle is slightly stretched, and the thick and thin filaments barely overlap, as this permits sliding along nearly the entire length of the thin filaments during muscle contraction (Marieb, 2004). If a muscle fibre is overstretched, it cannot develop tension, and if a muscle fibre is compressed, shortening will be limited. Muscles are at optimal operational length from 80% to 120% of their normal resting length (Marieb, 2004).

The study of muscle length adaptations requires measurement of passive length-tension properties of the muscle (Hoang *et al.*, 2005). At present, there are no simple tools to measure muscle length directly, indirect measurement consists of the clinical examination of joint ranges of motion (Fry *et al*., 2003). The assessment of quadriceps femoris muscle length is important because of its action on both the hip and knee muscles (Corkery *et al.*, 2007). The quadriceps femoris muscle length was assessed in this study using the modified Thomas test (Corkery *et al*., 2007). The test procedure involved the measurement of the degree of knee flexion. The participant was instructed to stand at the end of the diagnostics table and to hold their opposite knee and bring it to their chest. The participant then lay supine on the table with the test leg to be measured hanging off the table. The axis of the universal goniometer was placed over the lateral condyle of the femur, with the stationary arm of the goniometer placed on the lateral femur in line with the greater trochanter, and the moving arm of the goniometer parallel to the midline of the fibula in line with the lateral malleolus. A study in which Corkery *et al.* (2007), used the modified Thomas test to measure the quadriceps muscle length, found the mean value of the knee angle to be 53.5°. These findings are in line with a study by Harvey (1998), who found the mean value of the knee angle to be 52.5°.

Muscular work depends on the length-tension, force-velocity, and power relationships of the involved muscles. The effectiveness of force production is affected by muscle lengths, joint angles and muscle moment arms (Raymond, Joseph, and Gabriel, 2005). In turn, these variables are affected by changes in the position and orientation of the body, changes in cadence, and changes in seat height (Raymond, Joseph, and Gabriel, 2005). Seat height is one variable that can affect muscle moment arms and joint angles, and this highlights the importance of a proper bicycle setup (Bressel, 2001). A study by Umberger, Scheuchenzur, and Manos (1998), illustrated the effect of seat tube angle on joint kinematics. For the four respective seat tube angles tested (69°, 76°, 83°, 90°), the mean hip and knee angles were significantly different ($p < 0.05$), however, there was no significant difference found in the mean hip or knee range of motion. Differences in the hip and knee angles may lead to changes in the muscle recruitment patterns, muscle lengths, and muscle moment arms (Umberger, Scheuchenzur, and Manos, 1998). Maximum power produced by the cyclist has to be interpreted in terms of the length-tension and force-velocity-power relationships of the involved muscles (De Groot *et al.,* 1994).

Kinesio® tape functions to normalize length/tension ratios which creates optimal forces as well as tissue recovery (Kase, 2008) the author however, provides no research study or trial as a reference to show conclusive evidence of this effect. The measurement of the quadriceps muscle length/tension ratio is therefore important to this study as it may be directly affected by the application of the Kinesio® tape onto the participants' quadriceps femoris muscles.

2.3 An Overview of Cycling

2.3.1 Road Racing Bicycle

The standard road bicycle is made up of two triangles that share a common base – the seat post or tube (Beneke *et al*., 1989). The rear wheel is attached to the rear apex of the rear triangle and the head tube and front fork is attached to the front apex of the front triangle. Although the frame material may change, the basic shape remains constant (Beneke *et al*., 1989; Downs 2010).

There are angles that determine the geometry of a road racing bicycle frame (Beneke *et al*., 1989; Burke, 2003). The most important angle is that formed by the seat tube and the ground (Burke, 2003). The seat tube angle is designed to allow the knee to be over the pedal spindle of the forward foot when the crank arms are horizontal. The most common seat tube angles for road racing frames are 72° to 74° (Burke, 2003). The seat tube angle is related to femur length, the longer the femur the shallower the angle, and the shorter the femur the steeper the angle (Burke, 2003).

The ideal frame is the smallest possible frame which affords a good mix of comfort and handling (Burke, 2003). A smaller frame handles better than a larger frame, and is lighter and stronger (Burke, 2003). A short wheelbase also increases steering responsiveness (Burke, 2003). The overall wheelbase is kept to somewhere between 96.52 and 101.6 cm by a chain stay length that is 40.64 cm on a road racing bicycle (Burke, 2003).

Figure 2.1 The components of a road bicycle

The components attached to the frame comprise of the wheels, saddle, brakes, steering system, and the drive train (Beneke *et al*., 1989). The drive train is composed of the chain, derailleurs, cogset, and crankset (Downs, 2010). The drive train, also known as the transmission system, transforms the cyclist's energy into forward motion (Beneke *et al*., 1989). The drive train serves as the point where human power becomes mechanical motion by utilizing leg power from the pedals and transferring it to the chain and ultimately the rear wheel, making it turn (Downs, 2010)

In cycling the interaction between the cyclist and the bicycle is a complex one (Wishv-Roth, 2009). Riding position directly influences the power and physiological efficiency that can be produced by the athlete (Burke, 2003; Wishv-Roth, 2009). Optimal bicycle setup is vital to maximize performance in both the recreational and elite cyclist (Wishv-Roth, 2009).

2.3.2 Cycling Biomechanics

The cyclists riding position is influenced by many variables including: anthropometric measurements, athlete's strength and flexibility, muscle recruitment patterns and lower limb muscle lengths (Wishv-Roth, 2009). Pedaling technique is an important contributing factor to cycling performance and optimal muscle recruitment while cycling (Wishv-Roth, 2009). More than the equipment and technique used, however, the speed at which a cyclist can propel a bicycle depends on how much power the cyclist applies to the pedals (Burke, 2003). Peak power output appears to be highly correlated with cycling success (Faria, Parker and Faria, 2005).

Cycling power is produced by applying force to the pedals (Wishv-Roth, 2009). The crank cycle can be sub-divided into two main phases, namely; the propulsive/downstroke phase (0-180°) and the pulling/upstroke phase (181-360°) (Burke, 2003; Raymond, Joseph, and Gabriel, 2005). Certain literature includes third and fourth phases in the pedal cycle that are associated with the pushing and pulling phases in which the foot is pushed forward at the top dead centre (TDC) and the bottom dead centre point (Bertucci *et al*., 2005; Raymond, Joseph, and Gabriel, 2005). The first phase of the crank cycle, being the propulsive phase, is also known as the power phase (Raymond, Joseph, and Gabriel, 2005). During this power phase when the pedal is moving downward, a greater force is generated than in comparison with the upstroke phase, which is also known as the recovery phase (Bertucci *et al*., 2005; Raymond, Joseph, and Gabriel, 2005). The quadriceps muscle group is the prime mover to generate energy to the crank in the downstroke phase of the crank cycle (Raymond, Joseph, and Gabriel, 2005). The optimisation of the crank cycle in cycling can contribute to improvements in performance (Bertucci *et al*., 2005).

During pedalling, as the legs extend in the downstroke, muscle power is derived from the hip, knee, and ankle extensors, and half a cycle later as the legs flex in the upstroke, muscle power is derived from the hip, knee, and ankle flexors (Burke, 2003). Many of the main muscles involved in cycling, however, are biarticular muscles, and therefore, serve various functions at different phases of the pedal cycle (Burke, 2003; Raymond, Joseph, and Gabriel, 2005). The biarticular muscles that are active during the pedal cycle are the hamstrings, rectus femoris and gastrocnemius. The most important uniarticular muscles involved in cycling are the gluteus maximus, vastus lateralis, vastus medialis, soleus and tibialis anterior (Burke, 2003; Raymond, Joseph, and Gabriel, 2005). The muscles work in a coordinated sequence to maximise energy transfer from the cyclist to the bicycle (Raymond, Joseph, and Gabriel, 2005).

The single joint muscles are consistent in producing power at a similar portion of the crank cycle. The vastus medialis and vastus lateralis exhibit activity in the region that corresponds with the dominant knee extensor moment, this being from 45° before top dead centre (TDC) to 90° after top dead centre (Burke, 2003). Both vasti muscles exhibit rapid onset and cessation with constant activity in between during the downstroke phase (Raymond, Joseph, and Gabriel, 2005). The gluteus maximus, also a uniarticular muscle, is active during the downstroke phase, primarily from 70-150° and becomes relatively inactive during the upstroke phase (Burke, 2003; Asplund and St Pierre, 2004).

The biarticular muscles are responsible for the fine regulation of the moments about the joints (Raymond, Joseph, and Gabriel, 2005). The rectus femoris is a good illustration of how a muscle acts as a guide-wire to couple adjacent joint motions, as it flexes the hip and extends the knee, displaying similar activation timing (Burke, 2003). As a knee extensor the rectus femoris will exhibit activity for the same phase of the pedal cycle as the other vastii muscles, active predominantly in the downstroke phase from 0-150° (Asplund and St Pierre, 2004; Raymond, Joseph, and Gabriel, 2005). The hamstrings muscles exhibit peak activity late in the downstroke when the hip extensor and knee flexor moments coincide, and they effectively couple these joint motions together via the guide-wire effect (Burke, 2003). The hamstrings are predominantly active in the upward movement of the pedal, from 150-270° (Umberger, Gerritsen, and Martin, 2006). As cycling is repetitive in nature, restrictions in range of movement may occur (Burke, 2003). By improving muscle function it would be advantageous to the cyclist's performance in helping to correct the efficiency of the quadriceps contractions (Burke, 2003).

Pedalling technique is an important contributing factor to cycling performance and optimal muscle recruitment while cycling as it is a constrained cyclical movement (Bessot *et al*., 2007; Wishv-Roth, 2009). The commonly used fixed pedal constrains the foot in five degrees of freedom, therefore in addition to the loads required for propulsion, the constraint loads will be transferred by the joints of the lower limb (Wolchok, Hull, and Howell, 1998). Muscles activated in a defined pattern are not only necessary for optimizing the energy transfer from the cyclist to the pedals, but also in providing protection to the major joints (Raymond, Joseph, and Gabriel, 2005).

Dependant on the cyclist's position on the bicycle the hips are kept in a predominantly flexed position throughout the pedal cycle. At the TDC, the hips are at maximum flexion, and then undergo extension until the 180° position is reached at the bottom dead centre. The hip then undergoes flexion again as the pedal lifts the foot, and the opposite leg begins the downstroke phase (Burke, 2003). The knee begins the downstroke, maximally flexed at 110° and extends to 35° of flexion at the bottom of the pedal stroke (Asplund and St Pierre, 2004). While the knee extends it also adducts due to the angulation of the femoral condyles, leading to medial translation of the knee during extension (Asplund and St Pierre, 2004). The patellofemoral and tibiofemoral joints undergo large forces, exceeding body weight, while accommodating considerable knee joint mobility (Callaghan, 2005; Mesfar and Shirazi-Adl, 2005). Cyclists generate a large reaction force at the patellofemoral joint surface that is made even greater by the 110° of knee flexion achievable by a cyclist at the start of the downstroke (Callaghan, 2005). Movement of the patella, patella tracking, is actively controlled by the quadriceps femoris muscles (Cesarelli, Bifulco, and Bracale, 1999). The primary function of the patella is to increase the effective lever arm of the quadriceps femoris muscle forces required to resist or generate extensor moments (Mesfar and Shirazi-Adl, 2005).

2.3.3 Factors Determining Cycling Efficiency

2.3.3.1 Power

Cycling power is a critical performance factor for coaches, scientists and cyclists, and is the best measure of exercise intensity and cycling performance (Burke, 2003). Power is the rate of doing work expressed in watts (Powers and Howley, 1997). When measured whilst cycling, power represents the quantity of energy delivered to the pedals by the cyclist per unit of time. When power levels double, it indicates that twice as much energy is being delivered to the pedals by the cyclist per unit of time (Burke, 2003). Maximum power is influenced by pedaling rate, body position, and geometry of the bicycle (De Groot *et al*, 1994). Mechanical energy is delivered from the chain ring to the rear wheel through the chain and transmission (Burke, 2003). Friction in the bottom bracket bearings, chain elements, and rear transmission consumes a small portion of this energy.

2.3.3.2 Cadence

Cadence is the speed at which the pedals are turned and is reported in revolutions per minute (Green, Johnson, and Maloney, 1999). Several factors may alter a cyclists' pedaling cadence, including power output, duration of exercise, test mode, fitness level of the subject, and high inter-individual variability even among trained cyclists of similar fitness levels (Burke, 2003). In a study by Takaisha (2002; as cited by Burke, 2003) that examined blood flow during the pedaling cycle, the results showed that at a low cadence (50 rpm) blood flow and oxygenation to the quadriceps muscles was restricted during the first third of the crank cycle. At this point in the pedal cycle knee flexion and quadriceps muscle contraction is the greatest, as the leg moves through the pedal stroke to leg extension. The study concluded that the quadriceps muscle underwent marked blood flow occlusion during the downstroke phase of the pedal cycle (Takaisha 2002; as cited by Burke, 2003). Any pedaling cadence capable of maximizing blood flow to the muscles could overcome, at least partly, the inevitable blood flow restriction brought about by quadriceps muscle contraction and might represent an important physiological advantage (Burke, 2003). A higher pedaling cadence (greater than 90 rpm) has been shown to overcome this, as at a higher cadence, leg muscles contract and relax at a higher frequency, and this in turn enhances the effectiveness of the skeletal-muscle pump (Beneke et al., 1989; Burke, 2003). The contractions of working muscles around leg veins exerts a pumping action on the vessels, thus, the faster the pumping effect of skeletal muscles around the leg veins, the greater the ability to overcome gravity, and the quicker the blood returns to the heart. The advantages of higher cadences are, therefore, the improved blood flow to working muscles and the minimization of local muscle stress (Burke, 2003). Pedal rate is, however, not entirely constant and shows fluctuations that are caused by the power fluctuations (Ettema, Loras, and Leirdal, 2009).

2.3.3.3 Speed

Potential for speed depends more on muscle type and cardiovascular conditioning than on body type. Fast-twitch muscle fibers, which are more efficient at higher cadences, are well suited for short bursts of speed but do not process oxygen as efficiently as slow-twitch muscle fibers, which are more efficient at lower cadences (Burke, 2003). The speed at which a cyclist can propel a bicycle depends on how much power the cyclist applies to the pedals (Burke, 2003). It has been shown that the higher the power output, the higher the cadence (McIntosh, Neptune, and Horton, 2000). Therefore, the power the cyclist applies to the pedals directly affects the speed of the bicycle but, is in turn directly affected by the speed with which the cyclist can turn the pedals.

2.3.3.4 Time

Cycling success, even after days of racing on the bicycle in cycling stage races, often has the outcome determined only by a few seconds as was witnessed in the 1989 Tour de France, when Greg LeMond won by eight seconds, and, only on the final stage (http://www.bicycling.co.za/articles/tour-de-france-glossary accessed 28 September 2011). In the 2011 Tour de France, the first and second placed cyclists were separated by only eight seconds in the overall classification when they began the individual time trial on the second to last stage (http://www.bicycling.co.za/articles/time-trials accessed 28 September 2011). In this sense the importance of measuring the completion time of the time trials in this study is imperative. Should the results of this study show an improvement in completion time, it may show a valuable result in gaining those seconds that the outcome of cycling races so often are determined by.

2.3.3.5 Energy Systems and Fuel Sources

The energy used by muscles when contracting comes from adenosine triphosphate (ATP) (Beneke *et al*., 1989). As vigorous exercise begins, ATP is consumed within a few twitches (4-6 seconds), fortunately ATP is regenerated within a fraction of a second by three pathways: (1) direct phosphorylation, (2) anaerobic mechanism, (3) aerobic mechanism (Powers and Howley, 1997; Marieb, 2004). Events lasting longer than forty-five seconds use a combination of all three energy systems to supply the needed ATP (Powers and Howley, 1997). Carbohydrates are the primary fuel source during high intensity exercise (Beneke *et al*., 1989; Powers and Howley, 1997). Carbohydrates are stored in both the muscles and the liver as glycogen. Muscle glycogen stores provide a direct source of carbohydrates for muscle energy metabolism, and liver glycogen stores serve as a means of replacing blood glucose (Powers and Howley, 1997). During short term exercise, it is unlikely that blood glucose levels or muscle stores of glycogen would be depleted (Powers and Howley, 1997).

2.3.4 Cycling Efficiency and Economy

Gross efficiency is defined as the ratio of work accomplished to energy expended. It has been suggested that gross efficiency is one of the most important functional abilities of a cyclist as it determines the amount of power that can be produced for a given oxygen and energy expenditure (Hopker *et al*., 2010). Gross efficiency is an estimate of whole body efficiency (Burke, 2003). An efficient cyclist channels their effort into driving the bicycle forward, and gains a greater distance faster, and with less effort than the cyclist who allows energy to be dissipated unproductively (Beneke *et al*., 1989).

Repeated performance of a movement task facilitates neuromuscular adaptations, and this results in more skilled movement and muscle recruitment patterns (Chapman *et al*., 2008). Difference in pedaling skill is, however, still evident, and exists even amongst highly trained cyclists (Raymond, Joseph, and Gabriel, 2005).

There are also several external factors that influence a cyclist's efficiency and are important (Beneke *et al*., 1989; Burke, 2003). These include: incorrect bicycle set up or poor fit, friction within the drive train, bottom bracket, and chain elements, and the type of bearing and lubricant used in the internal bearings (Burke, 2003). Friction between the surfaces of components on the bicycle can dissipate roughly five to fifteen percent of a cyclist's energy (Beneke *et al*., 1989). Other factors that also effect cycling efficiency and need to be controlled in scientific studies include the surface ridden on, tyre pressure, tyre and wheel diameter, and tyre temperature (Burke, 2003). Rolling resistance created by the wheels, is proportional to how much of a wheels surface is in contact with the road/surface (Beneke *et al*., 1989). A narrow tyre, such as that found on a road bicycle, has little of its surface in contact with the road and, therefore, rolls with less resistance (Beneke *et al*., 1989; Burke, 2003).

Mass is another force working against the cyclist (Beneke *et al*., 1989). The effect of gravity results in a higher weight deforming the tyre and raising the bearing loads, resulting in a higher rolling resistance (Burke, 2003). Weights' effect on bicycle speed is, however, small (Burke, 2003). A heavier cyclist, combined with a heavier bicycle requires more leg power to overcome the gravity, particularly when climbing hills (Beneke *et al*., 1989).

2.3.5 The Cycle Ergometer versus Outdoor Cycling

Most studies designed to explore factors affecting cycling efficiency are limited by the fact that participants were tested in a laboratory setting (Burke, 2003). The best case studies occurred, however, when participants were tested while riding their own bicycles on an ergometer (Burke, 2003).

In laboratory testing situations the mean cycling velocity is imposed by the cycle ergometer (Burke, 2003). In real road cycling conditions the mean cycling velocity is less easily controlled and oscillates more, compared with the laboratory conditions (Bertucci *et al*., 2005). The power output and pedaling cadence primarily oscillate more in real life cycling (Bertucci *et al*., 2005). Certain factors are controllable in a laboratory setting that may enhance the outcome of the results. For example standing out of the saddle causes a change in the muscle recruitment pattern (Raymond, Joseph, and Gabriel, 2005).

2.4 Kinesio® tape

Kinesio® taping is a technique that was established in the 1970's by Dr. Kenzo Kase (Garcia-Muro *et al.*, 2010). The technique claims several main effects: to normalize muscular function, to diminish pain, to increase lymphatic and blood flow, to aid in the correction of possible articular malalignments and to protect against muscle fatigue and injury (Kase *et al*., 1996, as cited by Garcia-Muro *et al.*, 2010).

Of the reported effects of Kinesio® tape on the muscle, the increased ROM, reduced fatigue by normalizing length/tension ratios which creates optimal forces, as well as tissue recovery (Kase, 2008), are more pertinent to this study. The five main physiological effects of Kinesio® tape are on the skin, circulatory/lymphatic systems, fascia, muscle, and joint. The elasticity of Kinesio® tape is its most important feature in attaining these effects, by subcutaneously lifting the skin to improve fluid movement and produce positive results for the top layers of fascia, as well as the much deeper layers. To facilitate a muscle and enhance its function, the muscle should be taped from origin to insertion at 15%-50% tape tension (Kase, Wallis, and Kase, 2003).

The proposed five main physiological effects can be further discussed, illustrating the way in which Kinesio® tape proposes to achieve each of these effects. Through its application to the skin, Kinesio® tape stimulates the mechanoreceptors of the skin and decreases pressure on the mechanical receptors (Kase, Wallis, and Kase, 2003). By increasing the amount of space beneath the skin, Kinesio® tape affects the circulatory/lymphatic system by increasing interstitial lymphatic flow, enhancing fluid exchange between tissue layers, and equalizing temperature. The various layers of fascia are assisted by Kinesio® tape to maintain fascial position, and in cases of previous injury allow for fascial remodelling (Kase, Wallis, and Kase, 2003. Kinesio® tapes effect on muscle when applying the tape to facilitate a muscle is suggested, but not clinically proven, to act to increase ROM, improve muscle contraction, normalize length/tension ratios to create optimal force, assist tissue recovery, and decrease fatigue. Joints are another area where Kinesio® tape can be extremely effective, as joints are not isolated and they work directly with ligaments and tendons to perform tasks for the body. Kinesio® tape is said to improve joint biomechanics and alignment, reduce muscle guarding, and facilitate ligament and tendon function (Kase, 2008)

Research by Murray (2000), investigated the effects of Kinesio® tape for increasing joint ROM and increasing muscle strength. The study involved the application of two taping methods to the quadriceps femoris muscle after an anterior cruciate ligament repair. Three mechanisms were assessed on each participant (*n* = 2); no tape, athletic tape and Kinesio® tape. An improvement was only seen on the application of Kinesio® tape, where a significant increase in the active range of motion during knee extension with a decrease in knee lag was seen, as well as an increase in muscle strength seen on surface electromyography (EMG) of approximately 1½ times in amplitude.

Research has shown that Kinesio® tape applied on healthy tennis players (*n* = 14) was effective at decreasing fatigue by maintaining strength of the forearm extensors (Schneider, Rhea and Bay, 2010). The participants were required to hit a predetermined amount of either forehand or backhand tennis shots, each participants was required to hit the predetermined number of shots with no tape as the control, and then again with the application of Kinesio® tape to the forearm extensors. The results showed that strength in the control group was significantly decreased when compared to strength in the Kinesio® tape group (*p* = 0.032) The greatest percent change between the groups was from pre- to post- test, and this suggests that as the motor units fatigued during the workout, the Kinesio® tape aided in muscle contraction. It was suggested that in addition to improvements in muscular strength and power, Kinesio® tape may also have affected proprioception in this study (Schneider, Rhea and Bay, 2010). Research has, on the contrary, shown that Kinesio® tape did not improve proprioceptive response at the ankle with measures of reproduction of joint position sense (Halseth *et al.*, 2004). Little is known of the proprioceptive effect of Kinesio® tape, but the proposed mechanism is that there will be a facilitation effect on the mechanoreceptors (Halseth *et al*., 2004). Cutaneous mechanoreceptors may be stimulated by applying pressure to, and stretching, the skin (Halseth *et al.*, 2004). An elastic tape, such as Kinesio® tape, may cause proprioceptive stimulation while at the same time not limiting the enhancement of improved joint range of motion and muscle function (Murray, 2000).

Kinesio® tape uses elastic properties to reduce muscular and blood flow restrictions (Schneider, Rhea and Bay, 2010). Kase and Hashimoto (1998) illustrated in a clinical study the effect of Kinesio® tape on peripheral blood flow before and after taping. Kinesio® tape was applied to relatively healthy participants and participants with minor physical disorders; tendonitis, osteoarthritis, headaches (*n* = 9) on areas most likely to affect blood circulation to the affected area. The pectoralis major muscle was taped to measure the peripheral blood flow of the radial artery, the sternocleiomastoid muscle was taped to measure the peripheral blood flow of the superficial temporal artery, and the gastrocnemius muscle was taped to measure the flow of the dorsalis pedis artery. The participants' peripheral blood flow in the relative arteries was measured by Doppler Ultrasound immediately before the tape was applied, and then ten minutes after application. The researchers concluded that Kinesio® tape was effective in changing the peripheral blood flow for all participants that had physical disorders with an increase in flow ranging from 20.6% to 60.7%. The results were however not statistically analysed. To the researchers knowledge no other studies have been done on the effect of Kinesio® tape on peripheral blood flow and there is therefore paucity in the literature regarding the physiology of its effect.

Kinesio® tapes elastic properties should not limit ROM and may even enhance it, depending on the mode of application. According to Yoshida and Kahanov (2007) Kinesio® taping may increase active ROM of lower trunk flexion. Trunk ROM was recorded before and after the application of Kinesio® tape in asymptomatic individuals (n = 30). A significant difference ($p < 0.05$) was identified for trunk flexion ROM, however, there were no significant differences ($p > 0.05$) for trunk extension and lateral flexion. The Kinesio® taped asymptomatic participants flexion ROM was 17cm greater than the untapped asymptomatic participants in the sum of all scores (Yoshida and Kahanov, 2007). In a similar study Kinesio® tape (experimental group) and a sham Kinesio® tape (placebo group), were applied to the cervical spine in individuals with acute whiplash-associated disorders (n = 41). Both neck pain and cervical ROM were assessed and data recorded at baseline, immediately following Kinesio® tape application, and 24 hours after application. Participants receiving the application of Kinesio® tape experienced a greater decrease in pain immediately following application and at the 24 hour follow up (both $p < 0.001$), these participants also obtained a great improvement in ROM ($p < 0.001$). It was concluded that an application of Kinesio® tape, applied with proper tension, exhibited statistically significant improvements immediately following application, and at a 24 hour follow-up. The improvements, however, were small ($p < 0.05$) (Gonzalez-Iglesias *et al.*, 2009).

As cycling is repetitive in nature, muscular restrictions may occur and cause decreases in ROM as a result (Burke, 2003). The application of Kinesio® tape should serve to correct this by normalizing muscle function and length/tension ratios (Kase *et al.*, 1996, as cited by Garcia-Muro *et al.*, 2010; Kase, 2008). However, there is paucity of information regarding the application of Kinesio® tape and its effect on power output and hip and knee range of motion (flexion and extension) in cyclists.

2.5 Measurement tools

2.5.1 The Universal Goniometer

An accurate and reproducible method of joint ROM measurement is essential for the classification of success or failure in therapeutic intervention (Cleffken *et al*., 2007). Goniometry is a technique commonly used in physical therapy to assess the range or limitation of a patient's joint motions (Gogia *et al*, 1987). Studies conducted indicate that universal goniometric measurements of the hip and knee joint are both valid and reliable (Gogia *et al.*, 1987; Watkins *et al.*, 1991; Murray, 2000; Aalto *et al*., 2005). The universal goniometer is the instrument most commonly used to measure joint motion in the clinical setting and is named so because of its versatility (Norkin and White, 2003). Reliability of the universal goniometer is good, and reproducibility is better during the same measurement session, by the same tester and when keeping with the same patient position (Aalto *et al*., 2005). The universal goniometer has a moveable arm and a scale marked in 1-degree increments that will be used to record measurements once the moveable arm is aligned to the full extent of the joint ROM (Watkins *et al.*, 1991).

2.5.2 Cycle Ergometer

The term ergometer refers to the apparatus or device used to measure a specific type of work output (Powers and Howley, 1997). Sprint exercise on a computerized cycle ergometer has proved to be a useful means for studying the effect of fatigue on mechanical power production (Billaut *et al*., 2005; Bercier *et al*., 2009). Power delivered to the cycle ergometer must be produced by the muscles that span the hip, knee, and ankle joints (Martin and Brown, 2009). The cycle ergometer used in this study was a Tacx Fortius Virtual Reality Trainer. The Tacx Trainer uses an electromagnetic brake, as well as tyre friction to provide resistance to the pedal power (Jones, 2008).

Figure 2.2 The Tacx Trainer with electro-magnetic brake

Figure 2.3 The Tacx Trainer software program

2.6 The Hawthorne Effect

When conducting clinical research it should be borne in mind that it can be influenced by many factors, such as the Hawthorne effect, where the mere awareness of being under observation can alter a person's behaviour and thus the outcome of a specific intervention (De Amici *et al.*, 2000). McCarney *et al.* (2007), found that many patients appeared to respond better to treatment than those in normal practice due to the fact that they were participating in a clinical trial, and patients may therefore change behaviour when observed or treated.

The Hawthorne effect was first described in the 1920's and 1930's when Chicago's West Electrical Company's Hawthorne Works conducted an extensive research programme, investigating methods of increased productivity (Roethlisberger and Dickson, 1939; Mayo, 1993). It was observed that regardless of the changes made to the working environment there was an increase in productivity. Frank and Kaul (1978; *as cited by* Sood, 2008) defined this phenomenon as "an increase in worker productivity produced by the psychological stimulus of being singled out and made to feel important".

Even though it was first reported in industrial research, the Hawthorne effect may well have implications for clinical research. The Hawthorne effect may be an important factor affecting the generalisability of clinical research to routine practice (McCarney *et al.*, 2007). Despite relatively few studies on the Hawthorne effect it should be considered when analyzing the results, although it should not affect the assessment of the difference between intervention and control (de Amici *et al.*, 2000; McCarney *et al.*, 2007).

2.7 Conclusion

Assessment of the potentially beneficial effects of the application of Kinesio® tape to a cyclists quadriceps femoris muscles is important. An enhanced cycling performance may occur as a result of the proposed positive physiological effects of Kinesio® tape on the muscles, joints, skin, fascia, and circulation.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter gives an overview of how the study was conducted. The study design, participant selection, consultation procedure and the intervention used, as well as the statistical procedures performed will be discussed. This study obtained ethics clearance through the Faculty of Health Sciences' research committee at the Durban University of Technology and an ethics clearance certificate (**Appendix L**), was issued, and the study was conducted according to the Declaration of Helsinki (Rickham, 1964). The following flow chart is a summary of the order in which the study took place:

Made contact with cyclists

↓

Participant inclusion or exclusion

↓

Scheduled appointment if included

↓

Explanation of procedure

↓

Signing of informed consent form

↓

Case history, relevant physical examination, hip and knee regional examinations were performed

↓

ROM measurements of both hip flexion and extension and knee flexion and extension were taken by means of a universal goniometer, and muscle length-tension was measured by means of the modified Thomas test

↓

Participants own road bicycle was mounted on the cycle ergometer

↓

5 minute warm-up at work rate specified

↓

ROM measurements of both hip flexion and extension and knee flexion and extension were taken by means of a universal goniometer, and muscle length measured by means of the modified Thomas test

↓

1.5 km time trial was cycled and measurements of maximum and average power, maximum and average speed, maximum and average cadence, and completion time were recorded

↓

Kinesio® taping protocol was applied and followed by a 20 minute rest

↓

ROM measurements of both hip flexion and extension and knee flexion and extension were taken by means of a universal goniometer, and muscle length-tension measured by means of the modified Thomas test

↓

1.5 km time trial was cycled and measurements of maximum and average power, maximum and average speed, maximum and average cadence, and completion time were recorded

↓

Assessment of participants' perception of a change in their power output, speed and cadence was recorded

Figure 3.1 Flowchart illustrating overview of experimental chronology

3.2 Study Design

This study was designed as a quantitative, pre- and post- experimental trial (Mitchell and Jolley, 1992).

3.3 Sample and Recruitment

A sample size of 40 participants was recruited to participate in the study.

A convenience sampling recruitment method (Ferber, 2010) was followed. Advertisements **(Appendix B)** and word of mouth were used to recruit participants; advertisements were placed at the Durban University of Technology, local sports clubs and cycling shops.

Respondents to the advertisements were contacted telephonically and interviewed to assure suitability for the study.

Table 3.1 Questions and expected answers from respondents for them to qualify to participate in the research study

Questions asked of respondents	Answers from respondents to qualify to participate in research
1. Are you between the age of 20 and 45?	1. Yes
2. Do you cycle a minimum of 6 hours a week?	2. Yes
3. Have you been cycling regularly for at least one year?	3. Yes
4. Are you currently pain free in the lower back and lower limb regions, including the hip, knee, and ankle?	4. Yes
5. Do you have any chronic disease?	5. No

If a respondent met the criteria, an appointment was made at the Durban University of Technology Chiropractic Day Clinic.

3.4 Inclusion and Exclusion Criteria

3.4.1 Inclusion Criteria

1. Each participant agreed to sign a consent form **(Appendix C)**.
2. All participants chosen were between the ages of 20 and 45. This age group was selected to exclude chronic degenerative diseases which most often occur in the late fourth and fifth decades (Beers *et al*, 2006).
3. Participants were asymptomatic in regions from the lumbar spine to the lower extremity, including the hip, knee and ankle.
4. To ensure a minimum level of fitness throughout the study, participants must have been actively participating in cycling on a regular basis amounting to a minimum of 6 hours a week for a period of at least a year.
5. Each participant must have trained consistently on a road or mountain bicycle.

3.4.2 Exclusion Criteria

Participants were excluded from the study if they presented with:

1. Pain in the lower extremity.
2. Dysfunction due to organic causes or chronic disease.
3. Contra-indication to Kinesio® tape is the exclusion of excessively hairy subjects who refused to shave or trim the leg hair prior to the trial.

3.4.3 Participant Informed Consent

At the consultation the study was explained and a Letter of Information and Informed Consent **(Appendix C)** was issued to participants. If the participants agreed to take part in the study the informed consent document was then signed. The participants' names were not revealed in the data sheets. All names were coded and this was used during data capture and analysis. Only the researcher and her supervisor had access to the data. The relevant clinic paperwork that was completed, namely the case history, relevant physical examination, hip and knee regional examinations were discussed with the clinician on duty on the day of the consultation.

3.5 Procedure

A sample population size of 40 was recruited similar to the cohort of Sood (2008) and Cunninghame (2009). Each participant was subjected to the study for a once off clinical trial. The consultation was carried out at the Chiropractic Day Clinic at the Durban University of Technology. If the participant met the inclusion criteria, they were requested to read the letter of information **(Appendix C**) and an opportunity to ask any questions regarding the study was given to participants. A case history, relevant physical examination, hip and knee regional examinations were done at this consultation **(Appendices D**, **E, F** and **G** respectively**)**. Participants were asked to bring in their current road bicycle on which the majority of training was done. Participants were assessed on their own road bicycles and no adjustments were made to the bicycle setup to exclude any variables as a result. All participants were tested on road bicycles and used the same bicycle for both trials, thus maintaining the same riding position, with the same tyre pressure and gearing.

ROM measurements of both hip flexion and extension and knee flexion and extension were taken in that order by means of a universal goniometer pre- warm-up, and muscle length was measured by means of the modified Thomas test (Corkery *et al.,* 2007). The modified

Thomas test and range of motion measurements were taken by the researcher only, and one measurement was taken at each recording pre- warm-up, pre- time trial one, and pre- time trial two.

Each participant was then put through a 5 minute warm-up (Aisbett, Rossignol, and Sparrow, 2003; Pierre, Nicolas, and Frederique, 2006; Lucertini *et al*., 2009; Bercier *et al*., 2009; Martin and Brown, 2009). The participant was seated on their own road bicycle, mounted on an electromagnetic roller resistance ergometer (Tacx trainer). The warm-up consisted of a 5 minute cycling exercise at a work rate of 100W-120W and at a cadence of 90 rpm-100 rpm (Aisbett, Rossignol, and Sparrow 2003; Bercier *et al*., 2009; Martin and Brown, 2009), followed by a complete rest of 5 minutes, in which time ROM and muscle length measurements were performed; post- warm-up and prior to commencing the time trial. Throughout the warm-up and the time trial the participants' heart rate was also monitored. Calculation of post-exercise heart rate recovery on the cycle ergometer has been shown to be a reliable tool in assessing physical recovery in healthy people (Arduini, Gomez-Cabrera, and Romagnoli, 2011). The participant was allowed to commence the time trial once the heart rate recorded at the start of the warm-up was reached and recorded prior to each of the time trials.

Figure 3.2 The trial setup

The test protocol (time trial) comprised of a 1.5 km time trial route, which was pre-programmed by the Tacx trainer, from which measurements of maximum and average power, maximum and average speed, maximum and average cadence, and completion time were recorded. The 1.5 km course began with a 1 100 m flat section, then a 300 m ascent with a maximum gradient of 12%, and ended with a 100 m descent to the finish line.

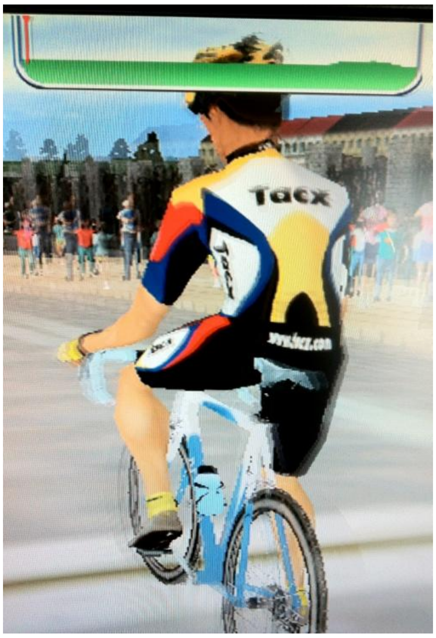

Figure 3.3 The virtual reality Tacx software; illustrating the 1.5 km course route profile

Following the time trial, the area of the participants' quadriceps muscle to be taped was cleaned thoroughly by means of alcohol and cotton wool to remove any sweat that may have prevented the proper adhesion of the tape to the skin. The intervention (Kinesio® taping protocol) was then applied from the origin of the rectus femoris on the anterior inferior iliac spine to the common patella tendon insertion of the quadriceps femoris on the tibial tuberosity (Kase *et al.*, 2003). The "Y" technique of taping was used as it is commonly used for surrounding a muscle to facilitate muscle stimuli (Kase *et al.*, 2003).

Figure 3.4 The "Y" taping technique

Figure 3.5 The Kinesio® tape application

A period of 20 minutes was allowed following the application of the Kinesio® tape intervention before the measurements were retaken. The protocol set out by Kase *et al.* (2003), states that the tape needs approximately 20 minutes to gain full adhesive strength and after approximately 10 minutes the patient will generally not perceive there is tape on their skin (Kase *et al.*, 2003). The 20 minutes allocated for the tape to gain full adhesive strength also allowed for 20 minutes of passive recovery from the time trial. This 20 minute recovery interval was the same as the duration used in other time trial studies (Schniepp *et al*., 2002; Pierre, Nicolas, and Frederique, 2006; Peiffer *et al*., 2010). Adenosine triphosphate (ATP) repletion following exhaustive exercise is approximated to be 95% complete in 3 minutes, and is crucial in the performance of short duration, high intensity work (Connolly, *et al*., 2003).

Following the allocated time period, ROM of both hip and knee flexion and extension was measured again by means of the universal goniometer, and muscle length - tension was measured by means of the modified Thomas test. Following this, the participant was allowed to start the next time trial, once the heart rate had returned to the same level as at the end of the warm-up period. This served to ensure that the participant was in the same physiological state (Arduini, Gomez-Cabrera, and Romagnoli, 2011). Thereafter, the participant then completed the same 1.5 km time trial route and measurements of maximum and average power, maximum and average speed, maximum and average cadence, and completion time were recorded once more. For each time trial, the participant began from a pedal position 45 degree forward to the vertical axis and movement was initiated by the dominant leg (Billaut, Basset, and Falgairette, 2005). Participants were strongly encouraged by the researcher and asked to finish each time trial in the shortest time possible by pedaling as fast as possible from the start. Participants remained seated throughout the entire time trial duration to prevent any changes in muscle recruitment pattern resulting from alterations in posture (Billaut, Basset, and Falgairette, 2005).

Following completion of the final time trial, the participants' perception of a change in their power output, speed, and cadence post- intervention were recorded **(Appendix H).**

3.6 Measurement Tools

3.6.1 Universal Goniometer

Range of motion of hip flexion and extension and knee flexion and extension were measured in that order (Watkins *et al.*, 1991; Aalto *et al*., 2005). In this study goniometer readings were recorded pre- warm-up, post- warm-up and pre- intervention, and post- intervention. The anatomical landmarks used for measurement were the greater trochanter of the femur, lateral epicondyle of the femur, and lateral malleolus of the fibula (Norkin and White, 2003).

The goniometer alignment used for the hip was as follows:

1. The centre fulcrum of the goniometer was placed over the lateral aspect of the hip joint using the greater trochanter as a reference.
2. The proximal arm was aligned with the lateral midline of the pelvis.
3. The distal arm was aligned with the lateral midline of the femur using the lateral epicondyle as a reference.

For the measurement of hip flexion, the participant was supine with the knees extended to start, and ending with the hip and knee in full flexion. For the measurement of hip extension the participant was prone with the hip and knee extended (Norkin and White, 2003). Coloured stickers/dots were used to mark the reference points used during measurements.

The goniometer alignment used for the knee was:

1. The centre fulcrum of the goniometer was placed over the lateral epicondyle of the femur.
2. The proximal arm was aligned with the lateral midline of the femur using the greater trochanter as a reference.
3. The distal arm was aligned with the lateral midline of the fibula using the lateral malleolus and fibular head as a reference.

For the measurement of knee flexion, the participant was supine with the hips and knees in extension to begin with, and ending with the hip and knee in full flexion. For the measurement of knee extension the participant was prone with the hip and knee extended (Norkin and White, 2003).

3.6.2 Cycle Ergometer

All time trials were performed on the participant’s own road bicycle mounted on an electromagnetic roller resistance trainer (Ettema, Loras, and Leirdal, 2009). Measurements of maximum and average power (watts), cadence (revolutions per minute), speed (kilometres per hour), and completion time (minutes) were recorded by a computer connected to the Tacx Trainer. The cycle ergometer software was programmed such that as the participant took their first pedal stroke for the 1.5 km time trial, the clock began and the respective measurements were recorded automatically (Cunninghame, 2009). The Tacx trainer was calibrated – as per the Tacx manual - prior to the commencement of the time trials.

Use of the same bicycle, for each participant, allowed for maintenance of the riding position for each trial, as well as ensuring there was no difference in the tyre pressure and gearing. With relative ease the cycling task can be used in a laboratory setting to study musculoskeletal function (Burke, 2003).

3.6.3 Participants' Perception of Power, Speed and Cadence

The participants' perception of a change in power output, speed and cadence, post-intervention was recorded **(Appendix H).** The table was adapted from a study conducted by Sood (2008).

3.7 Statistical Analysis

SPSS version 18 (SPSS Inc.) was used to analyse the data (**Appendix I**). Repeated measures ANOVA testing were used to compare the responses over time between the two treatment groups. A significant time x group effect indicated a differential treatment effect. Profile plots were generated in order to compare the direction and trend of the treatment effect. This was done intra- and inter- group analysis. A p value < 0.05 was considered as statistically significant (Esterhuizen, 2011).

CHAPTER 4

STATISTICAL METHODS AND RESULTS

4.1 Physical Characteristics and Demographic Data

The physical characteristics of the participants (*n* = 40) who completed this clinical trial are summarized in Table 4.1.1. The sample was made up of amateur cyclists (mean age: 33.75 ± 7.98 years), who were actively involved in road (*n* = 9), mountain bicycle (MTB) (*n* = 8), or both road and MTB (*n* = 23) training activities and races. Some of the participants also reported participating in multiday/stage races (*n* = 16) and triathlons (*n* = 8).

Table 4.1.1 Mean (±SD) physical characteristics (*n* = 40)

Characteristics	Mean (±SD)	Range
Age (years)	33.75 (±7.983)	20 - 45
Mass (kg)	77.475 (±9.829)	56 - 99
Stature (m)	1.77 (±0.081)	1.55 – 1.94
Body mass index	24.68 (±2.403)	20.7 - 30

Figure 4.1.1 reflects the preference of the cyclists to road or MTB cycling, or a combination thereof.

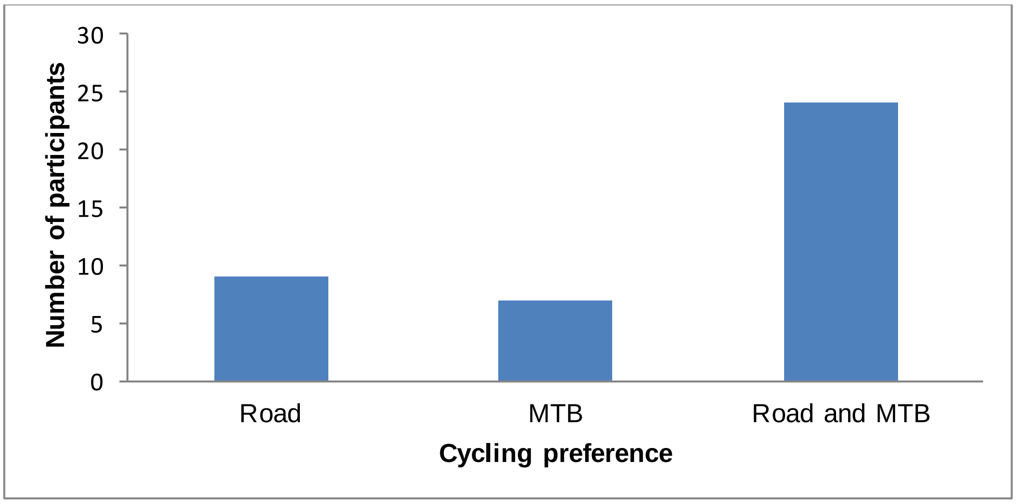

Figure 4.1.1 Cycling preference of participants

The inclusion criteria of the study allowed for male and female participants. Table 4.1.2 reflects that the vast majority of the participants were male (90%).

Table 4.1.2 Gender of participants

Sex	Number	Percent (%)
Female	4	10
Male	36	90

The participants were from multiple ethnic groups with the Caucasian group forming the majority of participants (*n* = 36). The other ethnic groups included Indian (*n* = 3) and Black (*n* = 1). Figure 4.1.2 represents the ethnic divisions of the participants that participated in this research.

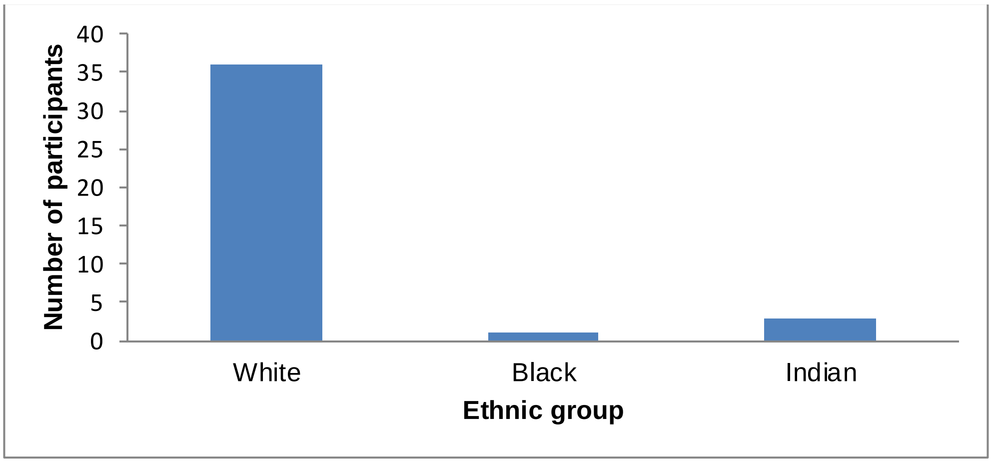

Figure 4.1.2 Ethnic group of participants

Figure 4.1.3 illustrates the participants' level of cycling experience. This experience ranged from meeting the inclusion criteria of one year actively cycling (*n* = 4) to a long history of cycling activity. The participants' level of cycling experience ranged from 1 year to 20 years, with a mean of 5.9 (SD ±4.179) years.

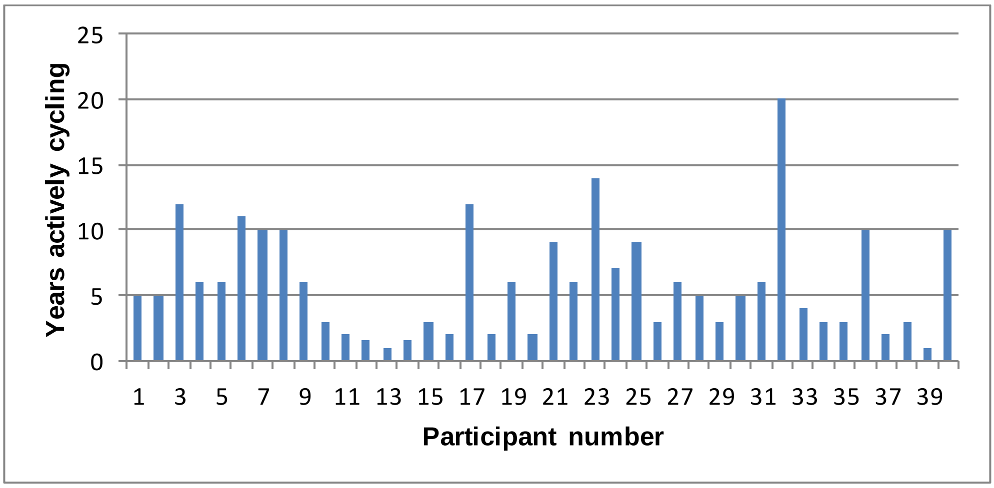

Figure 4.1.3 Level of cycling experience of participants

There was a variation in the number of hours a week the cyclists trained, this ranged from 6 hours to 12 hours a week, with a mean of 7.625 (SD ±2.1084) hours a week. Figure 4.1.4 reflects the training hours of each of the participants in an average week.

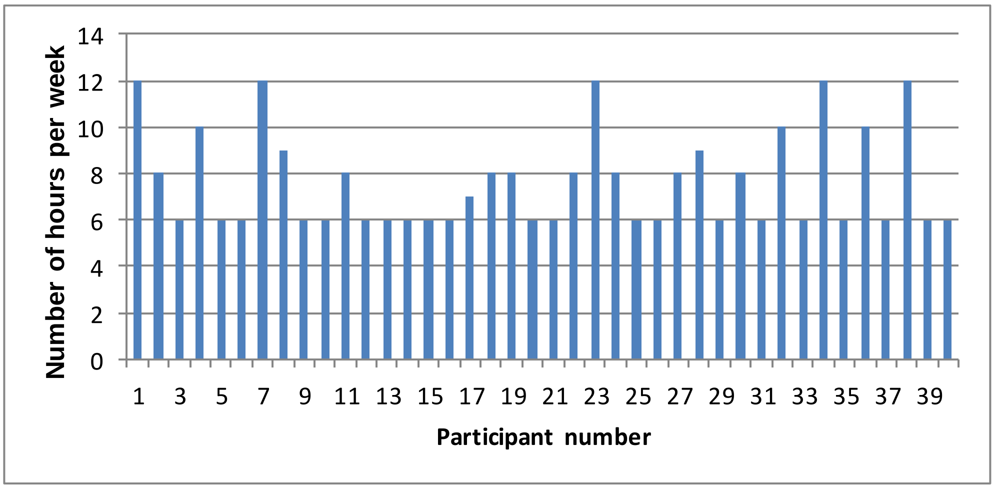

Figure 4.1.4 Training hours of participants

4.2 Hip and Knee Flexion and Extension

Paired t-tests were used to compare the pre- warm-up and pre- time trial (TT1) range of motion measurements. The paired t-tests were also used to analyze the control (pre- time trial 1) and Kinesio® taped (pre- time trial 2) range of motion measurements. The results of the comparisons will be shown in the following tables and figures.

The degree of hip flexion range of motion pre- warm-up, pre- TT1, and pre- TT2 are shown in Figure 4.2.1. In the hip flexion measurements post- warm-up and pre-TT1, there was a significant increase on the right ($p < 0.001$), the measurement on the left however was statistically insignificant ($p = 0.080$). There was a significant decrease in hip flexion measurement after Kinesio® tape application and pre-TT2 on the right ($p < 0.021$). Measurement on the left post- Kinesio® tape application was not significant ($p = 0.060$).

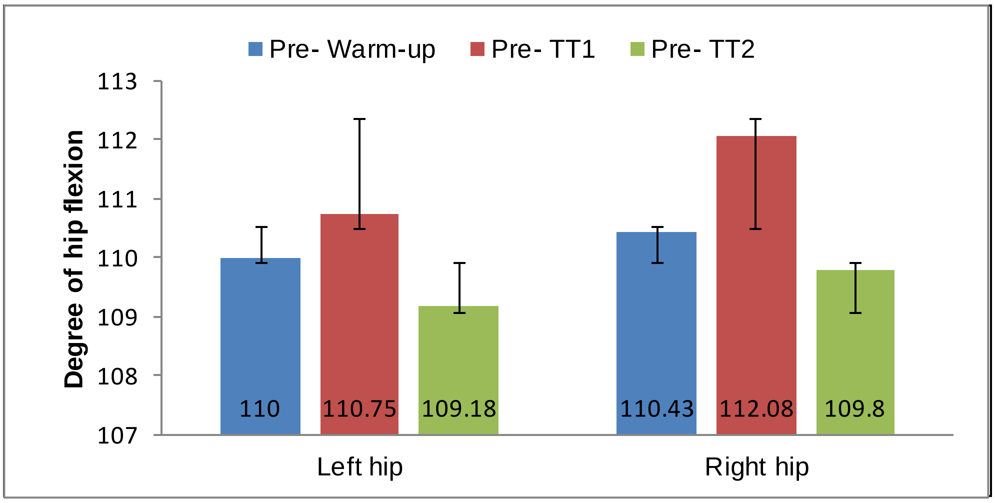

Figure 4.2.1 Hip flexion measurements pre- warm-up, pre- TT1 and pre- TT2

Table 4.2.1 Mean (±SD) hip flexion measurements, and range, pre- TT1 and pre- TT2

	Pre-TT 1		**Pre-TT 2**	
	Left hip (°)	**Right hip (°)**	**Left hip (°)**	**Right hip (°)**
Mean	110.75 (± 7.292)	112.08 (± 8.352)	109.18 (± 6.827)	109.80 (± 7.511)
Range	98 - 127	92 - 130	96 - 124	92 - 121

Repeated measures ANOVA; paired *t*-tests

Figure 4.2.2 shows that there was a significant increase in mean hip extension measurements after the warm-up on the right ($p < 0.006$) and on the left ($p < 0.002$) sides. There was a significant decrease in mean hip extension measurements after Kinesio® tape application on both the left ($p < 0.001$) and right ($p < 0.001$) sides. The mean, standard deviation, and range of hip extension pre-TT1 and pre- TT 2 are reflected in Table 4.2.2.

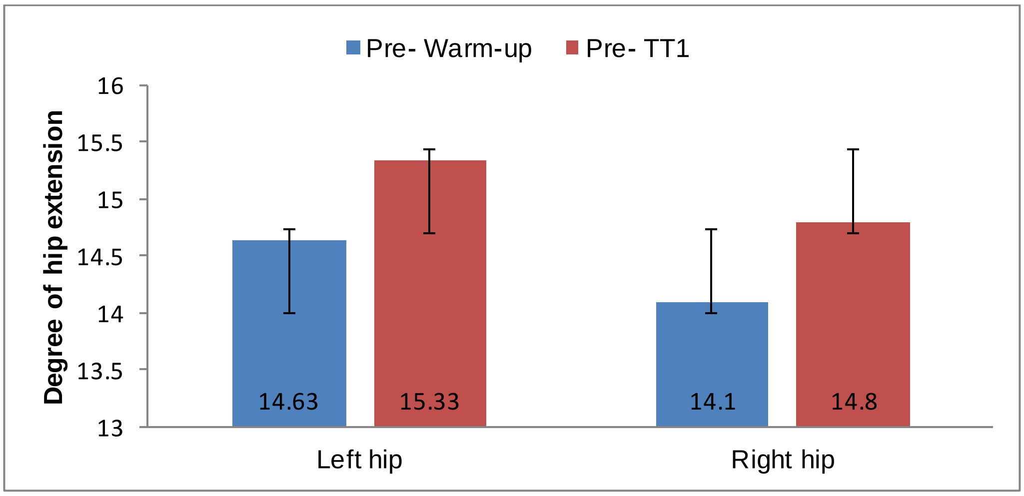

Figure 4.2.2 Hip extension measurements pre- warm-up and pre- TT1

Table 4.2.2 Mean (±SD) hip extension measurements, and range, pre-TT1 and pre- TT2

	Pre-TT1		**Pre-TT2**	
	Left hip (°)	**Right hip (°)**	**Left hip (°)**	**Right hip (°)**
Mean	15.33 (±3.612)	14.80 (±2.972)	12.95 (± 2.601)	12.53 (± 2.542)
Range	7 - 24	9 - 21	7 - 20	6 - 17

Repeated measures ANOVA; paired *t*-tests

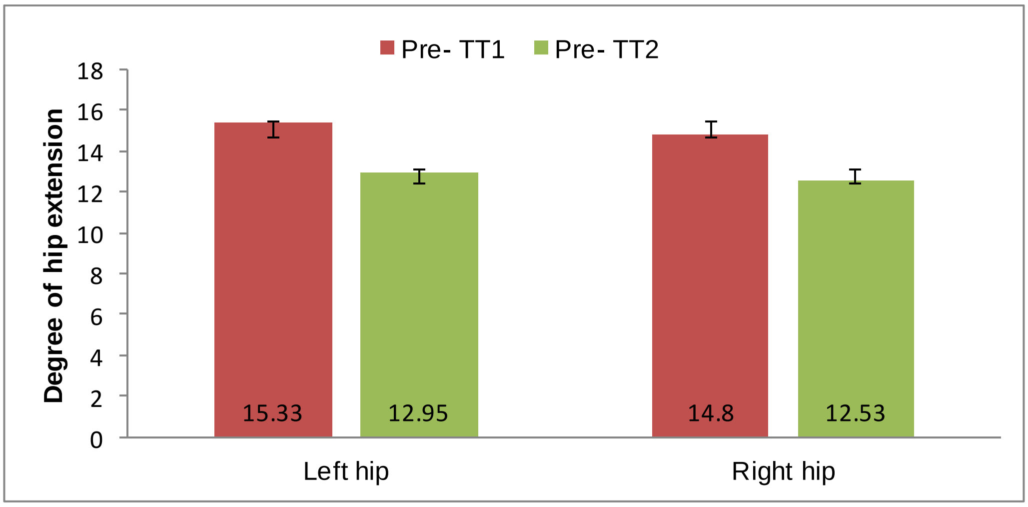

Figure 4.2.3 Hip extension measurements pre- TT1 and pre- TT2

Figure 4.2.4 shows that there was a significant increase in mean knee flexion measurements on both the right ($p = 0.001$) and left ($p < 0.001$) sides post- warm-up and pre-TT1.

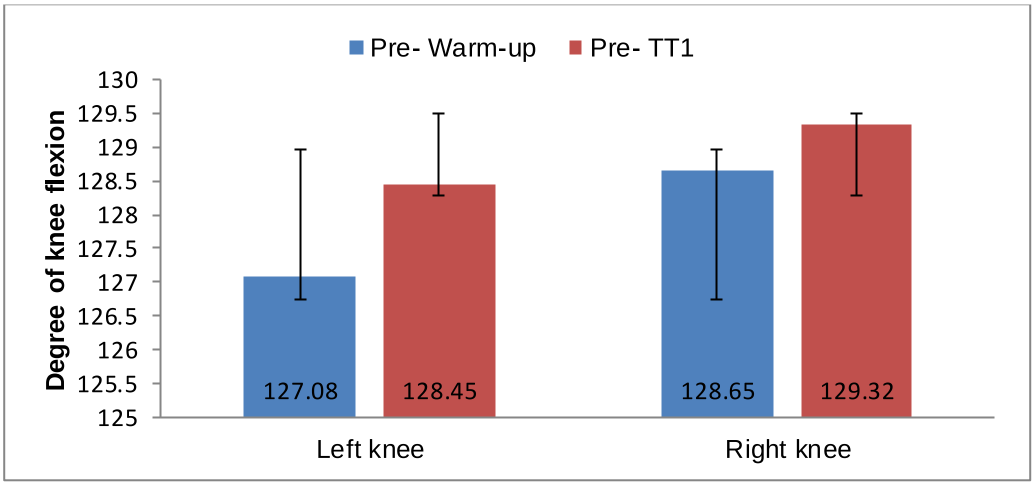

Figure 4.2.4 Knee flexion measurements pre- warm-up and pre- TT1

Paired t-tests used to analyze knee flexion showed there was no statistical significance for the measurements post- Kinesio® tape application as shown in Table 4.2.3.

Table 4.2.3 Mean (±SD) knee flexion measurements, and range, pre- TT1 and pre- TT2

	Pre-TT1		**Pre- TT2**	
	Left knee (°)	**Right knee (°)**	**Left knee (°)**	**Right knee (°)**
Mean	128.45 (±4.414)	129.32 (±4.263)	128.48 (± 4.657)	128.82 (± 4.344)
Range	119 - 137	120 - 140	118 - 141	118 - 141

Repeated measures ANOVA; paired *t*-tests

There was a significant increase in mean knee extension measurements after the warm-up as shown in Figure 4.2.5. This increase was evident on both the right ($p = 0.017$) and left ($p = 0.016$) sides.

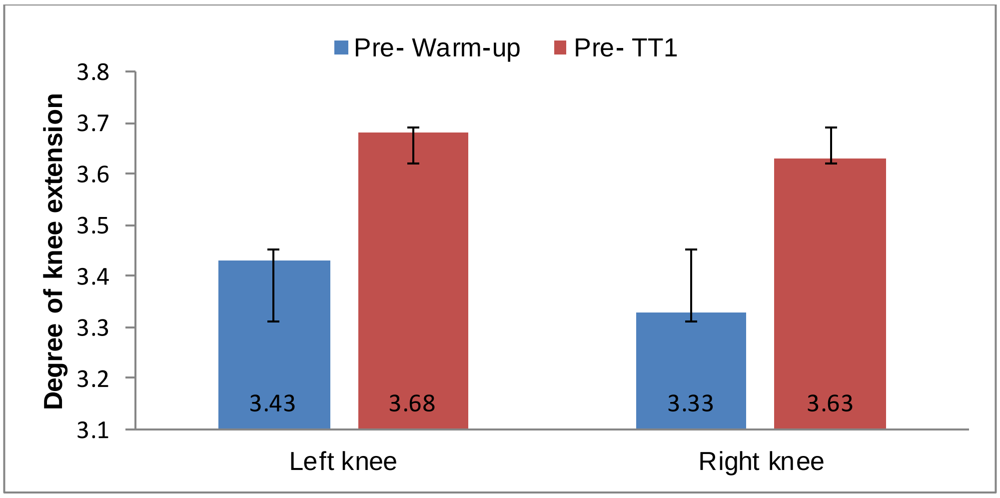

Figure 4.2.5 Knee extension measurements pre- warm-up and pre- TT1

There was no significant difference in the knee extension measurements post- Kinesio® tape application. T-tests used to make a comparison between the results of the measurements taken pre-TT1 and pre- TT2 showed the left (p = 0.688) and right knee extension (p = 0.822) to be of no statistical significance, as shown in Table 4.2.4.

Table 4.2.4 Mean (±SD) knee extension measurements, and range, pre-TT1 and pre-TT2

	Pre-TT1		Pre-TT2	
	Left knee (°)	**Right knee (°)**	**Left knee (°)**	**Right knee (°)**
Mean	3.68 (±0.730)	3.63 (±0.868)	3.73 (± 0.877)	3.65 (± 0.834)
Range	2 - 5	2 - 5	2 – 6	2 - 6

Repeated measures ANOVA; paired *t*-tests

4.3 Modified Thomas Test

Paired t-tests were used to compare the modified Thomas test measurements pre- warm-up, pre-TT1, and pre-TT2 post- Kinesio® tape application. Figure 4.3.1 shows that there was a significant increase in mean measurement after the warm-up on the left leg (p = 0.003), the mean measurement on the right leg however showed no statistical difference (p = 0.512). Post- Kinesio® tape application there was a significant increase for the mean measurement on the right leg (p = 0.041), the mean measurement on the left leg however showed no statistical significance (p = 0.088).

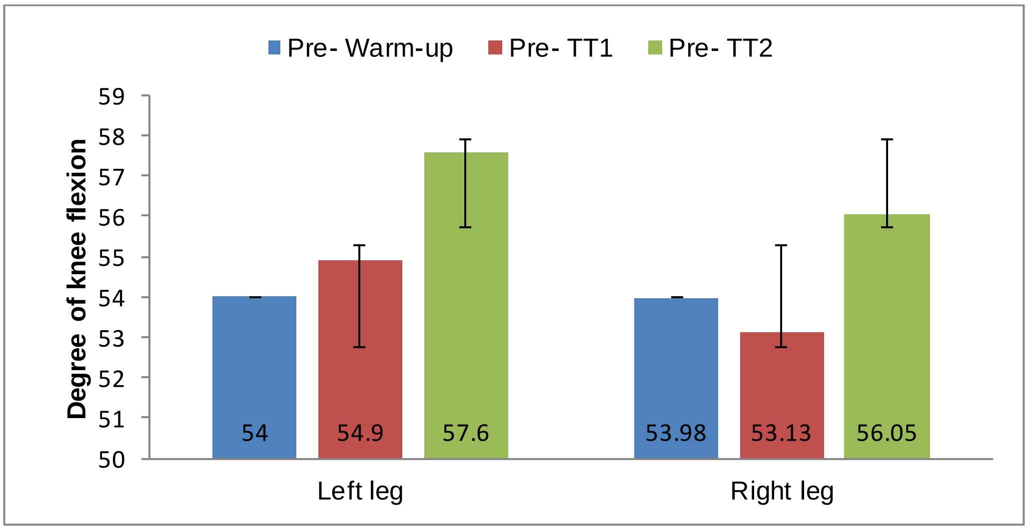

Figure 4.3.1 Modified Thomas test measurements pre- warm-up, pre- TT1 and pre- TT2

Table 4.3.1 Mean (±SD) modified Thomas test measurements, and range, pre- TT1 and pre- TT2

	Pre-TT1		**Pre-TT2**	
	Left leg (°)	**Right leg (°)**	**Left leg (°)**	**Right leg (°)**
Mean	54.90 (±7.030)	53.13 (±10.286)	57.60 (± 8.770)	56.05 (± 8.638)
Range	41 - 67	36 - 65	35 - 74	31 - 73

Repeated measures ANOVA; paired *t*-tests

4.4 Power, Cadence, Speed and Completion Time

The average and maximum power, average and maximum cadence, average and maximum speed and completion time of each of the participants was recorded during the 1.5km time trial course and is shown on Table 4.1.1. The average speed (p = 0.792), maximum speed (p = 0.336), average cadence (p = 0.057), and maximum cadence (p = 0.781) measurements showed no statistically significant differences when comparing TT1 and TT2 using the paired t-tests. Figure 4.4.1 shows there was a significant decrease in the maximum power on TT2 (p = 0.007), the average power showed no significant differences between TT1 and TT2 (p = 0.097).

Table 4.4.1 Mean (±SD) power, cadence, and speed statistics for TT1 and TT2 post-Kinesio® tape application

	TT1	TT2	*P* value
Maximum Power (watts)			
Mean	467.93 (±152.642)	430.15 (±112.194)	0.007*
Range	284 - 952	282 - 747	
Average Power (watts)			
Mean	272.65 (±80.384)	273.10 (±74.690)	0.907
Range	133 - 446	134 - 448	
Maximum Cadence (rpm)			
Mean	115.58 (±11.052)	116.35 (±19.946)	0.781
Range	91 - 141	71 - 151	
Average Cadence (rpm)			
Mean	98.78 (±10.136)	100.63 (±11.025)	0.057
Range	75 - 129	73 - 129	
Maximum Speed (km/h)			
Mean	49.280 (±6.2006)	49.725 (±6.3083)	0.336
Range	31.9 - 59.0	31.6 - 58.8	
Average Speed (km/h)			
Mean	37.340 (±4.4328)	37.402 (±4.2435)	0.792
Range	27.4 - 45.6	27.4 - 45.5	

***p < 0.05; Repeated measures ANOVA; paired *t*-tests**

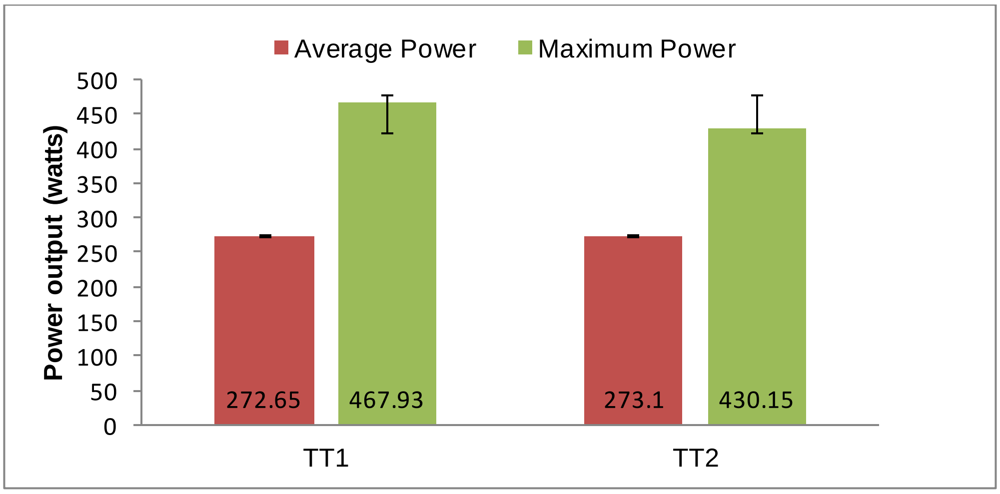

Figure 4.4.1 Mean average and maximum power output measurements in TT1 and TT2

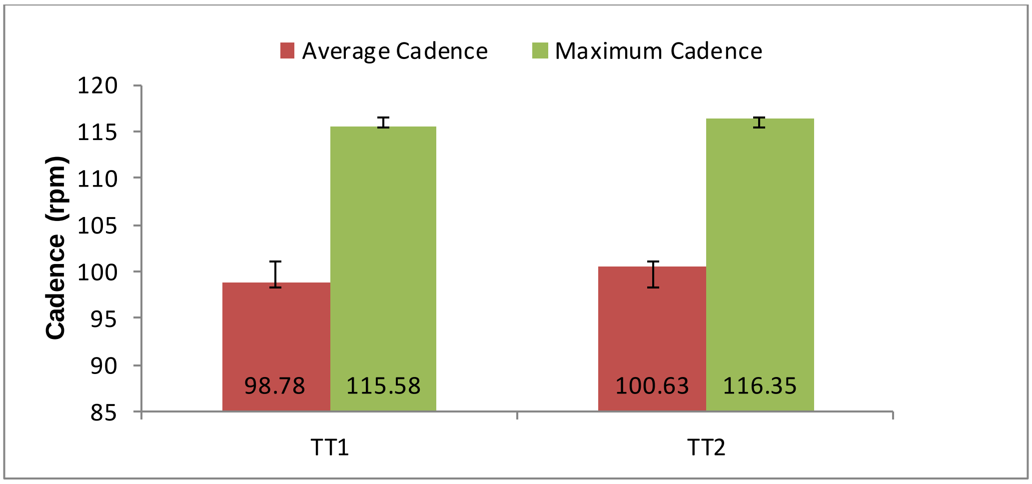

Figure 4.4.2 Mean average and maximum cadence measurements in TT1 and TT2

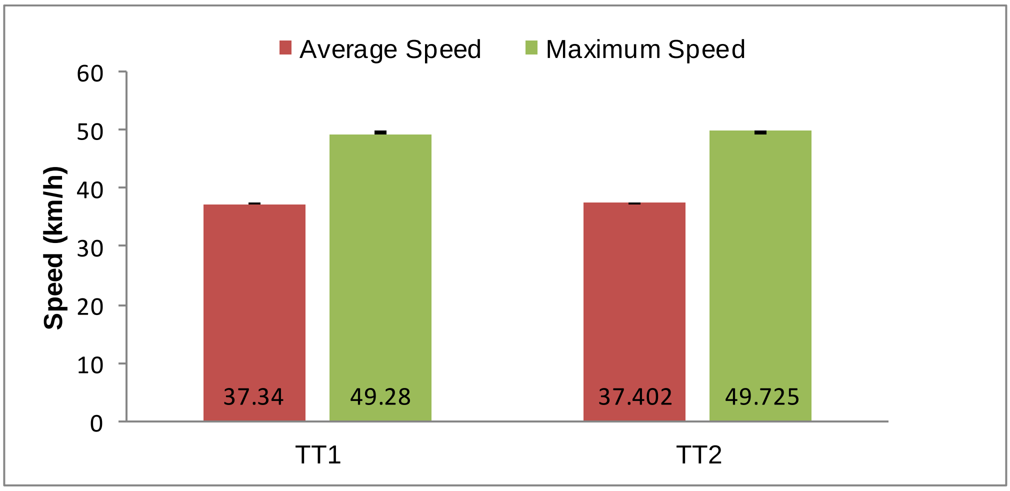

Figure 4.4.3 Mean average and maximum speed measurements in TT1 and TT2

Table 4.4.2 shows the mean (±SD) completion times of the participants in each of the time trials. There was a non significant decrease in completion time from TT1 to TT2 (p = 0.506). Only 0.5 seconds on average were saved in TT2.

Table 4.4.2 Mean (±SD) Completion time measurements for TT1 and TT2

	TT1	**TT2**
Mean	02:35:57 (±00:19:01.331)	02:35:07 (± 00:18:47.354)
Range	02:05:00 - 03:29:00	02:06:00 - 03:28:00

Repeated measures ANOVA; paired *t*-tests

As discussed in the literature review in Chapter Two a cyclist's body mass influences the rolling resistance. As a result of gravity, a heavier cyclist requires more leg power to resist these gravitational forces and added resistance as a result of increased mass, either from the cyclist or the bicycle equipment (Benneke *et al*., 1989). The participants' mass is reflected in comparison to their average power (Figure 4.4.4) and peak power (Figure 4.4.5) during TT1and TT2.

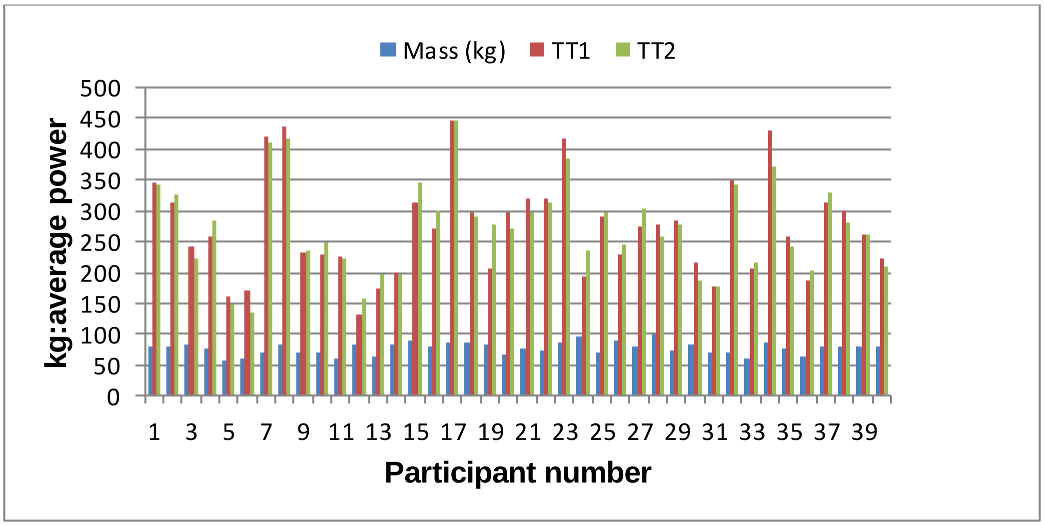

Figure 4.4.4 Mass related to average power output during TT1 and TT2

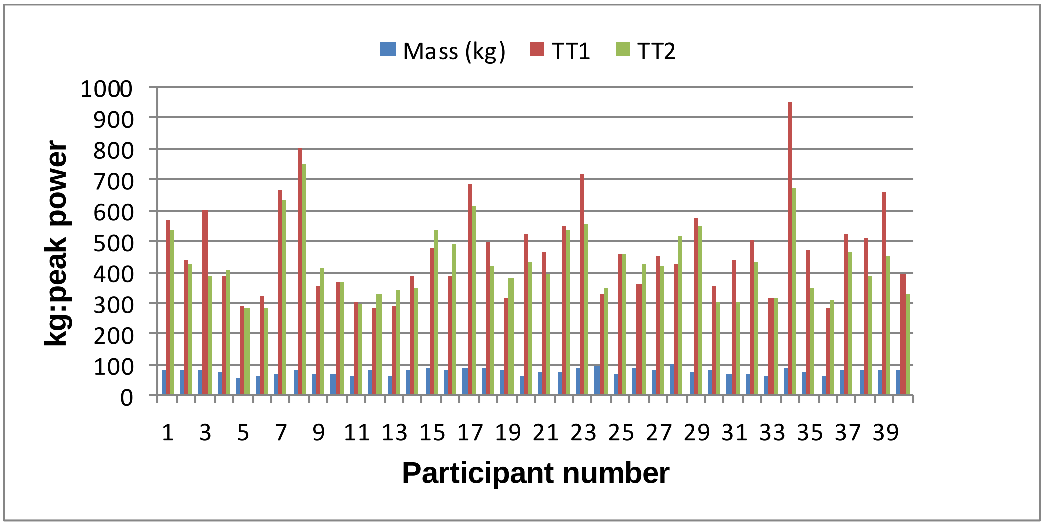

Figure 4.4.5 Mass related to peak power output during TT1 and TT2

The measurements of power, cadence, and speed recorded during TT1 and TT2 as previously shown in Table 4.4.1 and in Figures 4.4.1; 4.4.2; and 4.4.3 were also analyzed separately for the female (*n* = 4) and male (*n* = 36) participants. The gender specific results, however, showed no statistically significant differences. The only significant difference remained the reduction in the maximum power in the male population group (*p* = 0.016). It should be noted that the sample size of the females was very small and possibly underpowered to show any significant differences. Having analyzed the male population as a homogenous group revealed there were no further statistically significant differences.

Table 4.4.3 Mean (±SD) power, cadence, and speed statistics for TT1 and TT2 in the male population

	TT1	TT2	*P* Value
Maximum Power (watts) Mean	480.75 (±154.820)	443.97 (±109.799)	0.016*
Average Power (watts) Mean	280.11 (±81.173)	281.03 (±74.361)	0.828
Maximum Cadence (rpm) Mean	115.33 (±11.194)	115.78 (±20.525)	0.855
Average Cadence (rpm) Mean	98.50 (±10.506)	100.28 (±11.042)	0.086
Maximum Speed (km/h) Mean	49.567 (±6.4223)	50.172 (±6.4252)	0.216
Average Speed (km/h) Mean	37.753 (±4.4710)	37.856 (±4.2147)	0.690

$^*p < 0.05$; Repeated measures ANOVA; paired *t*-tests

Table 4.4.4 Mean (±SD) power, cadence, and speed statistics for TT1 and TT2 in the female population

	TT1	TT2	*P* Value
Maximum Power (watts) Mean	352.50 (±59.287)	305.75 (±7.805)	0.222
Average Power (watts) Mean	205.50 (±21.142)	201.75 (±21.639)	0.674
Maximum Cadence (rpm) Mean	117.75 (±10.905)	121.50 (±14.754)	0.230
Average Cadence (rpm) Mean	101.25 (±6.238)	103.75 (±12.093)	0.478
Maximum Speed (km/h) Mean	46.700 (±2.9597)	45.700 (±3.4186)	0.542
Average Speed (km/h) Mean	33.625 (±1.3401)	33.325 (±1.4886)	0.605

$^*p < 0.05$; Repeated measures ANOVA; paired *t*-tests

4.5 Participants Perception of a Change in Power, Cadence, and Speed

There was a general perception of an increase in power (60% of participants) compared with only 12.5% who felt a decrease and 27.5% who felt the same.

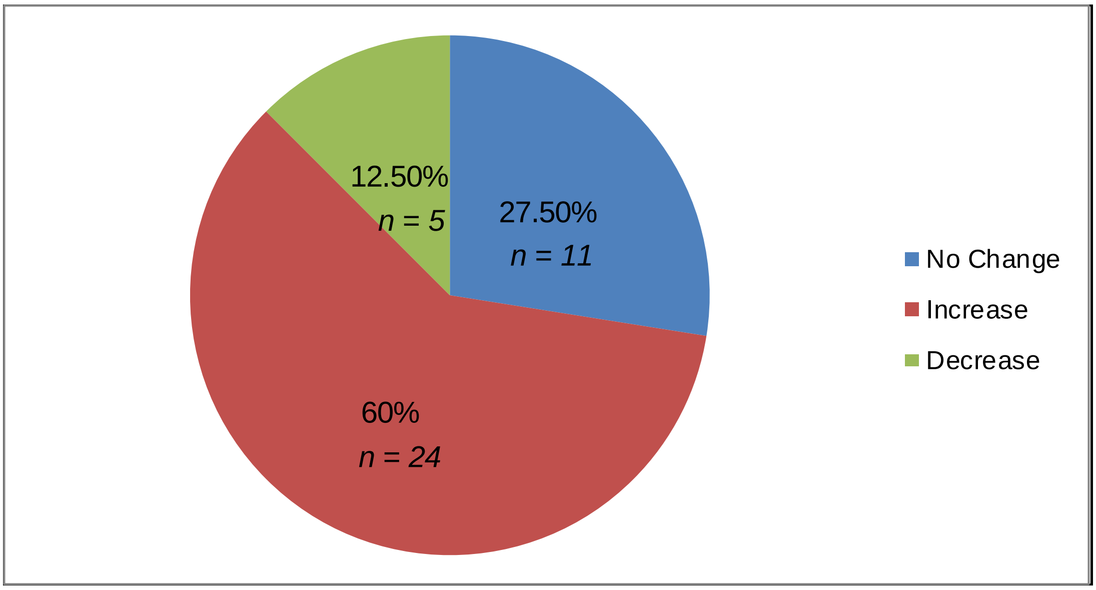

Figure 4.5.1 Participants perception of a change in power output TT2

The same percentage of participants felt an increase in cadence as those who felt no change in their cadence (47.5%) while only 5% felt a decrease in cadence. The participants' perception of cadence in TT2 is represented in Figure 4.5.2.

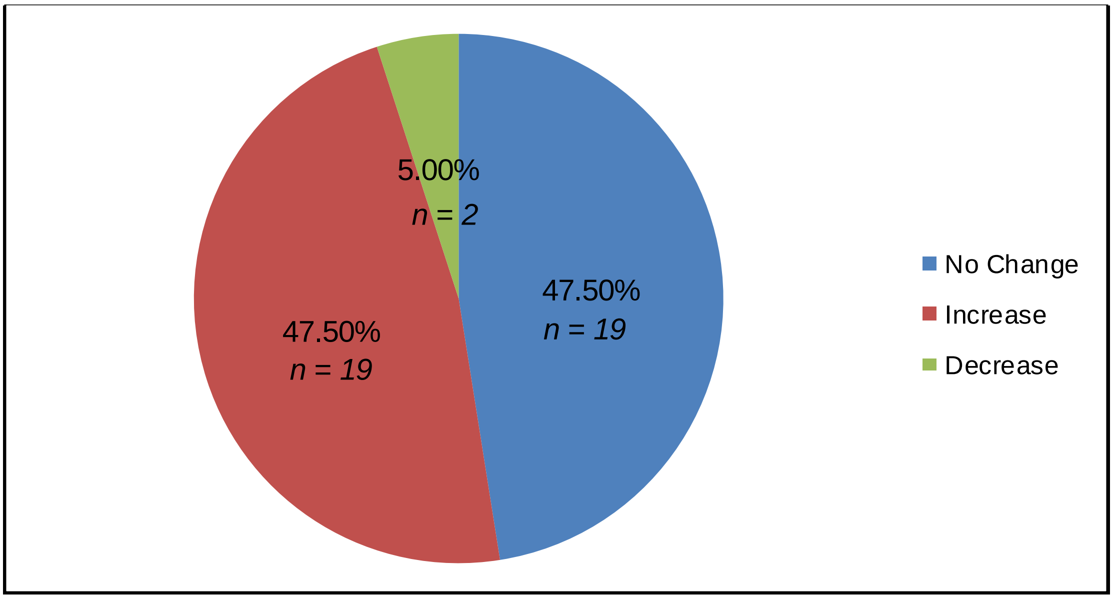

Figure 4.5.2 Participants perception of a change in cadence in TT2

Figure 4.5.3 reflects the participants' perception of speed in TT2.The majority of the participants thought their speed had increased (60%) while 32.5% felt it remained the same and only 7.5% thought it decreased.

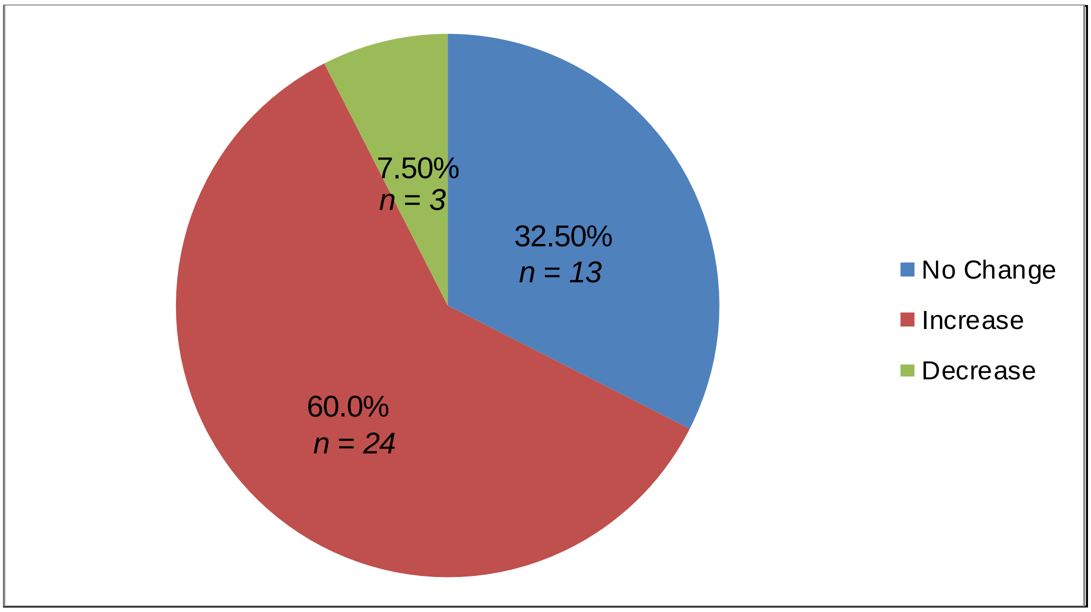

Figure 4.5.3 Participants perception of a change in speed in TT2

4.6 Hill Analysis

On completion of TT2 when each of the participants were asked how they felt in TT2 in comparison to TT1 it has been shown in Figure 4.4.1 that 60% of the participants had an increased perception of power. A large majority of the participants when asked referred of their own accord to the hill and stated; "I felt stronger on the hill in TT2". A trend was also noted by the researcher on analysis of the results in the form of a graph that allowed TT1 and TT2 to be overlapped. Although the average power may have been the same for both time trials, there was an increase in power seen on the hill section of the 1.5km course in TT2, (Figure 4.6.1).

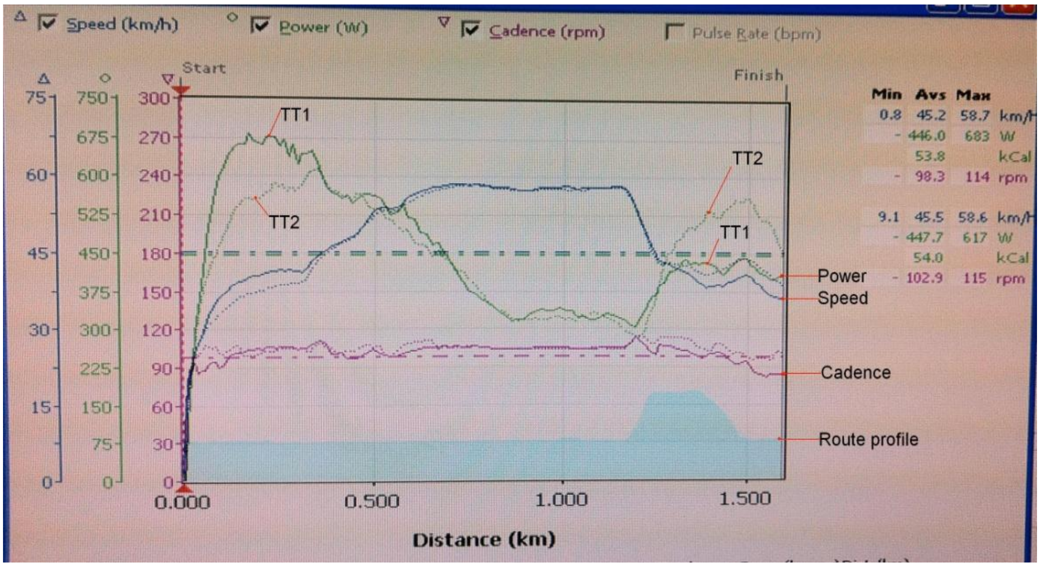

Figure 4.6.1 The overlapping graphs comparing TT1 (solid line) and TT2 (dotted line)

For this reason the results of the hill section of the course were analysed separately. As shown in Table 4.5.1 there was no statistically significant difference seen in the average power (p = 0.317), the maximum power (p = 0.128), or the average speed (p = 0.309). The average cadence (p = 0.028) and maximum cadence (p = 0.002) increased significantly on the hill section of the 1.5km course in TT2, as reflected in Figure 4.6.1.

Table 4.6.1 Mean (±SD) power, cadence, and speed statistics for TT1 and TT2 post-Kinesio® tape application on the hill section of the 1.5km course

	TT1	**TT2**	***P* value**
Maximum Power (watts) Mean Range	 333.20 (±70.017) 171 - 451	 343.20 (±76.900) 174 - 563	0.128
Average Power (watts) Mean Range	 273.747 (±62.5772) 144 – 401.8	 278.693 (±67.9577) 140.1 – 467.4	0.317
Maximum Cadence (rpm) Mean Range	 112.13 (±10.356) 89 - 141	 115.50 (±11.828) 95 - 141	0.002*
Average Cadence (rpm) Mean Range	 98.145 (±11.2673) 70.2 – 128.9	 100.595 (±11.8178) 75.9 – 127.4	0.028*
Average Speed (km/h) Mean Range	 34.363 (±4.0354) 26.2 – 42.1	 34.630 (±4.2073) 25.2 – 43.8	0.309

***p < 0.05; Repeated measures ANOVA; paired *t*-tests**

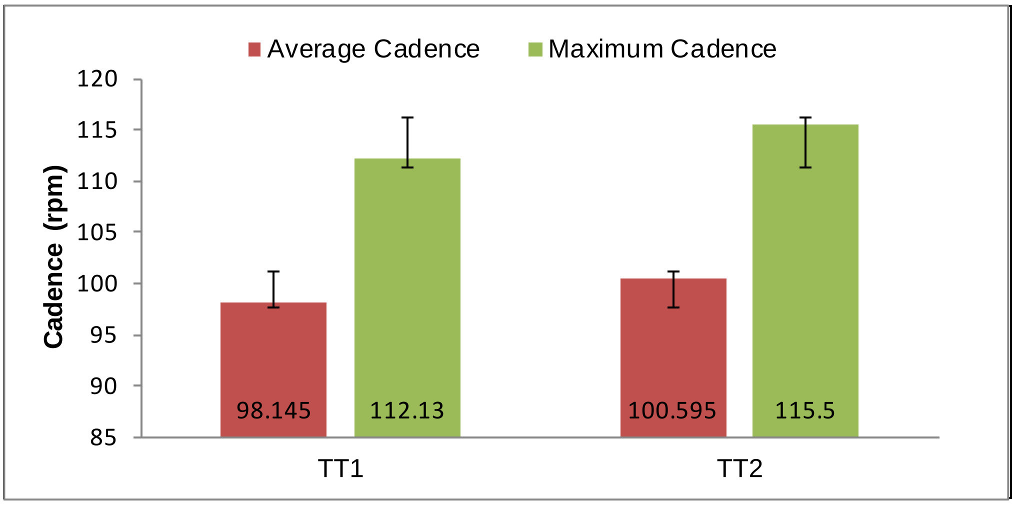

Figure 4.6.2 Average and Maximum cadence in TT1 and TT2 during the hill section of the 1.5km course

4.7 Conclusion

Therefore, Kinesio® taping resulted in right hip flexion, and right and left hip extension range of motion measurements decreasing, while left hip flexion, and bilateral knee flexion and extension range of motion measurements remained the same. The modified Thomas test left measurement increasing significantly, and the right leg showed no statistically significant difference.

Maximum power decreased significantly in TT2 while the measurements of average power, average and maximum cadence, and average and maximum speed showed no significant differences.

On the hill section of the 1.5 km course, the average cadence and maximum cadence increased significantly in TT2 with Kinesio® taping. The measurements of average and maximum power, and average speed, did not, however, change significantly.

The overall perception of the participants was that of an increase in power and speed post-Kinesio® tape application, with cadence either being perceived to stay the same or increase.

CHAPTER 5

DISCUSSION

5.1 Introduction

This chapter will discuss the outcomes of this research and methodological issues.

The sample utilized for this study consisted of 40 participants out of a research population of approximately 3 977 in Kwa-Zulu Natal. The sample size of 40 represented 1% of the total population in Kwa-Zulu Natal. Statistical analysis can, therefore, be deemed relatively accurate and representative of a normal distribution curve.

It is important to remember the following:

1. All patients in the study were asymptomatic
2. There was only one group and all participants were seen as their own control in comparing the results.
3. Measurements were recorded on Tacx Trainer software. Maximum and average power, maximum and average speed, maximum and average cadence, and time taken to complete the 1.5 km were recorded. The Taxc Trainer was calibrated.
4. Measurements of hip and knee flexion and extension were measured by means of a universal goniometer, and quadriceps muscle length tension was measured via the modified Thomas test.
5. Although the researcher attempted to maintain a homogenous sample group, the participants who participated in the research trials were varied in terms of their training hours and level of experience. Some cyclists were highly competitive, whilst others were more recreational cyclists.
6. Although the researcher attempted to maintain a homogenous sample group, the participants who participated in the research trials were varied in terms of their preference for road or off road cycling. Some of the participants actively participated in both road and MTB cycling, whilst others participated solely in either road cycling or MTB.

5.2 Demographics and Physical Characteristics

The forty participants that took part in the study were trained, amateur cyclists. The mean age of the participants who participated in the study was 33.75 (±7.983) years. In the sport of cycling this represents the sub-veteran age group. The sub-veteran age group represents the 30-34 year old cyclists, and the veteran age group represents the 35–39 year old cyclists. Competition in these categories is tough; as cyclists mature slowly there is a surprisingly low age related performance change (Beneke *et al*., 1989). This sample population is representative of an age group that has the financial resources to afford to participate competitively, as well as being more likely of having time to train.

The vast majority of the participants in the study were male, 90%. In the Kwa-Zulu Natal population of Cycling South Africa the members of both disciplines are comprised of 3 106 males and 871 females (Engelbrecht, 2011). The sample population of this study is, therefore, representative of the cycling population of Kwa-Zulu Natal. Table 4.4.3 and 4.4.4 reflect the power, cadence, and speed for each of the time trials in the male and female population respectively.

The ethnic profile of the participants is shown in Figure 4.1.2. The only black participant had only been cycling for one and a half years. This may be that previous lack of exposure and the expense of the sport are likely reasons for the low number of the black population involved in cycling as a sport (Mitchell, 2010). There is, however, a unique approach to developing cycling talent in Kenya, which has since spread to other African countries, which may change the future of the sport (Mitchell, 2010).

The mean stature of the participants in this study (1.77 ±0.081 m), falls between those described in the study of Ettema, Loras, and Leirdal (2009), at 1.81 ±0.05 m, Umberger, Scheuchenzur, and Manos (1998), at 1.75 ±0.06 m, and Pierre, Nicolas, and Frederique (2006), at 1.76 ±0.065 m. In terms of the participants' mean mass (77.475 ±9.829 kg), this sample compares well with that of Umberger, Scheuchenzur, and Manos (1998), at 77.9 ±8.1 kg, Ettema, Loras, and Leirdal (2009), at 76.7 ±10.0 kg, and Pierre, Nicolas, and Frederique (2006), at 70.4 ±10.5 kg.

As seen in the statistics of Cycling South Africa, the participation in both disciplines of cycling is popular, with a total of 3 977 cyclists in Kwa-Zulu Natal, representing 2 901 registered road cyclists and 3 365 mountain bikers (Engelbrecht, 2011). The participants cycling discipline in this study varied between solely road (n = 9), solely MTB (n = 8), and then a combination (*n* = 23) thereof, as shown in Figure 4.1.1. To the researchers knowledge there were eight of the forty participants who were only actively involved in the MTB discipline of cycling. The drive train on a mountain bicycle is different, and more involved (Lopes and McCormack, 2006). One of the main differences between the drive train on a MTB and that on a road bicycle is the third chain ring that is present on the MTB drive train, allowing for a wider range of gear selection (Downs, 2010). Various factors cause pedal strokes to vary among cyclists, including which type of riding the cyclist is doing (Lopes and McCormack, 2006). Mountain bikers exhibit a more uniform pedaling technique than cyclists in other disciplines (Burke, 2003). It has been suggested that mountain bikers acquire these skills due to cycling in conditions that require more uniform torque generation, such as climbing in loose soil, and encountering extreme variations in terrain (Burke, 2003; Downs, 2010). These variations amongst the cycling disciplines may have affected the manner in which the cyclists approached the 1.5 km course and their cycling efficiency. In future studies, it would be beneficial to obtain a detailed analysis of the pedal strokes of the participants, to allow for comparison between the pedal strokes among the different participants, as well as assessing the affect of Kinesio® tape on each pedal stroke. Equipment such as the Computrainer SpinScan graphically depicts one full 360° pedal stroke in 15° segments, giving data points reflecting measures of cycling efficiency, right and left power distribution, and areas where optimal power is not transferred to the drive train (http://www.breakawaysf.com/services/cycling-services/pedal-analysis-service/; http://www.racermateinc.com/computrainer.asp). Valuable information such as this would allow for the effect of Kinesio® tape to be assessed on each area of the pedal stroke.

5.3 Assessment of the Intervention Effect

5.3.1 Range of Motion

In comparing the range of motion measurements pre- warm-up and post- warm-up pre- TT1, there was a significant increase in mean measurement in all the ranges of motion measured except for hip flexion on the left side. Figure 4.2.2, Figure 4.2.4, and Figure 4.2.5, reflect the statistically significant increases in ROM measurements recorded for hip extension, knee flexion, and knee extension bilaterally. This is likely the result of intramuscular heat production that occurred during the warm-up, allowing the quadriceps muscles to stretch, enhancing flexibility and increasing joint ROM (Marieb, 2004). Warm-up exercises have been reported to increase intramuscular and core temperatures (Gillette *et al.*, 1991; Weijer, Gorniak, and Shamus, 2003). As a result of warm-up exercises increasing skin and body temperature a resultant increase in musculotendinous extensibility and muscle compliance would occur and enhance joint ROM, occurring immediately (Hubley, Kozey, and Stanish, 1984; Gillette *et al*., 1991; Weijer, Gorniak, and Shamus, 2003). This enhanced ROM was seen in this study post- warm-up, and is a positive finding as increased ROM about a series of joints is considered an important factor for fitness, and in preventing injuries (Hubley, Kozey, and Stanish, 1984; Gillette *et al*., 1991). It is possible, however, that a warm-up exercise may not produce the increase in intramuscular temperature necessary to affect the elastic components of the muscle, so that any change in muscle extensibility would be minimal (Weijer, Gorniak, and Shamus, 2003). This may have occurred at the left hip. As shown in Figure 4.2.1, an increase in hip flexion ROM on the left did occur post- warm-up, it was, however, not statistically significant (p = 0.080), but was marginally close to being statistically significant.

In a comparison of the hip flexion measurements pre- TT1 and pre- TT2 post- Kinesio® tape, application there was a significant decrease on the right (p < 0.021), but the left was not significant (p = 0.060) (Table 4.2.1). However, results shown in Figure 4.2.1 reflect a decrease on both the left and right sides, although the left side was not statistically significant it was marginally close to being so. In facilitating a muscle and enhancing its function the muscle should be taped at 15%-50% tape tension (Kase, Wallis, and Kase, 2003). The decreased hip flexion ROM seen may illustrate the effect of Kinesio® tape applied with a degree of tension, and the resultant pulling on the muscle that occurs with the aim of facilitating the quadriceps muscle contraction. It was hypothesised that Kinesio® tape applied to the quadriceps muscles would result in no significant difference in the hip and knee joint ROM (flexion and extension). As a statistically significant decrease is seen in hip flexion on the left the null hypothesis is rejected and is not supported for this measurement.

During the pedal cycle on a bicycle with a standard seat tube angle of 74 - 76°, the mean hip flexion measurement described in a study by Umberger, Scheuchenzur, and Manos (1998), was 92.75 ±5.85°, as measured during the pedal cycle. This is supportive that the measurements recorded during this study post- Kinesio® tape application at 109.18 ± 6.827° on the left and 109.80 ± 7.511° on the right, are sufficient for the range of hip flexion required during the pedal cycle. The application of Kinesio® tape to the cyclists' quadriceps muscles would, therefore, not limit the cyclist's movement during the pedal stroke.

Figure 4.2.3, shows there was a significant decrease in mean hip extension measurements after Kinesio® tape application on both the left ($p < 0.001$) and right ($p < 0.001$) sides. During hip extension, the quadriceps muscle would be eccentrically contracting (Moore and Dalley, 1999; Marieb, 2004). As discussed this decrease in ROM may be a result of the tension effect of the tape on the quadriceps muscle to enhance facilitation. The null hypothesis is rejected for hip extension as a decrease in measurements is seen bilaterally.

Although hip extension to the degree measured is not necessary in the pedal stroke, it may affect proprioception at the hip joint. Little is known, however, of the proprioceptive effects of Kinesio® tape, but it is thought that there is a facilitating effect on cutaneous mechanoreceptors by applying pressure to and stretching the skin (Murray, 2000). The sense of stretching is thought to signal information of joint movement or joint position (Halseth *et al*., 2004). Proprioception provides information about joint position, movement and balance via mechanoreceptors in the joints, muscles, tendons, and skin (Stillman, 2002; Strimpakos, 2009; Ju, Cheng, and Chang, 2011). Proprioceptive awareness is most evident during the learning of new skills, and once fully learned involves minimal proprioceptive consciousness of the involved joints, muscles, and other involved structures (Stillman, 2002). This is positive in a skill such as the pedal stroke, where following the learning effect of the structures involved; awareness would be able to shift to focus on perfecting the pedal stroke (Stillman, 2002; Ju, Cheng, and Chang, 2011). Studies that involve testing of proprioception highlight the possibility that skin contact might influence position sense and states that during testing, care should be taken to avoid skin stretch, thus reducing the influence of cutaneous mechanoreceptors on joint position sense (Strimpakos, 2009). As the cutaneous mechanoreceptors play a role in proprioception, it would be important to allow the application of Kinesio® tape to be worn consistently to allow for the involved structures to undergo the learning effect, and for the cyclist to be able to shift the focus back to perfecting the pedal stroke. Studies on Kinesio® tape have shown no improvement in proprioceptive response at the ankle with measures of reproduction of joint position sense (Halseth *et al*., 2004). There are limited studies, however, illustrating the proprioceptive effect of Kinesio® tape, with speculation that the effect may be greater in participants with a history of injury who have a diminished sense of proprioception (Schneider, Rhea and Bay, 2010).

In a comparison of the knee flexion measurements pre- TT1 and pre- TT2 post- Kinesio® tape application, no significant differences were seen (Table 4.2.3). This supports the null hypothesis that the application of Kinesio® tape to the quadriceps muscles would not have an effect on the joint ROM. During the pedal cycle the knee goes through approximately 75°

of motion. The knee begins the power phase with maximum flexion at 110°, and extends to approximately 35° of flexion at the bottom of the pedal stroke (Asplund and St Pierre, 2004). The mean measurements recorded in this study pre- TT1 (left: 128.45 ±4.414°; right: 129.32 ±4.263°), and pre- TT2 (left: 128.48 ± 4.657°; right: 128.82 ± 4.344°), are more than sufficient ranges to allow for the maximum knee flexion of 110° required during the pedal cycle.

There was no significant difference in the knee extension measurements post- Kinesio® tape application as shown in Table 4.2.4. The null hypothesis was accepted for the knee flexion and knee extension ranges of motion where no difference was seen in the measurements post- of Kinesio® tape application.

Although there were no significant differences in ROM at the knee joint, the effect that the Kinesio® tape may have on the patellofemoral joint cannot be overlooked. The reason for the predominance of patellofemoral problems in cyclists is the large force, exceeding body weight, which develops at the joint (Callaghan, 2005; Mesfar and Shirazi-Adl, 2005). The movement of the patella is actively controlled by the quadriceps femoris (Cesarelli, Bifulco, and Bracale, 1999), and therefore, the application of Kinesio® tape to the quadriceps femoris may serve to control patella tracking. The presence of a muscle imbalance would cause the patella to stray from its normal path, causing structural imbalance (Cesarelli, Bifulco, and Bracale, 1999), and ultimately affecting cycling efficiency. The potential protective effect of Kinesio® tape on the patellofemoral joint may be more evident over a longer period, where repetitive forces and strain, lead to early muscle fatigue, decreased cycling efficiency, and knee pain.

The “Y” technique of taping and method of application to the quadriceps muscles used in this study is said to facilitate muscle function (Kase, 2008). The technique of application used with the “I” strip starting at the origin of the rectus femoris muscle and the “Y” split occurring proximal to the superior patellar border has shown to have positive results in other studies (Murray, 2000; Brandon and Paradiso, 2005). The surface area of the quadriceps muscle however is much greater than that covered by this tape application. The “I” strip applied centrally and extending the length of the rectus femoris muscle would have had little effect on the vastus lateralis and vastus medialis muscles. If Kinesio® tape had been applied differently, and covered a greater surface area of the quadriceps muscle group, the results of the measurements may have been potentially greater. Techniques that may have been used include: the same application with two “I” strips added to the vastus lateralis and vastus medialis muscles; or the "Y" strips at the superior patellar border may have been looped back and applied to the medial and lateral surface areas of the quadriceps femoris muscle. In the case of the "Y" technique of facilitation being applied to the quadriceps muscle, and not only the muscle tendon as in this study, the five main effects of Kinesio® tape on the skin, circulatory/lymphatic systems, fascia, muscle, and joints, may have been potentially greater.

5.3.2 Quadriceps Length Tension/Modified Thomas Test

The results from Figure 4.3.1 showed that post- warm-up, there was a significant increase in mean measurement on the left side, but no statistically significant difference on the right side. But, post- Kinesio® tape application there was a significant increase in mean measurement on the right side, but no statistically significant difference on the left side. Fry *et al*. (2003) stated that indirect measurement of muscle length/tension by means of clinical examination of joint ranges is subject to a number of systematic and random errors, including: intra- and inter- tester errors, and variability in goniometric measurement and patient tone. Although the researcher took every precaution to eliminate such errors, the various steps necessary to follow in positioning the participant correctly for measurement may have resulted in changes in participant position for subsequent measurements. Firstly, the participants stood at the end of the bed, and may have sat with more or less of the pelvis positioned on the table for each of the measurements, changing the degree of the test leg hanging off the table. The participants were requested to hold the opposite knee to their chest, which may have been held more closely to the chest in one measurement than another and resulted in changes in the angle of the hanging test hip. Gabbe *et al.* (2005) states in the modified Thomas test the knee is flexed with gravity. This was enforced as patients were asked to; "allow the leg to hang off the bed". It was noted during testing, however, that certain participants maintained tension in the leg as they attempted to hold the leg in suspension themselves. As far as possible this was eliminated as the researcher took the measurements after participants were as relaxed as possible and in the optimum test position. The anatomical landmarks used for measurement were marked, and this eliminated error that may have resulted from using different points of reference for subsequent measurements.

Findings shown in Figure 4.3.1 indicate that the angles of both knees increased post-Kinesio® tape, application, even though only the increase on the right side was statistically significant (p = 0.041). This increase in the angle is representative of an increase in knee flexion and an increase in hip extension. This is indicative of the lengthening of the quadriceps muscles. Kase (2008) states Kinesio® tape creates optimal forces by normalizing length/tension ratios, this has not however, to the researchers' knowledge, been demonstrated in any clinical studies. The optimal forces that the tape may create may also be more evident in a symptomatic individual where the measurements show a greater or bilateral statistically significant difference post- Kinesio® tape application. The hypothesis that Kinesio® tape applied to the quadriceps muscles would result in no significant difference in the length/tension ratio of the muscles is rejected as a result of the increase in measurements seen on the right side. This was, however, only seen unilaterally and no definitive conclusions can therefore be made.

Although differences in outcomes between sides are evident in the statistical analyses of the measurements, the measurements are in line with previous studies that used the modified Thomas test. The mean value of the knee angle for quadriceps femoris muscle length of the participants in this study for the first measurement pre- warm-up (left: 54.00 ±6.571°; right: 53.98 ±6.487°), and the second measurement post- warm-up (left: 54.90 ±7.030°; right: 53.13 ±10.286°), falls between those described in the study of Corkery *et al*. (2007), at 53.5 ±11°, and Harvey (1998), at 52.5 ±7.56°. In previous studies that used the modified Thomas test to assess the length/tension of the quadriceps muscle (Harvey, 1998; Gabbe *et al*., 2005; Corkery *et al*., 2007) none had a study design that involved subsequent measurements, and this would have allowed for less random errors as a result of retesting. Corkery *et al*. (2007), aimed to establish a normative range of muscle length values for several muscles in the lower limb (n = 72), and the results of measurements of the modified Thomas test demonstrated there were statistically significant differences between the right and left quadriceps femoris muscles (p = 0.003). The male (n = 25) and female (n = 47) population groups in the study were also analysed separately, and although there were no significant differences between the quadriceps femoris muscle flexibility between the genders, both groups showed a difference in measurements between the left and right legs. The mean measurement in the combined groups were 54.4 ±10.4° on the left and 51.2 ±10.5° on the right, in the male group was 52.9 ±10.3° on the left and 49.1 ±9.4° on the right, and in the female group was 55.3 ±10.5° on the left and 52.3 ±11° on the right (Corkery *et al*., 2007).

Direct tools available to measure muscle length, although reliable, are expensive and not readily available, such as computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound imaging (Fry *et al*., 2003). Measurement of passive length-tension relations of a human muscle in vivo poses a significant challenge as the muscle being studied/tested needs to be “isolated” from other structures such as synergistic muscles and ligaments (Hoang *et al*., 2005). Tightness in muscles such as the iliopsoas muscle, a dominant hip flexor, or the hamstrings muscle, a dominant knee flexor, may have resulted in changes to the angle of the hip and knee respectively, affecting the outcome of the modified Thomas test in this study.

5.3.3 Power, speed, cadence and completion time

The average and maximum; power (watts), cadence (rpm), and speed (km/h) produced by the participants during the 1.5 km time trial was recorded by the Tacx Trainer software, and measured pre- and post- Kinesio® tape application. The Tacx Trainer used an electromagnetic brake as well as tyre friction to provide resistance to the pedal power. There is, however, no guarantee that the results obtained would be valid for outdoor cycling in which the surface ridden on, as well as wind speed and direction vary. During outdoor cycling there are also frequent changes in the saddle position of the cyclist as the inclination/slope of the terrain changes, which did not occur during the trials due to the lack of change in the actual bicycle inclination, and the short duration of the trial which would not have required a shift in saddle position for comfort to relieve saddle pressure. A shortcoming of a laboratory study of this nature, is therefore, the inability to precisely simulate outdoor cycling even though this study did attempt to address some of these factors by including a simulated hill in the time trial course.

In outdoor cycling the power output and pedaling cadence primarily oscillate more (Bertucci *et al*., 2005). This is a weakness of a laboratory study where oscillations, if any, are minimal, and the quadriceps muscles are not required to actively stabilize, and balance the bicycle and the cyclist. It has been shown that muscle oscillations significantly decreased ($p < 0.013$) whilst wearing compression garments (shorts), and this is speculated to enhance technique and reduce fatigue (Doan *et al*., 2003). The Kinesio® tape may serve to act in a similar way, and therefore may show greater results in an outdoor setting where the quadriceps would be active in stabilisation.

Friction between the surfaces of the components on a bicycle, namely the bottom bracket bearings, chain elements, and rear transmission consumes a small portion of the energy produced by the cyclist (Beneke *et al*., 1989; Burke, 2003). This will not affect the results of the trials in this study as the participants used the same bicycle for both trials, as a result these internal factors will not have an impact on the results. Use of the same bicycle also ensured the cyclists position did not alter, as the bicycle set up was the same for both time trials, allowing for comparison between the two time trials.

As discussed, the cyclist's riding position is influenced by many variables including: anthropometric measurements, athlete's strength and flexibility, muscle recruitment patterns and lower limb muscle lengths (Wishv-Roth, 2009). As the same bicycle was used for both trials, the anthropometric measurements would not pose as a variable, and therefore it can be assumed that any differences seen between the findings are as a result of the application of Kinesio® tape.

Riding position directly influences the power and physiological efficiency that can be produced by the athlete. As the Kinesio® tape was applied with 15%-50% tape tension the participants may have experienced the sensation of tightness on the quadriceps muscles, causing the cyclist to shift their saddle position to ease the tension on the quadriceps muscles. This shift in position would potentially activate other muscles that are active in the downstroke, such as the gluteus maximus muscles, allowing the quadriceps muscles to rest (Asplund and St Pierre, 2004; Raymond, Joseph, and Gabriel, 2005).

Repeated performance of a movement task facilitates neuromuscular adaptations, and this results in more skilled movement and muscle recruitment patterns (Chapman *et al*., 2008). This highlights the advantage of a learned effect. As muscles become accustomed to recruitment patterns and joint movement, should they not also become accustomed to an application such as Kinesio® tape that would have an effect on their function. The majority of the cyclists had never worn Kinesio® tape before, and only one had previously worn Kinesio® tape whilst cycling. Should the participants have previously been exposed to Kinesio® tape they may have responded better during the trials.

5.3.3.1 Power

Post- Kinesio® tape application, there was no statistically significant difference recorded in the average power (p = 0.097). Although not statistically significant Figure 4.4.1 reflects an increase in the mean average power of the cyclists. However, as small as the increase may have been, it was previously discussed in the introduction to this dissertation and the literature review, that this added gain in a cyclist's performance is extremely valuable. Figure 4.4.1 shows there was a significant decrease in the maximum power on TT2 (p = 0.007), with the mean maximum power recorded for TT1 being 467.93 ±152.642 W and for TT2 being 430.15 ±112.194 W. These recordings of maximum power are lower than the results obtained in a similar study by Peiffer *et al*. (2010), at 783 ±77 W for TT1 and 697 ±69 W for TT2; the results are, however, in line with the decrease in mean maximum power seen in TT2 (Peiffer *et al*., 2010). The study by Peiffer *et al*. (2010) had a very similar design consisting of a 1 km time trial, a 20 minute rest period, and an intervention between the two time trials. The reason for the difference in maximum power between this study and that of Peiffer *et al*. (2010) is most likely as a result of the difference in participants (n = 10) , with the latter study involving the participation of highly trained competitive cyclists. Difference in pedaling skill is, however evident, even amongst highly trained cyclists (Raymond, Joseph, and Gabriel, 2005) and high inter-individual variability exists, even among trained cyclists of similar fitness levels (Burke, 2003).

The majority of the participants' reached their maximum power output within the first 200m's of the time trial course as they applied pressure to the pedals in an attempt to gain speed as quickly as they could. Marieb (2004) states as individuals exercising begin to exercise vigorously, ATP stored in muscles is consumed within 4 – 6 seconds, and together stored ATP and CP (creatine phosphate) provide enough energy for maximum muscle contractions for 10 – 15 seconds. ATP is regenerated as fast as it is broken down, and CP is only replenished during periods of inactivity (Powers and Howley, 1997; Marieb, 2004). The energy systems used would have replenished the required fuels and enzymes necessary during the rest period. The participants were not encouraged to drink any glucose based drinks in the rest period, unless the drink had also been consumed prior to TT1 to exclude any variables. During short term exercise it is unlikely that muscle stores of glycogen or blood glucose levels would be depleted (Powers and Howley, 1997). The average person stores enough glycogen to last them over two hours with exercise of sustained moderate intensity (http://www.exrx.net/Nutrition/Glycogen.html).The carbohydrate stores of the cyclists in this trial would, therefore, not have been depleted during the short duration of the two 1.5 km time trials.

The decrease in mean maximum power ($p = 0.007$) seen in TT2, could be attributed to a learning effect. Although the 1.5 km time trial course was ridden during the warm-up to allow the participants to experience the course prior to the time trials, at a work rate of 100W-120W and a cadence of 90 rpm-100 rpm (Aisbett, Rossignol, and Sparrow, 2003; Bercier *et al*., 2009; Martin and Brown, 2009), many of the participants perceived the time trial course as "easy". However, when ridden at maximum effort, the course was perceived as taxing. As a result of the perception of the relative easiness of the course, the participants began TT1 with maximum vigorous effort and by the end of TT1 had a very different idea of the difficulty of the course, often stating "that was tough, the warm-up made it feel so easy". As a result many of the participants did not begin TT2 with the same vigorous effort, opting rather to pace themselves better in TT2. The participants were told to complete both time trials to the best of their abilities; however their approach to the course in the subsequent trials is likely the cause of the decrease in mean maximum power on TT2. The participants may have chosen to conserve their energy better for the hill section of the course on TT2, and this may also be a reason why the results show improved power output on the hill section.

There are several methods that may have been considered in monitoring the participants' physiological state. The heart rate in this study was monitored at the start of the warm-up, TT1, and TT2, and participants were only allowed to start the time trials when the heart rate had returned to that which it had been pre- warm-up. Although this ensured that heart rate had recovered sufficiently at the start of each of the trials, it may have been better to monitor the heart rate throughout the trial to obtain values of peak heart rate and heart rate recovery. The increase in heart rate that occurs during exercise is positively correlated with the increase in metabolic rate and oxygen consumption (VO2) as workload increases. Oxygen consumption (VO2) increases as the intensity of exercise increases, and remains elevated for longer time periods following high intensity exercise (Powers and Howley, 1997; Marieb, 2004). Intense exercise also results in greater blood concentrations of lactate (Powers and Howley, 1997). Lactate is the end product of the cellular metabolism of glucose and most of the lactate produced during the exercise diffuses out of the muscle into the bloodstream and is completely gone from the muscle within 30 minutes after exercise stops (Marieb, 2004). Lactate levels may have been tested prior to starting and following completion of each of the time trials to give a better indication of the physiological state of the participants.

A heavier cyclist, combined with a heavier bicycle, require more leg power to resist the forces of gravity, particularly when climbing hills (Beneke *et al*., 1989). When a cyclist climbs a hill, gravity slows the ascent (Burke, 2003). The methodology used in this study would have controlled for this. In this test setting no gravitational forces would have been experienced by the cyclist on the hill section of the course, as the sensation of climbing a hill was caused by the electromagnetic brake on the Tacx Trainer to provide resistance. The weight of the bicycle would also not have affected the leg power required to accelerate the bicycle forward.

5.3.3.2 Cadence

Each participant was permitted to select their own cadence. The average cadence (p = 0.057) and maximum cadence (p = 0.781) measurements showed no statistically significant differences when comparing TT1 and TT2. Figure 4.4.2, however, reflects an increase in average cadence from TT1 to TT2, and although not statistically significant it is worthy of discussion. The mean average cadence TT1 at 98.78 ±10.136 rpm, and TT2 at 100.63 ±11.025 rpm is in line with the literature that a higher pedaling cadence (greater than 90 rpm) is advantageous to a cyclist's performance (Burke, 2003). Most participants maintained a fairly steady cadence that did not alter much during the time trial course. There was, however, an increase in mean and maximum cadence seen on the hill section in TT2 with a mean average cadence of TT1: 98.145 ±11.2673 rpm, and TT2: 100.595 ±11.8178 rpm, and a mean maximum cadence of TT1: 112.13 ±10.356 rpm, and TT2: 115.50 ±11.828 rpm. The mean cadence (p = 0.028) and maximum cadence (p = 0.002) increased significantly on the hill section of the 1.5 km course in TT2, as reflected in Figure 4.6.1.

Gross cycling efficiency increases more with power output at a higher cadence than a lower cadence (Pierre, Nicolas, and Frederique, 2006). The mean cadences for both of the time trials are supportive of this overall cycling efficiency of the participants as the cadences were at the upper end of the suggested optimum cycling cadence of 90 – 100 rpm (Burke, 2003; Bertucci *et al*., 2005). Pedal rate is not, however, entirely constant and shows fluctuations that are caused by power fluctuations (Ettema, Loras, and Leirdal, 2009) as seen in the range of the average cadences recorded for TT1 at 75 – 129 rpm, and TT2 at 73 – 129 rpm. The cadence readings are however in line for both TT1 and TT2. Fluctuations in cadence also occur as a result of terrain, such as ascents and descents (Burke, 2003). In a laboratory setting this would not have occurred, and outdoor testing on a simulate hill course that would cause greater fluctuations in cadence, would give a better indication of the effect of Kinesio® tape on cadence.

As discussed in the literature review any pedaling cadence capable of maximizing blood flow to the muscles could overcome, at least partly, the inevitable blood flow restriction brought about by quadriceps muscle contraction and might represent an important physiological advantage (Burke, 2003). Higher pedaling cadences (>90 rpm) have been shown to overcome this (Burke, 2003). A benefit of the pedaling cadence achieved by the cyclists in this study may be the improved blood flow to working muscles as a result of enhancing the effectiveness of the skeletal-muscle pump. The potential positive effect of Kinesio® tape and its elastic properties to blood flow would have enhanced this further. During the downstroke phase of cycling blood flow occlusion occurs in the quadriceps muscles (Burke, 2003). The combined effects of the higher cadence and Kinesio® tape on blood flow would serve to overcome this.

Studies have noted that skin temperature is related to blood flow and muscle temperature (Isaji *et al*., 1994, as cited by Doan *et al*., 2003). An initial increase in skin temperature has been seen with the use of compression garments, allowing a decrease in warm-up time and enhancing muscle performance (Doan *et al*., 2003). Kinesio® tape may be proposed to act like a compression garment, in the sense that it applies pressure to the skin, aiding blood flow, as well as heat conduction (Halseth *et al*., 2004).

The pressure applied to the skin by Kinesio® tape also facilitates the cutaneous mechanoreceptors, potentially stimulating proprioception while simultaneously not limiting joint ROM enhancement (Murray, 2000). This proposed effect would further enhance cadence.

5.3.3.3 Speed

The findings from Table 4.1.1 shows there was no statistically significant differences in the average speed (p = 0.792) and maximum speed (p = 0.336). The time trial course was such that as the time trial began a great amount of power was required to gain speed, and as the speed increased and momentum was gained from the course the speed continued to increase until maximum speed was reached by most of the participants at the point where the hill section of the course began in the last 300m’s of the time trial, at which time the power output again increased to overcome the increased resistance of the hill and the speed rapidly decreased during hill climbing.

The 1.5 km course used in this study included a hill section, this is unlike many other tests done on a cycle ergometer and would have allowed for a better indication of the cyclists all round abilities. The winners of the major three week stage races (Tour de France, Giro d'Italia, Vuelta a Espana) in the last years have been cyclists who excelled in the hilly sections of the races (Bertucci *et al*., 2005). It is important to assess the cyclists on a course that incorporates a hill as this may better assess the effect of the intervention in an outdoor situation. In a similar study by Peiffer *et al*. (2010), a 1 km time trial course was selected, this course was however flat, involving no ascents or descents. The researchers chose not to measure speed as a variable and it is, therefore, not comparable to the 1.5 km course of this study (Peiffer *et al*., 2010).

5.3.3.4 Completion time

The time taken to complete the 1.5 km time trial was recorded, pre- and post- Kinesio® tape application, using the Tacx Trainer software. There was a non significant decrease in completion time between TT1 and TT2 (p = 0.506) as shown in Table 4.4.2. Although not statistically significant with the mean time for TT1 being 02:35:57 and for TT2 being 02:35:07, on average 0.50 seconds was saved in TT2. As previously discussed in the literature review, the relevance of this can not be overlooked, as many stage cycling races are won on the final day as the race comes down to only seconds separating the overall winners. A gain, no matter how small, in a highly competitive sport such as cycling where cyclists are continuously seeking the edge/advantage over their competitors, cannot be overlooked and is worthy of further research. In the study by Peiffer *et al*. (2010) there was an increase in completion time on TT2. This furthers the relevance of the completion time in this study as the study by Peiffer *et al*. (2010) involved the participation of highly competitive cyclists, who might have recovered more quickly as a result of their fitness levels.

After three weeks of racing the Tour de France, it is often won by a margin of less than a minute (Armstrong, 2004). In the 2011 Tour de France the first and second placed cyclists were separated by only eight seconds in the overall classification when they began the individual time trial on the second to last stage (http://www.bicycling.co.za/articles/time-trials accessed 28 September 2011). With a time difference of only eight seconds between them, there would have been no statistically significant difference in their results should the cyclist's times have been compared. However, there was enough of a difference between the two cyclists' time, for them to be acknowledged as first and second placed competitors. The smallest change like repositioning the hands on the handlebars could make a cyclist three seconds slower in a 40 km time trial (Armstrong, 2004). This highlights the importance of a product, such as Kinesio® tape, that could potentially give a cyclist the edge over other competitors. A minute amount of energy saved per revolution adds up significantly, and in racing it could mean the difference between victory and defeat (Beneke *et al.*, 1989). Over a longer distance of 20-40 kilometres, the average length of a time trial, the time gained would be cumulative.

5.3.4 Perception

The same percentage of participants felt an increase in cadence as those who felt the same (47.5%) while only 5% felt a decrease. The participants' perception of cadence in TT2 is represented in Figure 4.5.2. These perceptions are in line with the results that show no statistical difference, although in Figure 4.4.2 an increase can be seen and this is representative of the number of participants that would have experienced an increase in cadence.

Figures 4.5.1 and 4.5.3 show that the majority of the participants (60%) felt that they experienced an increase in power and speed respectively. Although this increase is not in line with the statistical results, the Hawthorne effect may have influenced the results (de Amici *et al.*, 2000; McCarney *et al.*, 2007).

The results of the patient's perceptions are not in line with the performance and the measurements of the power output, speed, and cadence. The patients' awareness that an intervention had been applied and the quadriceps muscles had been taped may have resulted in a skewed perception of abilities. However, this perception, over a longer distance, and in a competitive situation, may give competitors the psychological edge over other competitors. In a race situation, the cyclist's abilities are as much mental as they are physical, and believing that they are performing better will in turn have an outcome on their performance (Noakes, 2004).

5.4 In Summary

Although this study was based on a sample of trained amateur cyclists, there was a visual trend showing an increase in most of the power, speed, and cadence parameters assessed. The range of motion parameters revealed mixed results ($p > 0.05$), which warrant further research. The perception of an increase in the participants' power and speed is an important factor, which in a longer test situation may reveal the participants' perception coinciding more with the results. In a test situation such as in this trial, it may have been that after completing two vigorous time trials in a short space of time, it was the Kinesio® tape that allowed for the participants to perform as well as they did, and the results may have been greater following a longer recovery period.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The primary aims of this study were:

- To determine the effect of the application of Kinesio® tape to the quadriceps on cycling power output, cycling cadence, and cycling speed.
- To determine the effect of the application of Kinesio® tape to the quadriceps on hip and knee range of motion (flexion and extension).
- To asses the effect of Kinesio® tape applied to the quadriceps on the muscle length/tension.
- To determine the participants' perception of a change in the power output, speed and cadence post- intervention.

In terms of the specific objectives and associated hypotheses that were set out at the onset of the study:

- Hypothesis One: that Kinesio® tape applied to the quadriceps muscles would have no significant effect on the power and cadence of the pedal stroke, and therefore no resultant increase in speed, was accepted. The research does support the hypothesis, however, although not statistically significant there was an increase seen in all measurements post- Kinesio® tape application, except that of maximum power where a statistically significant decrease was seen.
- Hypothesis Two: was accepted for the knee flexion and knee extension ranges of motion where no difference was seen in the measurements post- Kinesio® tape application. Hypothesis Two was, however, rejected for hip flexion and hip extension where a significant decrease was seen in ROM.
- Hypothesis Three: that Kinesio® tape applied to the quadriceps muscles would result in no significant difference in the length/tension ratio of the muscles is rejected as a result of the increase in measurements seen. This was, however, only seen unilaterally and no definitive conclusions can therefore be made.

- Hypothesis Four: is rejected as the majority of participants perceived an increase in their power and speed post- Kinesio® tape application. The hypothesis is partially accepted for the participants' perception of cadence as there were an equal number of participants that perceived no change and that which perceived an increase.

6.2 Recommendations

1. This study should be repeated using two participant groups, which can be structured in various ways. A cross over trial such that Group One is taped for time trial one and then removes the tape for time trial two, and Group Two is not taped in time trial one and taped for time trial two. In another possible study design, participants in a control group would not be subjected to tape in either of the time trials, and these results would be compared to a Group Two that has Kinesio® tape applied for time trial two. Alternatively a non elasticated/rigid tape may be used on one of the treatment groups, and a comparison made to the Kinesio® tape group.
2. Research could be conducted to determine the effect of Kinesio® tape, in symptomatic participants, on cycling power, speed, and cadence, and range of motion. The symptomatic participants may present with knee pain, or have a history of injury.
3. Surface EMG could be used on the quadriceps muscles to increase objective data.
4. A similar study should be conducted to determine if a longer ride time, such as a 10–20 km time trial, post- Kinesio® tape application to the quadriceps muscles, has an effect on the power, speed, and cadence of participants. The longer ride time would then allow for the testing of Kinesio® tape to occur over a longer duration, which would not only assess the immediate effect of tape application.
5. Participants in this study were of varying cycling skills and abilities, therefore, it is suggested that future research in this area look to testing cyclists of similar fitness and experience levels or stratify the sample.
6. Future research may include and monitor participants' heart rate, lactate levels, and VO2 max throughout their participation in the trial to give a better indication of the participants' recovery, and to analyze this data as an outcome measure of the study.

7. A study could also be conducted on the application of Kinesio® tape to various other important muscles in cycling, such as the hamstrings, gluteus maximus, and gastrocnemius muscles, and not only the quadriceps muscles.
8. As the quadriceps muscles are predominantly active and dominant in the downstroke phase, future research could look to a testing protocol where participants stood for the duration of the time trial.
9. In future studies, it would be beneficial to obtain a detailed analysis of the pedal strokes of the participants, to allow for comparison between the pedal strokes among the different participants, as well as assessing the affect of Kinesio® tape on each pedal stroke.
10. Ideally future research should be conducted in the outdoor cycling field (road cycling/track cycling/mountain biking).

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APPENDIX A

Kinesio® tape Course Certificate


KINESIO®
#1 in Elastic Therapeutic Taping™

INTERNATIONAL PARTNERS:
Kinesio Japan
Kinesio USA
Kinesio Canada
Kinesio South America
Kinesio Brazil
Kinesio Argentina
Kinesio UK
Kinesio Spain
Kinesio Scandinavia
Kinesio Deutschland
Kinesio Poland
Kinesio France
Kinesio Italy
Kinesio Greece
Kinesio Russia
Kinesio India
Kinesio South Africa
Kinesio Middle East
Kinesio China
Kinesio Taiwan
Kinesio South Pacific
Kinesio Republic of Korea
Kinesio Mexico

Certificate of Course Completion

Dani Nelson

Has successfully completed the course requirements defined by Kinesio Taping Association International, as stated below

KINESIO TAPING KT1 FUNDAMENTALS AND KT2 ADVANCED	025-000-1F-120410-KTAIUK-SA	025-000-2A-120510-KTAIUK-SA
COURSE TITLE	COURSE CODE	COURSE CODE
Yolande de Jager	4th & 5th Dec 2010	16
INSTRUCTOR	SEMINAR DATE	HOURS
Johannesburg	South Africa	
CITY / STATE	COUNTRY	

05/12/2010

KINESIO TAPING ASSOCIATION — DATE

KINESIO TAPING ASSOCIATION IS AN APPROVED PROVIDER OF CONTINUING EDUCATION BY:
+ AOTA, for Occupational Therapists. Provider # CP1211867
+ Board of Certification Inc., for Athletic Trainers. Provider # P2293
+ NCBTMB, for Massage Therapists. Provider # 450030-06
+ State PT Associations, for Physical Therapists. Provider #

The course content is not intended for use outside the scope of practice of the learner's license or regulation.

APPENDIX B

Research Advert

Attention all Cyclists

Are you healthy, between 18 and 55 years of age, and interested in having your power output, speed, cadence and range of motion measured?

Research is being conducted at the Durban University of Technology on an intervention that may affect power output, speed, cadence and range of motion.

If you fulfill the criteria the once off consultation will be free of charge.

If you are interested in participating in this study, please contact **Dani – 082 682 0378 or 031 373 2205**

APPENDIX C

Letter of Information and Consent

Title of the Research Study: The effect of Kinesio® tape on quadriceps muscle power output, length/tension, and hip and knee range of motion in asymptomatic cyclists.

Principle Investigator: Dani Nelson (Contact: 031 373 2205)

Co-Investigator: Dr. A. Jones (Contact: 031 903 4467) (Qualification: M.Dip.C; MMEDSci (sportsmed); CCSP;CCFC)

Brief Introduction and Purpose of the Study: To determine if Kinesio® tape has any effect on power, cadence and speed, as well as hip and knee range of motion (flexion and extension) in asymptomatic trained amateur cyclists and to determine if there is any perceived change in power, cadence and speed.

Outline of the Procedures: You will need to bring your own road bicycle to the consultation. A case history, physical examination, hip and knee regional will be done. Range of motion measurements of both hip and knee flexion and extension will then be taken by means of a Goniometer (a simple non-invasive device). You will then need to participate in a 5 minute warm-up exercise. The warm-up will consist of a 5 minute cycling exercise at a work rate of 100W-120W and a cadence of 90 rpm-100 rpm followed by a complete rest of 5 minutes. Range of motion measurements of both hip and knee flexion and extension will then be taken again by means of a Goniometer. You will then be seated on your own road bicycle mounted on the Tacx trainer. You will then cycle a 1.5 km time trial route from which measurements of maximum and average power, maximum and average speed, maximum and average cadence, and completion time will be recorded. Kinesio® tape will then be applied to your quadriceps muscle on both legs. A period of 20 minutes will be allowed following the application of the Kinesio® tape intervention before the measurements are retaken. The range of motion of both hip and knee flexion and extension will then be measured again by means of the Goniometer. You will then again complete the 1.5 km time trial route. Thereafter you will be asked to answer 3 questions on your perception of any change in power, speed and cadence following the intervention. The consultation is expected to last about two hours.

Risks or Discomforts to the Participant: The testing is relatively harmless; however some muscle stiffness after testing or in the days following testing may be experienced.

Reason/s why the Participant May Be Withdrawn from the Study: You may withdraw at any stage of this study with no negative repercussions whatsoever.

Remuneration: There are no financial rewards offered in this study.

Costs of the Study: There are no costs to you for taking part in this study.

Confidentiality: All patient information will be kept confidential and will be stored in the Chiropractic Day Clinic for 5 years, after which it shall be shredded. Only the researcher and her supervisor will have access to the data.
If you have any queries about this study, which have not been satisfactorily explained by the researcher, please do not hesitate to contact the supervisor. You are not forced to take part in this study and participation is purely on a voluntary basis. You may withdraw at any stage of this study with no negative repercussions whatsoever.

Persons to Contact in the Event of Any Problems or Queries: Dr. A. Jones: 031 903 4467

Statement of Agreement to Participate in the Research Study:
(I,……………………………………………participant's full name, ID number……………………………., have read this document in its entirety and understand its contents. Where I have had any questions or queries, these have been explained to me by…………………………………….to my satisfaction. Furthermore, I fully understand that I may withdraw from this study at any stage without any adverse consequences and my future health care will not be compromised. I, therefore, voluntarily agree to participate in this study.

Participants' name (print)………………… Participants' signature………………… Date……………
Researcher's name (print)……………… Researcher's signature……………… Date……………
Witness name (print)………………………… Witness signature…………………… Date……………

APPENDIX D

DURBAN UNIVERSITY OF TECHNOLOGY
CHIROPRACTIC DAY CLINIC
CASE HISTORY

Date: ____ ________
File # ____________ Age: ________

Sex : __________ Occupation: ________________________________

Intern : ________________________________ Signature ________________________

FOR CLINICIANS USE ONLY:
Initial visit
Clinician: Signature :

Case History:

Examination:
Previous: Current:

X-Ray Studies:
Previous: Current:

Clinical Path. lab:
Previous: Current:

PTT:	Signature:	Date:

CONDITIONAL: Reason for Conditional:
Signature: Date:

<u>Intern's Case History:</u>

1. Source of History:

2. Chief Complaint : (patient's own words):

	Complaint 1	**Complaint 2**
□ Location □ Onset : Initial: Recent: Cause: □ Duration □ Frequency □ Pain (Character) □ Progression □ Aggravating Factors □ Relieving Factors □ Associated S & S □ Previous Occurrences □ Past Treatment Outcome:		

4. Other Complaints:

5. Past Medical History:

- □ General Health Status
- □ Childhood Illnesses
- □ Adult Illnesses
- □ Psychiatric Illnesses
- □ Accidents/Injuries
- □ Surgery
- □ Hospitalization

6. Current health status and life-style:

- ☐ Allergies
- ☐ Immunizations
- ☐ Screening Tests incl. x-rays
- ☐ Environmental Hazards (Home, School, Work)
- ☐ Exercise and Leisure
- ☐ Sleep Patterns
- ☐ Diet
- ☐ Current Medication
  Analgesics/week:
- ☐ Tobacco
- ☐ Alcohol
- ☐ Social Drugs

7. Immediate Family Medical History:

- ☐ Age
- ☐ Health
- ☐ Cause of Death
- ☐ DM
- ☐ Heart Disease
- ☐ TB
- ☐ Stroke
- ☐ Kidney Disease
- ☐ CA
- ☐ Arthritis
- ☐ Anaemia
- ☐ Headaches
- ☐ Thyroid Disease
- ☐ Epilepsy
- ☐ Mental Illness
- ☐ Alcoholism
- ☐ Drug Addiction
- ☐ Other

8. Psychosocial history:

- ☐ Home Situation and daily life
- ☐ Important experiences
- ☐ Religious Beliefs

9. Review of Systems:

- ☐ General
- ☐ Skin
- ☐ Head
- ☐ Eyes
- ☐ Ears
- ☐ Nose/Sinuses
- ☐ Mouth/Throat
- ☐ Neck
- ☐ Breasts
- ☐ Respiratory
- ☐ Cardiac
- ☐ Gastro-intestinal
- ☐ Urinary
- ☐ Genital
- ☐ Vascular
- ☐ Musculoskeletal
- ☐ Neurologic
- ☐ Haematologic
- ☐ Endocrine
- ☐ Psychiatric

APPENDIX E

Durban University of Technology
PHYSICAL EXAMINATION: SENIOR

DURBAN UNIVERSITY of TECHNOLOGY

File no : ______________________________ **Date :** __________ ________
Student : **Signature :**

VITALS:					
Pulse rate:			Respiratory rate:		
Blood pressure:	R	L	Medication if hypertensive:		
Temperature:			Height:		
Weight:	Any recent change? Y / N		If Yes: How much gain/loss	Over what period	

GENERAL EXAMINATION:		
General Impression		
Skin		
Jaundice		
Pallor		
Clubbing		
Cyanosis (Central/Peripheral)		
Oedema		
Lymph nodes	Head and neck	
	Axillary	
	Epitrochlear	
	Inguinal	
Pulses		
Urinalysis		

SYSTEM SPECIFIC EXAMINATION:
CARDIOVASCULAR EXAMINATION
RESPIRATORY EXAMINATION
ABDOMINAL EXAMINATION
NEUROLOGICAL EXAMINATION
COMMENTS

Clinician: **Signature :**

DURBAN UNIVERSITY of TECHNOLOGY

APPENDIX F

HIP REGIONAL EXAMINATION

File no: ________ Date: ________

Student: ________________________________ Signature: ________________________________

Clinician: ________________________________ Signature: ________________________________

Hip with complaint: Right ☐ Left: ☐

OBSERVATION

Gait: ________________________________

Posture: ________________________________

Weight-bearing symmetry: ________________________________

Balance and proprioception (Stork-standing test): ________________________________

Bony / soft tissue contours: Buttock contour ________________________________

Hip flexion contracture ________________________________

Lumbar lordosis ________________________________

Scoliosis ________________________________

Skin: ________________________________

Swelling: ________________________________

PALPATION

- **Anterior aspect**

			Right	Left
	Iliac crests			
	Greater trochanter			
	Pubic symphysis and tubercle			
	Femoral head			
	Femoral Δ	Femoral artery		
		Lymph nodes		
	ASIS's			
	Inguinal ligament			
	Inguinal hernia			
	Muscles -	Quadriceps		
		Adductors		
		Abductors		
		Psoas		

- **Posterior aspect**

			Right	Left
	Iliac crests posteriorly			
	Ischial tuberosity			
	Muscles	Piriformis		
		Gluteals		
		Hamstrings		
	PSIS's			
	Sciatic notch			
	SI joints			
	Lumbar Spine			
	Sacrum + coccyx			

ACTIVE MOVEMENTS (*note rom and pain*)

		Right	Left
	Flexion (110-120°)		
	Extension (10-15°)		
	Adduction (30°)		
	Abduction (30-50°)		
	Medial rotation (30-40°)		

			Right	Left
PASSIVE MOVEMENTS (*note end-feel, rom and pain*)			Right	Left
	Flexion (tissue stretch or approximation)			
	Extension (tissue stretch)			
	Adduction (tissue stretch or approximation)			
	Abduction (tissue stretch)			
	Medial rotation (tissue stretch)			
	Lateral rotation (tissue stretch)			
RESISTED ISOMETRIC MOVEMENTS (*note strength and pain*)			Right	Left
	Hip Flexion			
	Hip Extension			
	Adduction			
	Abduction			
	Medial rotation			
	Lateral rotation			
	Knee flexion			
	Knee extension			
REFLEXES			Right	Left
	Patella			
	Achilles			
DERMATOMES (*indicate deficits by level & location*)				
	Level			
	Location			
JOINT PLAY MOVEMENTS			Right	Left
	Caudal glide (long axis traction superior – inferior)			
	Compression@ 90^o (inferior – superior)			
	Medial ➢ lateral @ 180^o / @ 90^o			
	Lateral ➢ medial @ 180^o / @ 90^o			
	Internal rotation			
	External rotation			
	Anterior ➢ posterior			
	Posterior ➢ anterior			
	Quadrant (scouring) test			
SPECIAL TESTS			Right	Left
	Patrick FABER Test			
	Trendelenberg Test			
	Craig's Test			
	Leg Length	Actual		
		Apparent		
	Sign of the Buttock			
	Thomas Test (hip flexion contracture)			
	Rectus Femoris Contracture Test			
	Iliopsoas contracture Test			
	Ely's Test (rectus femoris hypertonicity)			
	Ober's Test (ITB contracture)			
	Noble Compression Test (ITB Friction Syndrome)			
	Piriformis Test			
	Hamstrings	Hamstring Contracture Test		
		Tripod Test		

APPENDIX G

DURBAN UNIVERSITY OF TECHNOLOGY
KNEE REGIONAL EXAMINATION

File:_______________Date:___________
Intern:_______________________________________Signature:_______________________________________
Clinician:____________________________________Signature:_______________________________________

OBSERVATION (Standing, Seated and during gait cycle).

A. Anterior view
Genu Varum:_________________________
Genu Valgum:________________________
Patellar position:_____________________
Tibial Torsion:________________________
Skin:__________________________________
Swelling:______________________________

B. Lateral view
Genu Recurvatum:______________________________________
Patella Alta:____
Patella Baja:____
Skin:____________________________________

C. Posterior view
Swelling:______________________________
Skin:__________________________________

D. General
Movement symmetry:___________________
Structures symmetry:___________________

ACTIVE MOVEMENTS
Flexion (0 - 135)_____________________
Extension (0 - 15)____________________
Medial Rotation (20 - 30)_______________
Lateral rotation (30 - 40)_______________

PASSIVE MOVEMENTS
Tissue approx_____________________________________
Bone-bone____
Tissue stretch_____________________________________
Tissue stretch_____________________________________

Patellar movement____

RESISTED ISOMETRIC MOVEMENTS
Knee: Flexion:_________________________
Extension:_______________________
Internal rotation:_________________
External rotation:________________

Ankle: Plantarflexion______________________________
Dorsiflexion_____________________________________

LIGAMENTOUS ASSESSMENT

One-Plane Medial Instability
Valgus stress (abduction)
Extended______________________________
Resting Position________________________

One-Plane Lateral Instability
Varus stress (adduction)
Extended____
Resting Position___________________________________

One-Plane Anterior Instability
Lachman Test (0-30°)_____________
Anterior Drawer Sign _____________

One-Plane Posterior Instability
Posterior "sag" Sign_______________________________
Posterior Drawer Test______________________________

Anterolateral Rotatory Instability
Slocum Test___________________________
Macintosh Test______

Anteromedial Rotatory Instability
Slocum Test_______________________________________

Posterolateral Rotatory Instability
Jacob ________________________________
Hughston's Drawer Sign_____
Reverse pivot shift test_________________

Posteromedial Rotatory Instability
Hughston's Drawer Sign______________________________

TESTS FOR MENISCUS INJURY

McMurray______________________________
"Bounce Home"_________________________

Anderson med-lat grind______________________________
Apleys

PLICA TESTS

Mediopatellar Plica ______________________
Plica "Stutter"____________________

Hughston's Plica______________________________

TESTS FOR SWELLING

Brush/Stroke Test ______________________

Patellar Tap Test______________________________

TESTS FOR PATELLA FEMORAL PAIN SYNDROME

Clarke's Sign ____________________
Waldron test____________________________

Passive patella tilt test______________________________

OTHER TESTS

Wilson's_______________________________
Fairbank's_____________________________
Noble Compression_____________________

Quadriceps Contusion Test______________________________
Leg Length Discrepancy______________________________

JOINT PLAY

Movement of the tibia on the femur — P | A:__________________ A | P:
Translation of the tibia on the femur — M | L:_______________ L M:__________________
Long axis distraction of the tibiofemoral joint — ______________________________
Inf, sup, lat, + med glide of the patella — ______________________________
Movement of the inf. tibiofibular joint — A | P:_______________ P | A:__________________
Movement of the sup. tibiofibular joint — A | P:_______________ P | A:__________________
Movement of the sup. tibiofibular joint — S | I :__________________ I | S__________________

PALPATION

Tenderness___________________________________
Joint line___________________________________
Ligaments____________________________________
Patella:_____________________________________
Patella tendon:______________________________
Bursae:______________________________________

Swelling______________________________
Nodules/exostoses______________________________
Muscles: thigh:______________________________
Leg :______________________________
Popliteal artery:______________________________

REFLEXES AND CUTANEOUS DISTRIBUTION

	R	L
Patellar Reflex (L3,L4)		
Medial Hamstring Reflex (L5,S1)		

DERMATOMES

	R	L		R	L
L2			S1		
L3			S2		
L4			S3		
L5					

APPENDIX H

DURBAN UNIVERSITY OF TECHNOLOGY

Patient Name: ***File #:*** ***Page:***

Date: ***Visit:*** ***Intern:***
Attending Clinician: ***Signature:***

S: ***Numerical Pain Rating Scale (Patient)*** ***Intern Rating***
Least 0 1 2 3 4 5 6 7 8 9 10 Worst

A:

0:

P:

E:

Special attention to: ***Next appointment:***

Date: ***Visit:*** ***Intern:***
Attending Clinician: ***Signature:***

S: ***Numerical Pain Rating Scale (Patient)*** ***Intern Rating***
Least 0 1 2 3 4 5 6 7 8 9 10 Worst

A:

O:

P:

E:

Special attention to: ***Next appointment:***

APPENDIX I

Participants' Perception of Change in Power, Cadence, Speed

	Power			Cadence			Speed		
No	⇑	⇓	⇔	⇑	⇓	⇔	⇑	⇓	⇔
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									

31									
32									
33									
34									
35									
36									
37									
38									
39									
40									

Key:

Increased	⇑
Decreased	⇓
No Change	⇔

APPENDIX J
Data Sheet

Participant Number: ____________________

Participants File no.: __________________

Range of motion measurements (Goniometer)

	Prior to warm-up	Prior to time trial 1	Prior to time trial 2
Hip flexion			
Hip extension			
Knee flexion			
Knee extension			

Muscle length measurements (Goniometer)

	Prior to warm-up	Prior to time trial 1	Prior to time trial 2
Modified Thomas test			

Power, cadence, speed, and time readings (Cycle Ergometer)

	Time Trial 1	Time Trial 2
Maximum **power**		
Average **power**		
Maximum **speed**		
Average **speed**		
Maximum **cadence**		
Average **cadence**		
Completion **time**		

Participants' perception of a change in power, cadence, speed

	Power	Cadence	Speed
Participants' perception			

APPENDIX K

Letter from Statistician

<u>LETTER OF CONFIRMATION (STATISTICAL ANALYSIS)</u>
<u>10 March 2011</u>

I,Tonya M Esterhuizen, confirm that I provided Ms Dani Nelson with the statistical analysis (methodology) on the 14th January 2011 regarding the following research topic:
The effect of Kinesio® tape on quadriceps muscle power output, length/tension, and hip and knee range of motion in asymptomatic cyclists.

I also confirm that I will be performing the statistical analysis of the data for this study.

[redacted]-------------------------------
Signature
Qualification: ---M.Sc----------------------------------

APPENDIX L

DURBAN UNIVERSITY of TECHNOLOGY

Faculty of Health Sciences

ETHICS CLEARANCE CERTIFICATE

Student Name	Dani Keren Nelson	**Student No**	20921496
Ethics Reference	012/11	**Date of FRC Approval**	23.05.2011
Qualification	M.TECH: CHIROPRACTIC		
Research Title:	The effect of Kinesio® Tape on Quadriceps muscle power output and hip and knee range of motion in asymptomatic cyclists.		

In terms of the ethical considerations for the conduct of research in the Faculty of Health Sciences, Durban University of Technology, this proposal meets with Institutional requirements and confirms the following ethical obligations:

1. The researcher has read and understood the research ethics policy and procedures as endorsed by the Durban University of Technology, has sufficiently answered all questions pertaining to ethics in the DUT 186 and agrees to comply with them.
2. The researcher will report any serious adverse events pertaining to the research to the Faculty of Health Sciences Research Ethics Committee.
3. The researcher will submit any major additions or changes to the research proposal after approval has been granted to the Faculty of Health Sciences Research Committee for consideration.
4. The researcher, with the supervisor and co-researchers will take full responsibility in ensuring that the protocol is adhered to.
5. ***The following section must be completed if the research involves human participants:***

	YES	NO	N/A
❖ Provision has been made to obtain informed consent of the participants	√		
❖ Potential psychological and physical risks have been considered and minimised	√		
❖ Provision has been made to avoid undue intrusion with regard to participants and community			√
❖ Rights of participants will be safe-guarded in relation to: - Measures for the protection of anonymity and the maintenance of Confidentiality.	√		
- Access to research information and findings.	√		
- Termination of involvement without compromise	√		
- Misleading promises regarding benefits of the research			√

S[redacted]

26/05/11
DATE

S[redacted]

26/5/11
DATE

S[redacted]

27/05/2011
DATE

31/05/2011

SIGNATURE: CHAIRPERSON OF RESEARCH ETHICS CO

APPENDIX M

Statistical Results

Table 1: Hip range of motion pre- TT1

		Flexion R (°)	Flexion L (°)	Extension R (°)	Extension L (°)
N	Valid	40	40	40	40
	Missing	0	0	0	0
Mean		112.08	110.75	14.80	15.33
Std. Deviation		8.352	7.292	2.972	3.612
Minimum		92	98	9	7
Maximum		130	127	21	24

R = Right; L = Left

Table 3: Hip range of motion pre- TT2 and post- Kinesio® tape application

		Flexion R (°)	Flexion L (°)	Extension R (°)	Extension L (°)
N	Valid	40	40	40	40
	Missing	0	0	0	0
Mean		109.80	109.18	12.53	12.95
Std. Deviation		7.511	6.827	2.542	2.601
Minimum		92	96	6	7
Maximum		121	124	17	20

R = Right; L = Left

Table 3: Knee range of motion and modified Thomas test measurements pre- TT1

		Knee Flex R (°)	Knee Flex L (°)	Knee Ext R(°)	Knee Ext L (°)	Thomas Test R (°)	Thomas Test L (°)
N	Valid	40	40	40	40	40	40
	Missing	0	0	0	0	0	0
Mean		129.32	128.45	3.63	3.68	53.13	54.90
Std. Deviation		4.263	4.414	.868	.730	10.286	7.030
Minimum		120	119	2	2	6	41
Maximum		140	137	5	5	65	67

R = Right; L = Left; Flex = Flexion; Ext = Extension

Table 4: Knee range of motion and modified Thomas test measurements pre- TT2 and post-Kinesio® tape application

		Knee Flex R (°)	Knee Flex L (°)	Knee Ext R (°)	Knee Ext L (°)	Thomas Test R (°)	Thomas Test L (°)
N	Valid	40	40	40	40	40	40
	Missing	0	0	0	0	0	0
Mean		128.82	128.48	3.65	3.73	56.05	57.60
Std. Deviation		4.344	4.657	.834	.877	8.638	8.770
Minimum		118	118	2	2	31	35
Maximum		141	141	6	6	73	74

R = Right; L = Left; Flex = Flexion; Ext = Extension

Table 5: Paired t-tests to compare pre- warm-up and pre- TT1 range of motion measurements

	Mean	N	Std. Deviation	Std. Error Mean	P value
Hip Flexion 1R (°)	110.43	40	8.629	1.364	<0.001
Hip Flexion 2R (°)	112.08	40	8.352	1.321	
Hip Flexion 1L (°)	110.00	40	7.749	1.225	0.080
Hip Flexion 2L (°)	110.75	40	7.292	1.153	
Hip Extension 1R (°)	14.10	40	3.112	.492	0.006
Hip Extension 2R (°)	14.80	40	2.972	.470	
Hip Extension 1L (°)	14.63	40	3.521	.557	0.002
Hip Extension 2L (°)	15.33	40	3.612	.571	
Knee Flexion 1R (°)	128.65	40	4.197	.664	0.001
Knee Flexion 2R (°)	129.32	40	4.263	.674	
Knee Flexion 1L (°)	127.08	40	4.281	.677	<0.001
Knee Flexion 2L (°)	128.45	40	4.414	.698	
Knee Extension 1R(°)	3.33	40	.944	.149	0.017
Knee Extension 2R (°)	3.63	40	.868	.137	
Knee Extension 1L (°)	3.43	40	.903	.143	0.016
Knee Extension 2L(°)	3.68	40	.730	.115	
Thomas Test 1R (°)	53.98	40	6.487	1.026	0.512
Thomas Test 2R (°)	53.13	40	10.286	1.626	
Thomas Test 1L (°)	54.00	40	6.571	1.039	0.003
Thomas Test 2L (°)	54.90	40	7.030	1.112	

1R = Pre- warm-up right side; 1L = Pre- warm-up left side; 2R = Pre- TT1 right side; 2L = Pre- TT1 left side

Table 6: Paired t-tests to compare pre- TT1 and pre- TT2 post- Kinesio® tape application range of motion measurements

	Mean	N	Std. Deviation	Std. Error Mean	P value
Hip Flexion 2R (°)	112.08	40	8.352	1.321	0.021
Hip Flexion 3R (°)	109.80	40	7.511	1.188	
Hip Flexion 2L (°)	110.75	40	7.292	1.153	0.060
Hip Flexion 3L (°)	109.18	40	6.827	1.079	
Hip Extension 2R (°)	14.80	40	2.972	.470	<0.001
Hip extension 3R (°)	12.53	40	2.542	.402	
Hip Extension 2L (°)	15.33	40	3.612	.571	<0.001
Hip Extension 3L (°)	12.95	40	2.601	.411	
Knee Flexion 2R (°)	129.32	40	4.263	.674	0.424
Knee Flexion 3R (°)	128.82	40	4.344	.687	
Knee Flexion 2L (°)	128.45	40	4.414	.698	0.956
Knee Flexion 3L (°)	128.48	40	4.657	.736	
Knee Extension 2R (°)	3.63	40	.868	.137	0.822
Knee Extension 3R (°)	3.65	40	.834	.132	
Knee Extension 2L (°)	3.68	40	.730	.115	0.688
Knee Extension 3L (°)	3.73	40	.877	.139	
Thomas Test 2R (°)	53.13	40	10.286	1.626	0.088
Thomas Test 3R (°)	56.05	40	8.638	1.366	
Thomas Test 2L (°)	54.90	40	7.030	1.112	0.041
Thomas Test 3L (°)	57.60	40	8.770	1.387	

2R = Pre- TT1 right side; 2L = Pre- TT1 left side; 3R = Pre- TT2 right side; 3L = Pre- TT2 left side

Table 7: Power (watts), speed (km/h), and cadence (rpm) results for TT1

		Maximum Power	Average Power	Maximum Speed	Average Speed	Maximum Cadence	Average Cadence
N	Valid	40	40	40	40	40	40
	Missing	0	0	0	0	0	0
Mean		467.93	272.65	49.280	37.340	115.58	98.78
Std. Deviation		152.642	80.384	6.2006	4.4328	11.052	10.136
Minimum		284	133	31.9	27.4	91	75
Maximum		952	446	59.0	45.6	141	129

Table 8: Power (watts), speed (km/h), and cadence (rpm) results for TT2 post- Kinesio® tape application

		Maximum Power	Average Power	Maximum Speed	Average Speed	Maximum Cadence	Average Cadence
N	Valid	40	40	40	40	40	40
	Missing	0	0	0	0	0	0
Mean		430.15	273.10	49.725	37.402	116.35	100.63
Std. Deviation		112.194	74.690	6.3083	4.2435	19.946	11.035
Minimum		282	134	31.6	27.4	17	73
Maximum		747	448	58.8	45.5	151	129

Table 9: Paired t-tests to compare pre- TT1 and pre- TT2 post- Kinesio® tape application power (watts), speed (km/h), and cadence (rpm) measurements

	Mean	N	Std. Deviation	Std. Error Mean	P value
Max Power 1	467.93	40	152.642	24.135	0.007
Max Power 2	430.15	40	112.194	17.739	
Ave Power 1	272.65	40	80.384	12.710	0.907
Ave Power 2	273.10	40	74.690	11.809	
Max Speed 1	49.280	40	6.2006	.9804	0.336
Max Speed 2	49.725	40	6.3083	.9974	
Ave Speed 1	37.340	40	4.4328	.7009	0.792
Ave Speed 2	37.402	40	4.2435	.6709	
Max Cadence 1	115.58	40	11.052	1.747	0.781
Max Cadence 2	116.35	40	19.946	3.154	
Ave Cadence 1	98.78	40	10.136	1.603	0.057
Ave Cadence 2	100.63	40	11.035	1.745	

1 = TT1; 2 = TT2; Max = Maximum; Ave = Average

Table 10: Paired t-tests to compare pre- TT1 and pre- TT2 post- Kinesio® tape application power (watts), speed (km/h), and cadence (rpm) measurements separated by gender

Sex		Mean	N	Std. Deviation	Std. Error Mean	P value
Female	Max Power 1	352.50	4	59.287	29.644	0.222
	Max Power 2	305.75	4	7.805	3.902	
	Ave Power 1	205.50	4	21.142	10.571	0.674
	Ave Power 2	201.75	4	21.639	10.820	
	Max Speed 1	46.700	4	2.9597	1.4799	0.542
	Max Speed 2	45.700	4	3.4186	1.7093	
	Ave Speed 1	33.625	4	1.3401	.6700	0.605
	Ave Speed 2	33.325	4	1.4886	.7443	
	Max Cadence 1	117.75	4	10.905	5.452	0.230
	Max Cadence 2	121.50	4	14.754	7.377	
	Ave Cadence 1	101.25	4	6.238	3.119	0.478
	Ave Cadence 2	103.75	4	12.093	6.047	
Male	Max Power 1	480.75	36	154.820	25.803	0.016
	Max Power 2	443.97	36	109.799	18.300	
	Ave Power 1	280.11	36	81.173	13.529	0.828
	Ave Power 2	281.03	36	74.361	12.393	
	Max Speed 1	49.567	36	6.4223	1.0704	0.216
	Max Speed 2	50.172	36	6.4252	1.0709	
	Ave Speed 1	37.753	36	4.4710	.7452	0.690
	Ave Speed 2	37.856	36	4.2147	.7024	
	Max Cadence 1	115.33	36	11.194	1.866	0.885
	Max Cadence 2	115.78	36	20.525	3.421	
	Ave Cadence 1	98.50	36	10.506	1.751	0.086
	Ave Cadence 2	100.28	36	11.042	1.840	

1 = TT1; 2 = TT2; Max = Maximum; Ave = Average

Table 11: Completion time of TT1 and TT2

Paired Samples Statistics						P value
		Mean	N	Std. Deviation	Std. Error Mean	
Pair 1	Completion Time 1	02:35:57	40	00:19:01.331	00:03:00.460	0.506
	Completion Time 2	02:35:07	40	00:18:47.354	00:02:58.250	

1 = TT1; 2 = TT2

Table 12: Paired t-tests to compare pre- TT1 and pre- TT2 post- Kinesio® tape application power (watts), speed (km/h), and cadence (rpm) measurements on the hill section

	Mean	N	Std. Deviation	Std. Error Mean	P value
Hill 1 Max Power	333.20	40	70.017	11.071	0.128
Hill 2 Max Power	343.20	40	76.900	12.159	
Hill 1 Ave Power	273.747	40	62.5772	9.8943	0.317
Hill 2 Ave Power	278.693	40	67.9577	10.7450	
Hill 1 Ave Speed	34.363	40	4.0354	.6381	0.309
Hill 2Ave Speed	34.630	40	4.2073	.6652	
Hill 1 Ave Cadence	98.145	40	11.2673	1.7815	0.028
Hill 2 Ave Cadence	100.595	40	11.8178	1.8686	
Hill 1 Max Cadence	112.13	40	10.356	1.637	0.002
Hill 2 Max Cadence	115.50	40	11.828	1.870	

1 = TT1; 2 = TT2; Max = Maximum; Ave = Average