The Effectiveness of Pain Neuroscience Education in the Treatment of Recreational Marathon Runners with Chronic Running Related Knee Injuries

By

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I, Tyren Naidoo, declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgements indicate to the contrary).

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ABSTRACT

Background: Running has a long history as a mode of exercise and in recent years the popularity of running has increased especially in South Africa. However, it may have adverse short- and long-term effects through running-related injuries. For marathon runners, one of the most common consequences of this is injury to the knee joint complex. Recreational runners presenting with injuries have partially recovered from their injury yet continue to experience pain. Which emphasises the necessity for treatment to be more comprehensively through a biopsychosocial model Pain Neuroscience Education (PNE) component, where a greater understanding of how the nervous system processes injury and pain is utilised.

Aim: To assess the effectiveness of Pain Neuroscience Education (PNE) combined with chiropractic care versus chiropractic care alone for the reduction of pain due to chronic running-related knee pain in recreational marathon runners within the eThekwini Municipality.

Methodology: The study used a quantitative randomised controlled single-blinded design, in which the participants were blinded. The study design followed a phase II randomised clinical trial. Recreational marathon runners from the eThekwini region, both male or female, between the ages of 18 and 65, were recruited for this study. Participants were randomly assigned and received either Pain Neuroscience Education (PNE) and chiropractic care or chiropractic care only. Both Group 1 and 2 had a sample size of 23 each, with a total sample size of 46 participants. Data was captured on a Microsoft Excel spreadsheet and imported into SPSS version 27 for analysis.

Results: There was no significant difference between the intervention and control group, with respect to Pain Catastrophization Scale (PCS), and the Lower Extremity Functional Scale (LEFS) recordings. However, both the Intervention and control group under analysis showed a decrease in their Numerical Pain Rating Scale (NRS) readings, where the control group showed a higher mean score (decrease) over time compared to the PNE (intervention group).

Conclusion: Chronic running-related knee pain did not change significantly. The findings correlate with the complexity of pain in previous PNE studies. Given the anatomical changes associated with running-related knee injuries, it was not surprising that running activities and range of motion did not change significantly either.

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CHAPTER ONE: INTRODUCTION

1.1 INTRODUCTION

This chapter aims to introduce the study by providing a background and highlighting the rationale. Within this chapter, aims and objectives of the study are also outlined, as well as the flow of the dissertation.

1.2 BACKGROUND

Running has a long history as a mode of exercise (Gray, Poggemiller and Tracy, 2017) and, in recent years, the popularity of running has and will continue to increase (Sanchez, Corwell and Berkoff, 2006; Ellapen et al. 2013).

The marathon is one of the most challenging endurance competitions which exists (El Helou et al. 2012), it can be classified as one of the largest mass participating sporting events which athletes, of varying caliber and fitness levels, put themselves through (Gordon et al. 2017b).

Struwig (2016) found that distance running has become increasingly popular among South Africans. Whilst international popularity of long-distance running is evident, statistics tend to reveal that South Africans concentrate more predominantly on ultra-marathon racing (Symonds, 1995). Recreational marathon running is an easy activity to maintain an active lifestyle, maintain a healthy body mass, has multiple fitness benefits and favorable effects on the cardiorespiratory system, versus a sedentary lifestyle. However, it may have adverse short and long term effects through running-related injuries (RRI), i.e. overuse and musculoskeletal injuries (Lopes et al. 2012; Struwig, 2016). The incidence with RRI is very high and varies from 20.3 to 84.9% with an etiology that is diverse and multifactorial (Bredeweg et al. 2012; Li et al. 2022). According to Schubert, Kempf and Heiderscheit (2014), approximately 56% of recreational runners and as many as 90% of those training for marathons encounter and suffer from RRI each year. Knee pain can be encountered anteriorly, posteriorly, superiorly, inferiorly, medially and even laterally in relation to the patellofemoral joint (Kunene, Taukobong and Ramklass, 2020). Knee pain has become a common clinical presentation among runners and eventually presents as a threat to their quality of life and running performance, during training and marathon running (Kunene, Taukobong and Ramklass, 2020).

Knee pain among marathon runners includes both internal and external factors, which are multifactorial. Internal factors include structural dysfunctions of the body — mainly muscle force imbalances. Compared to external factors, namely running equipment, the environment, training load and method of gait (Kunene, Taukobong and Ramklass, 2020). Knee pain in marathon runners requires comprehensive assessment, treatment and rehabilitation programmes, especially since the causes of knee pain tend to vary from athlete to athlete, depending on the structure of the injured knee.

According to Kunene, Taukobong and Ramklass (2020), in order to be both effective and efficient with the rehabilitation of knee pain, the approach needs to be a team approach — where team members include a variety of healthcare practitioners. Evidence of rehab strategies that are readily available or have been used in the treatment of running-related knee pain is limited.

Zimney et al. (2019) introduced a strategy called PNE, which incorporates the multidimensionality of a pain experience and helps the patient grasp pain through understanding the neurophysiological components that may be part of their own pain experience. Pain neuroscience education uses multiple metaphors, examples and analogies to explain the neurophysiological process of pain occurring with the patient, that may contribute to the patient’s pain experience.

1.3 AIM OF THE STUDY

To assess the effectiveness of PNE combined with chiropractic care versus chiropractic care alone for the reduction of pain due to chronic running-related knee pain, in recreational marathon runners within the eThekwini municipality.

1.4 STUDY OBJECTIVES

Objective one:

To determine the effectiveness of pain neuroscience education (Schröder et al.) for the treatment of recreational marathon runners with chronic running-related knee injuries using the pain catastrophising scale (PCS).

Objective two:

To estimate the effectiveness of PNE, in the reduction of pain for the treatment of recreational marathon runners with chronic running-related knee complex and joint injuries, using the pain catastrophising, numerical pain rating and lower extremity functionality scales respectively (PCS, NPR, LEFS).

Objective three:

To determine self-reported changes in functionality of the knee joint of the treatment of recreational marathon runners with chronic running-related knee injuries, using the lower extremity functional scale (LEFS).

1.5 RATIONALE BEHIND THE STUDY

The marathon is one of the single greatest tests of individual endurance. The word “marathon” can be used as a noun to describe a long distance foot race in a twentieth-century setting (Lucas, 1976). For years, marathon running was considered a dangerous life-risking activity, yet humans still engage in these activities (Lucas, 1976).

Due to the special nature of marathons, participants displayed very distinct types of intention as to why they entered these events. Reasons such as intrinsic reward, goal achievement, socialisation and camaraderie are popular reasoning (Kruger and Saayman, 2013). Motivation can be defined in many ways, furthermore according to Symonds (1995), “most regard it as an intervening process or an internal state of an organism that impels or drives it to action.” This being mentioned as motivation for participation is directly associated with the benefits of running and this is possibly why runners may continue to run.

It should not be overlooked that, at some point, runners will inevitably sustain running-related injuries (RRI) (Bredeweg et al. 2012; Li et al. 2022), which can be explained due to the repetitive nature and the high impact of each foot strike (Ellapen et al. 2013).

For marathon runners, one of the most common consequences of this is injury to the knee joint complex (Sanchez, Corwell and Berkoff, 2006; Ellapen et al. 2013). Running related injuries tend to usually present in the lower limb extremities in which 10-17% and 4-8% are diagnosed as patella femoral pain (PFP) and iliotibial band syndrome (ITBS) respectively (Mulvad et al. 2018), indicating that the knee is one of the most vulnerable regions prone to injury, accounting for 41.7% of all running induced injuries (Orfao-Fugareu, 2004; Knechtle and Nikolaidis, 2018). Since the most common site of injury is the knee, prevention and treatment of pain is essential to keep runners active (Lenhart et al. 2014).

In runners, pain has become a large way of life. However, without the capability to experience pain humans would not be able to survive (Louw, Hilton and Vandyken, 2014). According to Puentedura and Louw (2012), every disease process can be explained by an underlying deviation from normal function, such as a pathogen or, more specifically, an injury.

The biopsychosocial model of sport medicine suggests that a larger degree of expression of the symptom in an athlete would indicate a greater underlying pathology (Puentedura and Louw, 2012). Evidence, however, suggests that many athletes presenting with physical signs have partially recovered from their injury yet will continue to experience pain. Which emphasises the necessity for athletes to be treated more comprehensively through a biopsychosocial model (pain neuroscience education) component, where a greater understanding of how the nervous system processes injury and pain is utilised (Puentedura and Louw, 2012).

1.6 CONCLUSION

1.6.1 Structure of Dissertation

The subsequent chapters will be structured as follows:

Chapter two will present the literature review and provide an overview of marathon running and pain neuroscience education. This will be followed by an analysis of the current and past literature on the prevalence, risk factors and effective management of chronic running-related knee injuries.

Chapter three will detail the methodology of the study which will achieve the aims and objectives. All study designs, measurements, methods and techniques will be explained.

Chapter four will expound the results of this study.

Chapter five will discuss the results in terms of the current literature.

Chapter six will provide a conclusion, along with any limitations related to the study and present the recommendations that have stemmed from the investigation of the randomised controlled trial.

CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is a review of the literature with the factors that contribute to the topic of this study. It looks at a brief introduction to marathon running, pain neuroscience education, the normal mechanics of running, the gait cycle, biomechanics of the gait cycle during running, the incidences and prevalence of chronic running-related knee injuries, the risk factors associated with running-related knee injuries, and the effective management of knee injuries sustained. It concludes with the relevance of this literature in the healthcare community.

2.2 INTRODUCTION TO MARATHON RUNNING

The marathon is the benchmark test of endurance (Jayaseelan, Weber and Jonely, 2019). Stemming back to the first modern Olympic Games in Athens in 1896, it has undergone an evolution into today's conventional 42.195km race (Jayaseelan, Weber and Jonely, 2019). Running, as a discipline, has since grown in popularity over the years due to its ease of accessibility and cost-effectiveness (Nassif, 2016). Throughout the '70s running a marathon was thought to be only for elite athletes and could not be run rewardingly or safely by anyone (Symonds, 1995). An alternative to road running is trail running, which is defined as running on any surface or terrain other than the road such as sand, grass or rocks and gravel. Trail running in America was born when San Francisco runners made a bet. The bet was a gesture in which there was a challenge to see who could run from Mill Valley to Dipsea by the Sea, on the 19th of November 1905. Later the great new sport began and that very bet stood as The Dipsea Race.

Progression of the marathon has grown tremendously in number through the expansion in the '70s and '80s — not exclusive to male athletes, but also including the young, the old and the disabled. Additionally, marathon running in the '60s provided an important platform for the emancipation of female participation in sport. With unofficial record breaking attempts, up to the present record of 2 hours and 19 minutes held by Keira D'Amato (Coyle, 2007) (Jayaseelan, Weber and Jonely, 2019). Entries for marathons, which are hosted worldwide in major cities, exceed 5 000 participants and have attracted local as well as international athletes, of varying backgrounds and capabilities. In modern society, the world has seen a sharp division into an expanding number of intense exercise enthusiasts and a larger section of highly sedentary individuals. Marathon running statistics show an increase from 25 000 runners in 1976 to approximately 2 million in the year of 2010 (Burkule, 2016). According to Lenhart et al. (2014), running as an exercise, globally, has now reached over 13.9 million people. However, despite the benefits of running, studies have identified injury incidence rates as high as 79% as early as within the first six months (Burkule, 2016) (Lenhart et al. 2014).

Whilst the popularity of long distance running globally is evident, the introduction of marathon running in South Africa dates back to the early nineteenth century (Symonds, 1995). South Africa was readmitted to international athletics in 1992, after 32 years of isolation in which the rest of the World was ready to welcome South African athletes with open arms; achievements and opportunities. South African runners then followed this up with some strides into the international circuit, where 1996 would have been the biggest year of all of South Africa marathoning - in which Josiah Thugwane stunned the World to win the gold medal at the Atlanta Olympics. Road running within a South African context can be explained by the country proudly hosting two of the largest and most prestigious ultra-marathons in the world — The Two Oceans ultra and The Comrades Marathon, known to many as The Ultimate Human Race (Knechtle and Nikolaidis, 2017).

2.2.1 Elite and amateur marathon runners

Marathon and other long distance running events are primarily about endurance. However, when making comparisons between elite and recreational marathon runners, there are many minor and major differences, which are grouped predominantly by training volume, load, body composition, tendon function, the length and frequency of stride, and foot strike patterns.

Whist performance differs greatly between the two groups of athletes; elite distance runners have higher maximum oxygen capacity (VO2max), which is an indication of a greater ability to deliver and feed oxygen to their muscles compared to a recreational marathon runner — meaning elite runners have better running economy against the recreational type of runner (Gordon et al. 2017a). According to Jaenes et al. (2021), elite runners can complete a marathon in just over 2 hours, whereas recreational marathon runners rarely finish the distance in under 3 hours.

2.3 NORMAL MECHANICS OF RUNNING

2.3.1 Gait cycle

The gait cycle is an alternating motion of both legs limiting the forward propulsion of the body (Nassif, 2016). It can be split into two separate phases — the stance phase (60%), and the swing phase (40%) (Tongen and Wunderlich, 2010) (Millar, 2019). The cycle can be counted when one foot of the runner makes contact with the ground and ends when the same initial foot contacts the ground again (Nassif, 2016).

Running is defined as a gait in which there is an aerial phase — the aerial phase is a time where no limbs of the individual are in contact with the surface (Tongen and Wunderlich, 2010). Running is an essential component to most activities and sport, whether it is the purpose to run faster than an opponent or to develop adequate take-off speed and velocity.

More specifically, the activity of running often occurs at speeds faster than walking, although professional speed walkers may clock speeds of up to 4.6 meters per second, using an unorthodox gait where the hip is dropped upon each step. However, during walking there is never a time where both feet of the walker, are off the ground surface. Therefore the stance phase is longer than half the gait cycle and always starts with periods of double support, in which both the feet of the individual are on the surface (Nassif, 2016). When discussing the stance phase of the gait cycle, it can be explained by the duration in which one foot is in contact with the ground. Therefore there are two stance phases per gait cycle, one for each limb (Nassif, 2016). In conclusion with the expansion of the phases of the gait cycle, the start of the swing phase can be signaled by the toe off, corresponding to the time for which the foot is unsupported by the surface of the ground (Tongen and Wunderlich, 2010; Nassif, 2016).

2.3.2 Biomechanics of the gait cycle during running

Novacheck (1998) stated that one of the differences between walking and running happens when double support through the stance phase, of the gait cycle, changes to two instances of double float at the start and end of the swing phase of gait. Additionally, further transition from walking to running occurs when the velocity or distance covered per unit of time is increased. Speed in combination of the initial contact of the foot increases, where a change from hindfoot to forefoot is noticed (Nassif, 2016) (Millar, 2019). As running speed increases, it is coupled and associated with an increase in the flexion of the hip and knee joints. Increased dorsiflexion and plantarflexion movements of the ankle, creates larger forces on the respective joints involved through the kinetic chain of movement (Millar, 2019).

According to Wille et al*.* (2014), during running the two most important concepts in dealing with the biomechanics of the gait cycle are the ground reaction and kinetic chain forces. The kinetic chain can be explained as a system of connected body segments, i.e., when a muscle in the system spans across a joint is activated or recruited, a movement is produced ultimately causing the next joint in the chain to move. In contrast to the kinetic chain force, the ground constantly exerts a force on the foot, during the stance phase of the gait cycle — this is known as the ground reaction force (GRF) (Schubert, Kempf and Heiderscheit, 2014). The GRF are forces which are equal in magnitude but opposite in the direction to the force experienced by the weight bearing limb and can be produced in various planes such as; the horizontal, vertical or rotary movement planes (Schubert, Kempf and Heiderscheit, 2014; Millar, 2019).

Running is associated with loads of approximately 2.5 times the body weight of the individual and can therefore add to the GRF produced, which contributes to the increased possibility of injury occurrence (Schubert, Kempf and Heiderscheit, 2014). Force transfer by the lower limbs occur on impact of the feet on the ground and the force is transferred into the pelvis via the spine in a closed-kinetic chain. Force is then transmitted to the upper limb, shoulders and returned back inferiorly along the spine into the pelvis and lower limbs through the thoraco-lumbar fascia, therefore generating raised speed and efficient performance (Lewis and Garibay, 2015; Millar, 2019).

2.3.3 Incidence and prevalence of road running related injuries

Despite the various benefits to running, marathon running does have a high risk of injury, with 20% to 80% of runners self-reporting an injury within a 6 month period, which can be as high as 90% in those training for longer distances (Lopes et al*.* 2012; Swanevelder et al. 2021). Much research has been published on the number of running-related injuries to marathon runners of all experience levels, i.e. novice to elite athletes, predominantly on non-elite athletes (Fredericson and Misra, 2007). It was noted by Fredericson and Misra (2007) that injuries in marathon runners can be multifactorial, but are most often due to incorrect training techniques. The most common factors for injury were found to be: an increase in weekly kilometers too quickly, previous injury and competitive training reasons. According to (Damsted et al*.* 2018) a previous history of injury is continuously reported in the literature as a very strong risk factor for injury development. However, the variation in the incidence of running-related injuries in the literature may be partially due to the variations in the methodology, as well as the fact that the definition of a running injury may have caused further variations between research studies (Fredericson and Misra, 2007; Van Middelkoop et al. 2008). The definition of a running-related injury was later described as any self-reported complaint involving muscles, joints, tendons and bones mentioned by the individual to be caused or attributed to running (Lopes et al. 2012).

Since the inception of sport injury research, the phenomenon “training too much, too soon” has been recognised in playing a large role in injury development and seems to coincide within running-related injury findings (Damsted et al*.* 2018). Theoretically, injury occurs when the cumulative training load, over several running sessions exceeds the body’s load capacity for adaptive tissue repair (Damsted et al. 2018). It was clear that more experienced marathon runners are less prone to injury, with the number of years running being inversely proportional to the incidence of injuries (Fredericson and Misra, 2007).

The most common site of lower limb extremity injuries is the knee joint complex. In which location specific incidence ranges from 9% to 50% (Taunton et al. 2003; Van Middelkoop et al. 2008; Hoffman and Krishnan, 2014). The anatomy of the knee is made up of two parts. The part between the end of the thigh bone (femur) and the superior part of the shin bone (tibia) is called the tibiofemoral joint. The patellofemoral joint is between the inferior end of the thigh bone (femur) and the kneecap (patella). In an anatomical description of the knee joint complex the joint is surrounded by synovial fluid, which enabling adequate lubrication of the joint complex. The bone surfaces are covered by smooth articular cartilage allowing them to glide smoothly together without friction. The knee joint complex is made up of numerous ligaments such as the; cruciate and collateral ligaments, which are located inside the knee and at the lateral and medial aspects of the knee respectively. there are two meniscal cartilages in the knee joint complex that serve as shock-absorbers - one on the inner and one on the outer side. Their location allows for evenly distribution of the load from the thigh bone to the thin bone when walking and running. However, among marathon runners, stress fractures accounted for 3.7% of exercise-related injuries, although literature reports that stress fractures may be relatively less common in ultramarathon runners compared to shorter distance runners, but more common in the foot with marathon and ultramarathon runners, respectively (Hoffman and Krishnan, 2014).

2.4 PAIN NEUROSCIENCE EDUCATION

Pain Neuroscience Education (PNE) is relatively young since its inception 15 years ago. This is also part of the reason that researchers, clinicians and specialists are very eager to use it clinically (Afzal et al*.* 2019).

The inability to detect and feel pain introduces a significant risk to survival for any human being, however, living in constant pain (chronic) is not a normal human experience. Chronic pain can be described as pain that persists past the normal time of healing, persisting for 3 to 6 months or longer (Wijma et al. 2016). Chronic pain can amount to large medical costs, reduced income and contribute to massive economic debt, having a negative impact on the individual's quality of life (Wijma et al. 2016). In contrast, constant pain serves as a very strong motivating force for humans to look into recovery and pain relief (Louw et al*.* 2016b) (Louw et al*.* 2011).

Pain Neuroscience Education (PNE) is a popular form of physical therapy used in patients with chronic pain (Wijma et al*.* 2016). Pain Neuroscience Education (Schröder et al.) is a protocol established to help individuals to understand the biology and physiology underpinning their pain experience. Pain Neuroscience Education enables a thorough explanation of the neurophysiology of pain and the biopsychosocial interactive in an interactive manner (Wijma et al. 2016). This suggests that the possibility that a suitable cognitive and behavioral outcome will occur, resulting in improved clinical outcomes (Pas et al. 2018). According to Louw et al. (2011), several studies have focused their approach and strategies at providing pain relief through the form of education, however, the educational concept of PNE differs from orthodox biomedical education by using strategies which do not focus on anatomical or biomechanical explanations for pain (Theory one), but rather also the neurophysiology and the representation of the meaning behind the pain itself (Cox et al. 2017) (Theory two). Blickenstaff, Pearson and Practice (2016), demonstrated that PNE could positively affect a person's pain ratings, disability and movement limitations. It was found to allow patients to re-evaluate their pain, target their beliefs and formulate more appropriate coping skills to ultimately alter their cognitive perceptions, to lead to a favorable outcome at the end of treatment (Robins et al. 2016).

However, PNE administered in isolation is limited in achieving optimal outcomes (Louw et al. 2013; Porter, 2017; Pas et al. 2018); Moseley and Butler, 2015; Robins et al. 2016; Cox et al. 2017). Similarly, chiropractic care can result in a change to the sensorimotor integration (Taylor, Holt and Murphy, 2010), however, chiropractic care can only attain specific biomechanical and biomedical outcomes and can, on occasion, fail to obtain optimal clinical and performance outcomes. Literature on clinical reviews evaluating interventions for pain have reported that the more recent practice guidelines find consistent recommendations for the necessity of integrated treatments together with PNE (Puentedura, Flynn and Practice, 2016).

Since the application of PNE is vast, it can be utilised in many different injuries and by numerous health professionals, including; physiotherapists; chiropractors; biokineticists and athletic trainers, which makes its influence on patients viable (Robins et al. 2016). Therefore, research is required to broaden future management and treatment options, not only in low back pain cases (where the majority of research resides) (Louw et al. 2013), but also in extremity related conditions such as lower extremity pain, which is not only specific to older adults with chronic back pain (Rufa et al. 2019; Moseley, 2004; Moseley and Butler, 2015; Lluch et al. 2018b). The recreational marathon runner is an optimum population in which to test this combination of chiropractic care and PNE versus chiropractic care, in order to define which treatment protocol is more effective in the context of an extremity condition (in this case knee pain).

2.5 INTRINSIC RISK FACTORS

2.5.1 Age and body mass index

Running injuries are common, affecting up to 50% of long distance runners per year, however, according to Fields, 2011 the participation trend in road racing has changed considerably. In particular, the average age of runners in road races is approximately 40 years of age, including 46% of marathon runners. Therefore, in accordance with this, injuries are more common among master and/or veteran runners. The literature suggested that potential causes of greater muscle injury in the elderly were due to age-related changes in the muscle, such as decreased strength and increased stiffness and rigidity (Fields, 2011; Millar, 2019). In addition to this, a second possible belief is that a normal muscle injury that is experienced during training may take longer to repair with ageing, since older runners continue running at similar training programmes to that of younger runners (Fields 2011).

Trappe, 2007 stated that marathon running performance among both men and women was generally fastest, as indicated by world record performances, when individuals were 25 to 35 years of age. Generally, peak endurance performance differs slightly and is maintained until the age of 30 to 35, followed by a mild decrease from the age of 50 to 60 years and then progressively steeper and more severe in decline after the age of 75 years and older (Beat et al. 2011). However, additionally, it was also noted that the time taken to complete a marathon gradually increases with age, with significant reduction in performance after the age of 70 years. In contrast to the decline with performance, research supports the premise that continued running late into life decreases the decline in physiological function with age and is beneficial for overall health and wellbeing (Trappe, 2007). In recent years, the marathon running performance among master runners - older than 50 years, has shown an improvement with respect to performance and time. Having been noted, it has also been argued that master runners of 50 years and older improved their times at a greater rate when compared to that of younger runners (Jokl, Sethi and Cooper, 2004; Beat et al. 2011).

Body mass index (BMI) can be described as a calculation which assess relative body mass in relation to height, it is significantly correlated with total body fat content. The BMI should be used to assess overweight and obesity and to monitor changes in the body weight. It can be calculated as weight ($\frac{weight\ (kg)}{height\ (m2)}$) (BMI, 1998).

According to (Van Gent et al*.* 2007) male runners with a height of 1.7m or greater have been shown to be at higher risk of sustaining new injuries. This, however, may be due to larger forces acting on the bones, muscles and connective tissue (Millar, 2019). Malliaropoulos, Mertyri and Tsaklis (2015) conducted a study with body mass and BMI in which there was no association found between BMI and the risk of sustaining an injury.

2.5.2 Gender

Due to the popularity of running increasing as a recreational activity for its beneficial health effects, runners have placed themselves at an additional risk of developing running related injuries (RRI) (Buist et al. 2010a).

However, in terms of gender, males and females have different risk injury profiles for the development of RRI (Buist *et al.* 2010a; Millar, 2019). Female runners were found to be twice as likely to sustain a RRI in comparison to their male counterparts (Buist et al. 2010a). In both genders, the most common injury by far was to the knee joint (Fredericson and Misra, 2007). RRIs are multifactorial, however, women demonstrated different structural characteristics such as; increased hip width to femoral length ratio leading to increased hip adduction and internal rotation, therefore contributing to raised genu valgus alignment and abduction. These differences in structure predisposed female runners to different biomechanical patterns of movement, which could add to the developmental injury (Van Gent et al. 2007; Buist *et al.* 2010a; Millar 2019). Chumanov, Wall-Scheffler and Heiderscheit (2008) stated that increased non-sagittal motion of the pelvis and hip has been implicated in the difference in lower limb extremity injury rate between male and female runners. Women displayed the tendency to sustain injuries such as patellofemoral pain syndrome, iliotibial band (ITB) syndrome or injury to the gluteus medius muscle group (Chumanov, Wall-Scheffler and Heiderscheit, 2008).

Whereas in male runners, the presence of a deviant Q-angle predisposed them to the development of injury in the lower limb (Ellapen et al. 2013). Ellapen et al. 2013 study noted that the Q-angle is an indicator of muscle symmetry with the quadricep femoris muscle. Therefore — a larger Q-angle increases the compressive forces applied to the knee joint, which, in turn, contribute to possible injury.

Van Gent et al*.* (2007) reported that female runners were more likely to experience injuries in the hip joint, compared to that of male runners who were more likely to suffer from calf and hamstring injuries. Hollander et al*.* (2021) reported that female runners were more likely to sustain bone stress injuries, whereas male runners were more prone to Achilles tendon injuries. The response differs due to the hormonal difference between women and men, in which estrogen was associated with collagen synthesis and could therefore alter the tendon healing capacity for example — i.e. Achilles tendinopathy (Hollander et al*.* 2021).

Bone stress injuries are common running-related overuse injuries, as a result of cumulative microtrauma to the bone, in which younger females seem to have a higher risk for bone stress compared to male runners (Hollander et al. 2021).

Ellapen et al. (2013) and Chumanov et al. (2008) both found that muscle activity during locomotion, with the gluteus Medius and vastus lateralis muscle groups, could have caused a difference in injury profiles between male and female runners. Ellapen et al. (2013) observed gender specific changes in morphology of the pelvis and thigh of females. Females displayed greater hip internal rotation which could possibly contribute to gender-related differences in injuries sustained respectively. Furthermore, females who had tight hip flexors created an anterior pelvic tilt changing the length tension relationship between posterior muscle groups — posterior rotators/extensors and anterior hip rotators/flexors. This induced a decrease in normal flexion of the hip joint and increased the likelihood of the runner to be prone to sustaining a lower back and hip injury, in the form of a musculoskeletal injury (Ellapen et al. 2013; Millar, 2019).

2.5.3 Ethnicity

Literature shows that endurance running events, with respect to half, full and ultra-marathon distances, have become a social phenomenon, with a variety of ethnic groups participating in the sport (Aschmann et al. 2013; Millar, 2019). Aschmann et al. (2013) described African athletes in the last decades dominated marathon running, where top positions were all held by Kenyan and Ethiopian runners.

Endurance running globally is dominated by African athletes, with a few runners from South Africa also performing well, from 800m to the iconic marathon distance (Harley et al. 2009).

The superiority in marathon running was not based on unique factors, but rather a combination of factors that the East African athletes acquired. Several authors have analysed many possible reasons as to why their overwhelming dominance has been clear such as; social factors, nutritional difference between Kenyan and Ethiopian diets, genetic predisposition, higher maximal oxygen uptake and running economy as a result of intensive running during their childhood, living at high altitude and difference in oxidative enzyme profiles (Aschmann et al. 2013). When comparing black Kenyan runners to white runners from Africa, consistent findings that may be associated with their superior performance and ability to resist fatigue was their lower plasma lactate concentrations at sub-maximal running intensities compared to their white counterpart runners (Harley et al. 2009; Millar, 2019). However, from literature on South African black and white runners, no consistent findings on either physiology or biomechanical levels has been able to explain the difference in lower plasma lactate concentration (Harley et al. 2009).

In addition, a possible reason was that approximately 50% of the Kenyan and 39% of the Ethiopian population live below the poverty line (Aschmann *et al.* 2013). Therefore, both nationalities compete at events mostly for economic reasons (33%), tradition (18%), talent (18%) and glory (14%). The financial incentives resulted in more athletes from East Africa travel abroad. A typical/perfect example, is the 1986 Boston City marathon, the introduction of prize money caused an influx of Kenyan participation because of their possibilities of earning enough money to support their families (Aschmann et al. 2013).

2.6 EXTRINSIC RISK FACTORS

2.6.1 Running with a load

Running while carrying a load is common in humans and runners, however, carrying a load may also influence running biomechanics and leg stiffness (Silder, Besier and Delp, 2015). In relation to increased leg stiffness it has been associated with an increased risk of bone-related injuries (Lussiana, Hébert-Losier and Mourot, 2015; Silder, Besier and Delp, 2015; Millar, 2019). Additionally, it was found that running with a load coupled together with high-intensity shock forces place a greater strain on the lower limbs, hence leading to muscle fatigue and higher risk of possible injury occurrence (Abe et al. 2011).

2.6.2 Terrain

Literature shows that running off-road i.e., stones, gravel, grass and/or uneven terrain requires a higher energy demand, compared to running on road. Running on such terrain may also cause changes to the characteristics of the normal stride (Creagh, Reilly and Lees, 1998). With the difference in terrain, runners adjust their limb stiffness to be able to maintain continuous support mechanics while running, placing the runner at greater risk for injury. (Müller, Grimmer and Blickhan, 2010). Tessutti et al. (2010) states that the type of running surfaces have an influence on load absorption mechanics by runners, however, independent of the surface compliance, runners are capable of adapting to a change in surface at first by their foot strike with the new surface after the initial change of the surface. The findings from running on different surfaces shows many running coaches orientate their athletes to use a natural grass surface instead of artificial surfaces, due to the biomechanical compensatory mechanism which lowers the risk of developing musculoskeletal injuries (Tessutti et al. 2010; Millar, 2019).

2.6.3 Choice of footwear

The choice of correct footwear for road running, especially for longer distance running (marathon running), is essential and can be either a contributing or preventative factor with the development of an injury (Fuller et al. 2015; Millar, 2019). Lack of footwear (barefoot), poor choice and/or incorrect footwear has been found to be a significant contributing factor to injuries sustained while running (Fuller et al. 2015; Millar, 2019).

More research and development has been focused on designing the ideal running shoes for improved marathon performance, changes in various properties have resulted in improved running efficiency and economy (De Andrés-sánchez, De Torres-Burgos and Arias-oliva; Hunter et al. 2019).

The main reason why significant research and development has gone into such detail with running shoe modification is because running economy is inversely related to metabolic costing. This means that as running economy is improved — metabolic costs are reduced, allowing for an improvement in running performance and running time. Alteration and changes in the running shoe itself, over the years, have included changes in shoe mass, energy return, properties in the foam cushioning material and shoe bending stiffness (Hunter et al. 2019). Due to the continual advancements in technology and material the quest to development the ideal running shoe is likely to be a never-ending pursuit. For example, a classic is Nike the brand who released the Nike Vaporfly 4%, which they believed would be capable of improving running economy by providing minimal weight with excellent energy return, with the use and inclusion of a carbon fibre plate in the sole of the shoe (Hunter et al. 2019).

2.7 TRAINING ERRORS AND FACTORS ASSOCIATED WITH ROAD RUNNING

2.7.1 Training plan

Runners change the frequency, intensity and volume of their training in a variety of ways to optimize their marathon times and performance (Doherty et al. 2020). However, (Nielsen et al. 2012) reported that 60% to 70% of most running related injuries are as a result of training errors, such as a change in training routine or excessive mileage. Saragiotto et al. (2014) suggested that the number of days run per week, how long each run is, and the distance of each session may affect the risk of developing a possible injury. In addition, common training errors such as the following were found — sudden increase in training distance (overall), running a number of races in quick succession, sudden excessive speed or hill training days and running too many hard/taxing days without spreading adequate lighter/easier days allowing for rest and recovery (Noble, 1996). According to Saragiotto et al. (2014), a weekly distance was a risk factor for running injuries, runners who ran a distance of more than 64km per week might be more at risk of sustaining a running-related injury. With number of training days in the week, it was found that those runners who trained a minimum of five sessions per week were more susceptible to sustain an injury compared to that of those who trained a minimum of three days in the week (Nielsen et al. 2012).

Running-related injuries caused by training errors are commonly related to overuse, which is an overload of the musculoskeletal system. An overuse injury is defined as one caused by repetitive microtrauma without a single, identifiable event responsible for the injury (Saragiotto et al. 2014). It is important to note that with injury, runners can adopt different biomechanical patterns when injured, most likely in an attempt to establish motor protection of the injured structure during running. The change of pattern, can lead to overloading of the musculoskeletal system that were previously intact before the injury — causing a secondary injury (Saragiotto et al. 2014).

2.7.2 Nutrition

Nutrition in runners plays an essential role in maintaining performance and preventing fatigue during marathon running (Kluitenberg et al. 2015). The balance between nutrition, diet and correct fueling is very important. Nutritional demands of training and racing are congruent with the distance being raced (Tiller et al. 2019).

Fluid intake and the balance of essential electrolytes during training is very pivotal in the prevention of dehydration and ensuring successful completion of marathon racing distances (Williamson, 2016; Millar, 2019).

Muscle glycogen serves as a key fuel for training and racing during a marathon, whereas carbohydrates “carbo-loading” can enhance marathon performance by allowing the competitor to run at their optimal pace for a longer time period before fatiguing (Burke, 2007). Burke (2007) recommended that the runner who consumes adequate carbohydrates to promote replenishment of muscle glycogen between training sessions benefit largely.

In terms of an optimal diet for marathon runners (Schröder et al. 2008) found that their diet comprised of 55% to 60% of energy in the form of carbohydrates, 30% energy in the form of fat and 10% to 15% of energy in the form of protein. However, runners who used carbohydrate drinks compared to water showed enhanced levels of endurance during performance. This illustrated that the more carbohydrates consumed, the better the runners potential endurance performance would be (Williamson, 2016).

Due to the role of dietary protein in muscle protein turnover, there has been a lot of attention given to dietary protein in the prevention of muscle injuries. The literature concurs with the provision of dietary proteins enhances the adaptive processes to both resistance and endurance-based activities — therefore increasing protein in the diet may alleviate markers of muscle damage, however, other studies also are suggestive that often no benefit is observed with no measurable reduction in muscle damage on exercise induced injuries to the muscle (Close et al. 2019). According to Close *et al.* (2019) it is crucial to understand the change in possible energy demands and make sure that sufficient protein is consumed for repair — especially since the muscle could become anabolic resistant.

Although injuries are going to be encountered in recreational marathon runners, there are several nutrition solutions that can be implemented in a bid to reduce the risk of injury and decrease recovery time. Many of these solutions involve maintaining that runners do not have chronic low energy availability and cycling energy intake throughout the season to maintain race weight (Close et al. 2019). Therefore, nutrition as a possible factor contributing towards running-related injuries, due to an increase in bodily fuel consumption during exercise, is associated with marathon running (Close et al. 2019; Millar, 2019).

2.7.3 Health care providers role

The factors discussed above have been intensively researched in road running, which has led to the development of injury profiles — related to marathon road running on the road (Kluitenberg et al. 2015; Millar, 2019). The role of the healthcare provider is extremely important when identifying and managing current injuries, prevention and reducing the possible reoccurrence in future injuries (Van Niekerk, 2016). For the best possible outcome, healthcare workers should have a sound understanding of the intrinsic and extrinsic risk factors — how they can be changed by the behavior of the runners and practitioners, as well as medical conditions of the runners and medication (McBean, 2015; Van Niekerk, 2016). As the number of marathon events and participation has generally seen a rise, trends suggests that the incidence of emergency situations would be expected to increase proportionately (Smith, Schuemann and Hoogenboom, 2013). Based on the rise in popularity, it was estimated by Smith, Schuemann and Hoogenboom (2013), that approximately 6 to 8 runners from the United States die each year while competing in marathon event distance, due to cardiac disease, physical and/or environmental factors.

Since casualties associated with marathon running has been investigated, sport medicine teams providing care and coverage at marathon events could include a physician, registered nurse, emergency medical responder, massage therapist and a chiropractor (Smith, Schuemann and Hoogenboom, 2013). According to Konczak and Ames (2005), surveillance studies conducted on marathon runners allowed professionals to establish injury profiles and associated risk factors and treatment protocols for improved treatment options and management of running related injuries. With this development, it is substantially important to ensure inter-referrals between healthcare providers, such as doctors, surgeons, physiotherapists, biokineticists and chiropractors (Konczak and Ames, 2005; Smith, Schuemann and Hoogenboom, 2013). However, there is a paucity and difference in the existing literature on recreational marathon runners, compared to elite and pro athletes.

2.8 CONCLUSION

The relevant literature review pertaining to the topic was briefly described in this chapter. The literature presented in this chapter outlined the incidence and prevalence of RRI as well as PNE. Intrinsic and extrinsic risk factors were discussed in order to determine the most significant factors associated with sustaining an injury while road running. Training errors and environmental factors were included in the discussion as these may also influence the risk of acquiring an injury while road running. The following chapter will describe the methodology used in this study.

CHAPTER THREE: METHODOLOGY

3.1 INTRODUCTION

This chapter will present and discuss the research methods and data collection tools used in this study.

3.2 STUDY DESIGN

The study used a quantitative randomised controlled single-blinded design (Evans and medicine, 2010), in which the participants were blinded. Participants were randomly assigned and received either Pain Neuroscience Education (Schröder et al.) and chiropractic care or chiropractic care only (Maguire, Chesterton and Ryan, 2019). Randomisation was done with the use of an opaque envelope procedure, which an independent party drew from in order to assign participants into the respective groups (Altman and Bland, 1999). The study design followed a phase II randomised clinical trial (Evans and medicine, 2010).

3.3 TARGET POPULATION

The study population was defined as recreational marathon runners in the eThekwini region. Recreational marathon runners were individuals who participated in marathon events — 42.195km, who may or may not have been affiliated to a registered running club and who received no income for their participation. They were grouped into a social category (Barandun et al. 2012; Vickers, Vertosick and Rehabilitation, 2016), and according to Bredeweg et al. (2012) were generally inactive before they began running and therefore their musculoskeletal systems were not conditioned to the repetitive high impact forces of elite and professional runners. Most recreational marathon runners had no definitive criteria or definition, however, tend to be socially inclined and less structured with reference to training programmes and blocks (Janssen et al. 2020).

3.4 STUDY LOCATION

A number of recreational marathon runners resided in the eThekwini district. The region was well-known nationally and internationally by runners and was home to the largest ultra-marathon event in the World — deemed the Ultimate Human Race — The Comrades Marathon (Knechtle and Nikolaidis, 2017).

3.5 PARTICIPANT RECRUITMENT

Recruitment of participants began only after full IREC approval was granted (Appendix G). All participants were screened against the inclusion and exclusion criteria for participation in the study. Participants were made aware of the research study (Appendix G), by means of advertising at races, race expos, running clubs, newsletters and stores which were done through an online and hard copy platform (flyers Appendix G) (Messier et al. 2008; Rasmussen et al. 2013). This allowed participation to be entirely voluntary and there was no cohesion of participants.

3.6 SAMPLING

3.6.1 Sample Size

The participants were randomly assigned into one of the two groups (Group 1: PNE and chiropractic care, Group 2: chiropractic care only). A power analysis for a chi-squared test was conducted in G-POWER to determine a sufficient sample size. An alpha of 0.05, power of 0.80, a medium effect size (w = 0.8) and 4 degrees of freedom was used. Both Group 1 and Group 2 will have a sample size of 23 each, with a total sample size of 46 participants.

3.6.2 Sample Characteristics

3.6.2.1 Inclusion Criteria

- Signed informed consent.
- Participants aged 18 to 65 years (Knechtle and Nikolaidis, 2018; Larsen et al. 2020).

- Participants who are male or female with symptomatic chronic knee pain (greater than 3 months duration).
- Participants with a weekly training volume between 30 and 80km/week (Rasmussen et al. 2013).
- Participants who had completed 2 or more marathon events within the past 2 years (virtual and non-virtual).
- Participants with a score greater than 40 on the central sensitisation inventory scale (CSI) (Mayer et al. 2012).

3.6.2.2 Exclusion Criteria

- Professional and elite marathon runners (Rüst et al. 2011).
- Participants who have had previous total knee replacement or any other lower limb surgery within the past six months of the affected knee, co-existing inflammatory, metabolic or neurologic disease (Messier et al. 2008; Lluch et al. 2018b).
- Participants who have contraindications to chiropractic care and PNE.
- Participants who have previously received chiropractic care and/or PNE can require a 3 month wash out period before they can be eligible to enter the study.
- Participation in other pain trials prior (3 months) to recruitment.
- Lack of the ability to adhere to the protocol, cognitive impairment, illiteracy or unable to speak English (Lluch et al. 2018b).

3.6.2.3 Sample Strategy

Convenience sampling was used to recruit participants from the population. All participants had to adhere to the inclusion and none of the exclusion criteria. The central sensitisation inventory (CSI) scale was used to screen participants (Mayer et al. 2012). A CSI score > 40 made the participants eligible for enrolment.

3.6.2.4 Blinding and Randomisation

The study used a randomised controlled single-blinded design to estimate the effectiveness of a combination of PNE and chiropractic care versus chiropractic care alone, in the reduction of pain, function and the increase in ra-ge of motion for the treatment of recreational marathon runners, with chronic running related knee joint injuries (Plint et al. 2006). Randomisation was performed using the alternating envelope system. Participants entering the Durban University of Technology Chiropractic Day Clinic drew from an envelope randomly assigning the participant to either Group 1 or 2. The envelopes contained identical information, except the designation into the intervention or control group (Louw et al. 2017). This was carried out by an independent individual, who was blinded to the content and nature of the study, to ascertain correct execution of the randomisation procedure (Van Ittersum et al. 2014).

3.7 MEASUREMENT TOOLS

1. Pain catastrophisation scale

   The pain catastrophisation scale (PCS) is a self-reported questionnaire that was used to assess inappropriate coping strategies and catastrophic thinking about pain and the injury to the knee joint. The PCS was completed twice i.e., at the initial consult and the final consult. The scale has been used in previous PNE studies and demonstrated strong construct validity, reliability and stability (Appendix G).

2. Numerical pain rating scale

   The numerical pain rating scale was used (NRS) (Farrar et al. 2001) and could be graphically or verbally delivered. Participants were required to fill in the pain rating scale at the initial, the second and the final consult (Williamson and Hoggart, 2005). All three measurements were used to obtain a baseline, intermediate and final assessment reading.

3. The lower extremity functional scale (LEFS)

   Participants were required to fill in the questionnaire to obtain a baseline reading and to assess initial function, ongoing progress and outcomes — functional impairment and effectiveness of the intervention (Binkley et al. 1999; Willy et al. 2019). The LEFS was easy to administer and score with respect to a large range of disabilities and conditions to the lower-limb extremity sites (knee) (Binkley et al. 1999). According to Watson et al. (2005), the LEFS was found to be reliable, valid and responsive for use in patients with lower limb extremity dysfunction. The scale had content which does not include extraneous questions on symptoms such as giving way, locking or effusion, making it easy to administer and score (Watson et al. 2005; Mehta et al. 2016) (Appendix F).

3.7.1 Educational tools for PNE intervention

1. A video was aired in the first consultation, only for the Group 1 (Intervention) which received the PNE. The video, *Understanding Pain and What to Do about it in Less Than Five Minutes*, was designed in order to assist grasping the vital concepts through visual stimulus (Hunter, 2014). The video was aired via laptop during the consultation.

2. A number of images and diagrams was used:
   - The somatosensory cortex picture (Louw et al. 2017)
   - The metaphorical alarm system depiction of central sensitisation before and after a painful experience image and content was used and the noisy neighbour metaphor (Louw et al. 2017).

3.7.2 Validity and Reliability

According to (Heale and Twycross, 2015) validity was defined as the extent to which a concept or outcome was accurately measured. Another measure of quality in a quantitative study was the reliability or the accuracy of the measurement tools utilised, this process was focused on reducing error in the measurement process. The concept deals with how measurement tools consistently had the same results if used under the same situation repeatedly (Kimberlin and Winterstein, 2008). The measurement tools used in this study have been used in various other valid and reliable studies (Wang et al. 1993; Farrar et al. 2001; Willy et al. 2019).

3.8 RESEARCH PROCEDURE

Recruitment of participants began only after full IREC approval was granted (Appendix D, Appendix E). Participants were recruited through email, telephonically and advertising at races, race expos, running clubs, newsletters and stores. Participants had appointments booked at the Durban University of Technology Chiropractic Day Clinic and Dr K Padayachy's (research supervisor) private practice by the Durban University of Technology Chiropractic Day Clinic reception staff and researcher, respectively. Follow-up consultations over the next 3 weeks were coordinated by the researcher, in which letters of information and informed consent were signed and made available on the initial consult.

For this randomised controlled single-blinded trial, in which the participants were blinded, patients with chronic knee pain, were recruited from the eThekwini Municipality region. Participants were randomly assigned in a 1:1 ratio to one of the two groups. Each participant received four consultations in total, one per week for four weeks (Lluch et al. 2018b). The consultations were estimated to last 40 to 50 minutes each (Larsen et al. 2020). Baseline assessments were performed before the intervention and at the final consultation in the fourth week, after the intervention, respectively, for each group.
Covid-19 protocols, in accordance to The Durban University of Technology Chiropractic Day Clinic, were followed at all. Participants received sanitizer to sanitise their hands and were required to use a mask at all times — since 1.5m distances cannot be maintained by the researcher with the intervention and control groups.

3.9 MAIN DATA COLLECTION PROCESS

3.9.1 Group 1 PNE and chiropractic care (Intervention Group)

On the first consult, the participants were introduced to the intervention via a brief introductory level (pace based), case history, short physical, measurements (baseline assessment) and special tests as well as chiropractic care — which included adjustments limited to the knee joint only. An educational tool *Understanding Pain and What to Do about it in Less Than Five Minutes* was aired to the participant. The first session was a longer session lasting 50 to 60 minutes, whereas the second, third and fourth follow-up sessions were 40 to 50 minutes long. On the second, third and fourth consult questions that arose was answered and further PNE in the form of metaphors and pictures was delivered with repeated chiropractic care. The fourth and final consultation consisted of recordings and measurements. Chiropractic care such as adjusting the knee joint was conducted. Adjusting was specific to the affected knee/s.

3.9.2 Group 2 Chiropractic care only (Control Group)

On the first consult the participants had a case history, short physical, measurements (baseline assessment), special tests and chiropractic care. The second, third and fourth consult were a repeat of the first consult excluding the case history. The fourth and final consultation consisted of recordings and measurements.

Participants in both groups received the same chiropractic care, with the only difference being the PNE intervention. Adjustments were limited to the knee joint only. No dry needling or other additional modalities were used. Group 1 (Intervention) received four sessions with the proposed intervention, since evidence was suggestive that one to two consultations per week was sufficient over four weeks (Nijs and Meeus 2015; Louw et al*.* 2016a).

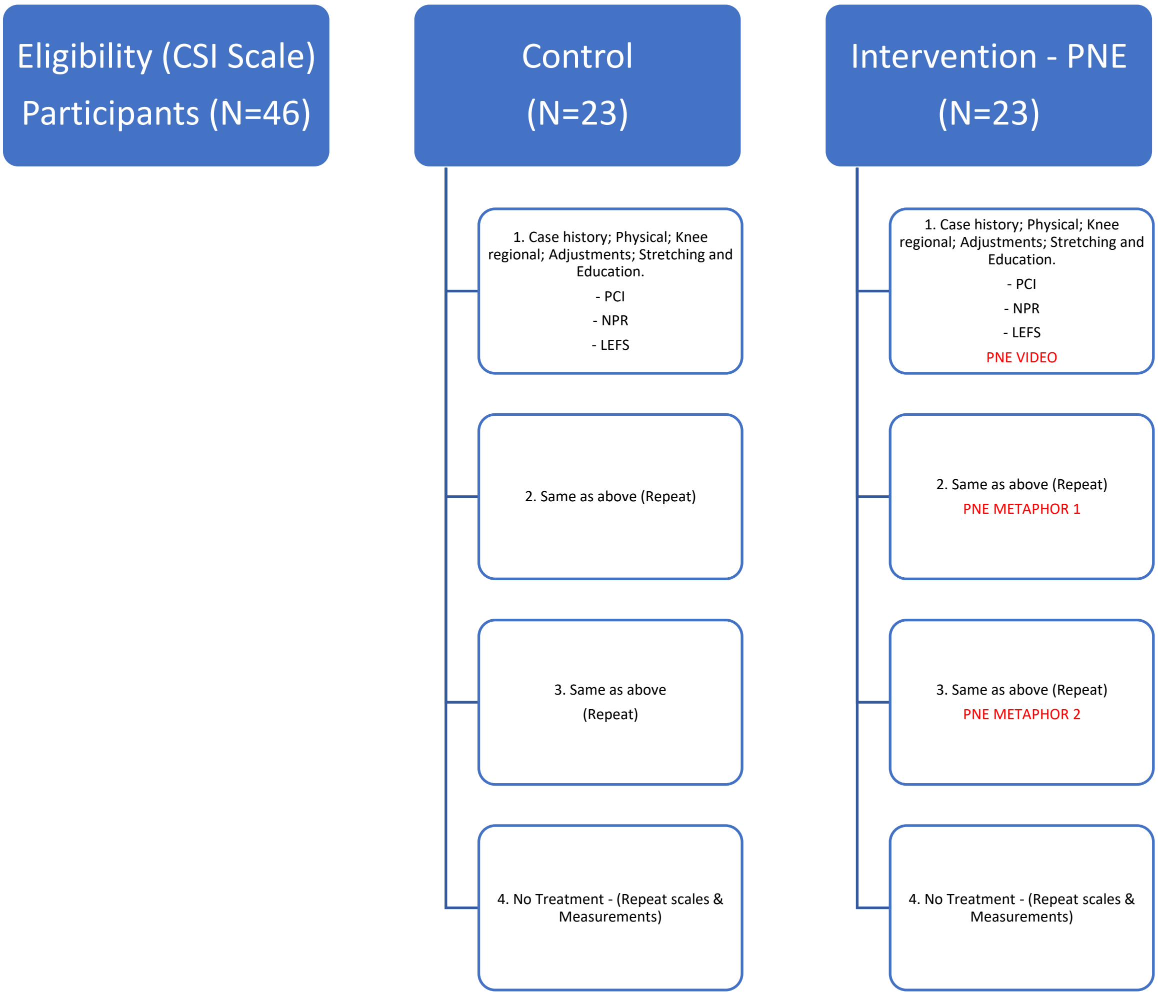


Fig. 3.1 Flow chart to research procedure.

3.10 DATA MANAGEMENT AND STATISTICAL ANALYSIS

Data was captured into an Microsoft Excel spreadsheet and imported into SPSS version 27 for analysis.

Outcomes were compared between treatment groups and within participants over time using a repeated measures ANOVA model. The time x group interaction effect will be the intervention effect. Profile plots will be used to show the direction and trend of the intervention and control groups over time. A p-value <0.05 will indicate statistical significance (Field, 2013).

3.11 ETHICAL CONSIDERATIONS

The trial was in accordance with the DUT ethical committee, ethical clearance number 120/21, and registered accordingly with a clinical trial PAC202209718136908. Any changes to the trial protocol were communicated to the ethics committee and the trial registry. All participants were given a letter of information about the trial and signed informed consent forms before participation (Larsen et al. 2020).

The ethical considerations that was applied to the study include:

- Permission was obtained from the Durban University of Technology Chiropractic Clinic in writing or email.

- Informed consent included a clear process for providing adequate information to and promoting the voluntary enrolment of subjects (Mills et al. 2004). All participants needed to read and sign the letter of consent.

- Participation in the study was completely voluntary and no remuneration was awarded for participation.

- All completed paperwork, case history, physical, regional and information was used and analysed by the researcher, research supervisor and co-supervisor only. Once the data and information had been analysed, it would be stored at the DUT Chiropractic Department for 5 years and destroyed thereafter, by means of a paper shredder and deleted files, respectively, for electronic information.

- The process and outcomes of this trial of subjects and selection was fair and based on scientific appropriateness, minimised vulnerability and risk, and maximised benefits (Miller, Silverman and medicine, 2004; Mills et al. 2004; Nardini, 2014).

- Participants were shown respect for all their rights and welfare of the participants, both during and at the conclusion of the trial (Mills et al. 2004).

- In this clinical trial, autonomy was maintained by allowing the participants withdrawal from the trial, even if the consent form was signed, at any time, without a given reason (Mills et al. 2004; Cummings and Mercurio, 2010)

- The concept of justice was to distribute the benefits equally amongst the study population and to treat all participants in the similar manner. In this clinical trial, all the participants were selected at random, with non-biased decisions regardings religion, gender or ethnicity (Mills et al. 2004; Cummings and Mercurio, 2010).

- Balances the benefits of the trial against the risks and cost. This was accounted for as the trial will provide results and further insights to manage and treat chronic knee injuries in recreational marathon runners (Nardini, 2014).

- The principle of non-maleficence was to translate into the duties to maximise benefits while minimising harm to the participants (Artal et al. 2017).

3.12 CONCLUSION

This chapter highlighted the type of research methodology used in this study. It also outlined the characteristics of the study population and the methods used to statistically analyse the data. Lastly, the chapter explained the ethical principles that were adhered to in this study. Chapter four will present the results of this study and chapter five will discuss the results.

CHAPTER FOUR: RESULTS

4.1 INTRODUCTION

This chapter presents and explains the results of the statistical analysis from the data collected, with particular emphasis on the statistically significant and relevant findings

4.2 AIMS AND OBJECTIVES

The aim of the study was to assess the effectiveness of PNE combined with chiropractic care versus sole chiropractic care for the reduction of pain due to chronic running-related knee pain in recreational marathon runners, within the eThekwini Municipality.

The first objective was to determine the effectiveness of PNE (Schröder et al.) for the treatment of recreational marathon runners with chronic running-related knee injuries using the pain catastrophising scale (PCS). The second objective was to estimate the effectiveness of PNE in the reduction of pain for the treatment of recreational marathon runners with chronic running-related knee complex and joint injuries, using the pain catastrophising, numerical pain rating and lower extremity functionality scales, respectively, (PCS, NPR, LEFS). Finally, the third objective was to determine self-reported changes in functionality of the knee joint of the treatment of recreational marathon runners with chronic running-related knee injuries using the lower extremity functional scale (LEFS).

4.3 DATA SOURCES

4.3.1 Primary data sources

The primary source of data was collected from the participants who met the inclusion and exclusion criteria for the clinical trial number (PACTR202209718136908).

4.3.2 Secondary data sources

The secondary source of data included: books, research dissertations, journal publications and articles, internet websites and directories, electronic and telephonic communication with the research supervisor (Dr K Padayachy), co-supervisor (Professor A Louw) and statistician (Professor T Esterhuizen). All the above-mentioned data sources can be found in the reference list.

4.4 RESULTS

4.4.1 Response rate

The data was collected from participants who satisfied the inclusion and exclusion criteria of the study. The sample size for the study was n=46 participants. The study obtained a total of 46 participants.

However, due to unforeseen circumstances such as riots, violent striking/protesting, Covid-19 and severe floods, three participants did not adhere to the treatment duration of four consecutive consultations, one per week for four weeks.

Therefore, 43 participants followed the treatment protocol, which gave the study a response rate of 93% (drop out rate of 7%). In conclusion of all 46 (N=46) participant’s data were included in the study.

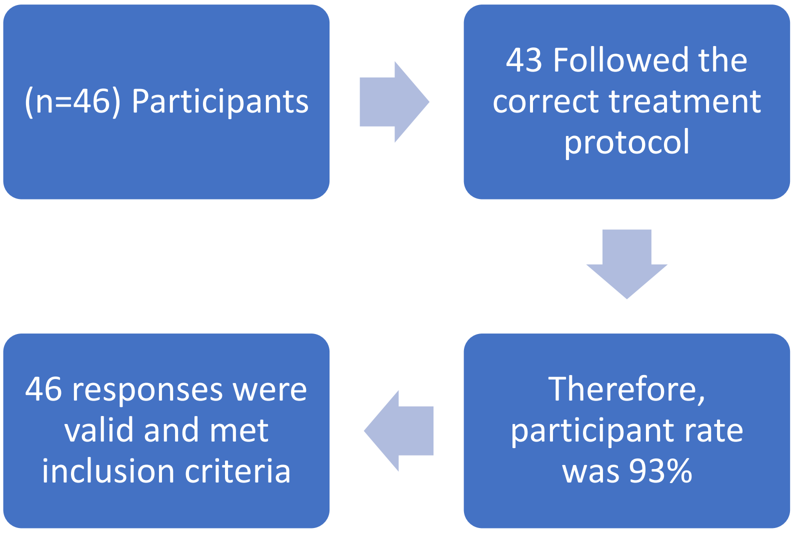


Fig. 4.1. Flow chart to sample size

4.4.2 Demographics of participants

The demographic factors of the participants were gender, ethnicity, height and age.

4.4.2.1 Gender and ethnicity

In this study, participants were included from various gender and ethnic groups. However, the majority (63.04%) of participants were male (p=0.07) (Table 4.1). Whereas (47.83%) were of white ethnicity followed by Indian (30.43%), Black (17.39%) and Coloured (4.35%) (Table 4.2)

Table 4.1, Descriptive analysis of Gender

GENDER	Freq.	Percent
Female	17	36.96
Male	29	63.04

The Gender description of the participants expressed as a percentage

Table 4.2, Descriptive analysis of Ethnicity

ETHNICITY	Freq.	Percent
Black	8	17.39
Coloured	2	4.35
Indian	14	30.43
White	22	47.83

Table analysis of the ethnicity of the participants expressed as a percentage

4.4.2.2 Height

The Shapiro-Wilk test was used to assess normality of continuous variables, such as height and body mass. Accordingly, height was found to be a normally distributed variable. Therefore, mean and standard deviation was calculated.

Table 4.3, Descriptive analysis of Height

Variable	Mean	Std. Err.	95% C.I
HEIGHT	2.97	0.053	(2.86, 3.07)

Height of the participants, mean, standard deviation expressed as percentages

4.4.2.3 Body mass and Age

The median, minimum and maximum value and Inter Quartile Range (IQR) was calculated for body mass and age variables. Median age of the participants was 32 years, while the minimum and maximum age were 18 and 65, respectively.

Table 4.4, Descriptive analysis of Body mass and Age

Variable	Median	Min	Max	IQR
BODY MASS	74	56	103	13
AGE	32	18	65	13

The mean, minimum, maximum and inter quartile ranges of body mass and age of participants

Table 4.5, Descriptive analysis of Gender by group:

Variable	Group	
Gender	Intervention	Control
Female	5 (21.74%)	12 (52.17%)
Male	18 (78.26%)	11(47.83%)

The proportion test showed gender has statistically significant difference between control and Inte/rvention groups with P-value 0.035. There was a higher male proportion in the intervention group.

Table 4.6 Description analysis of Ethnicity by group

Variable	Group	
Ethnicity	Intervention	Control
Black	4 (17.39%)	4 (17.39%)
Coloured	1 (4.35%)	1 (4.35%)
Indian	8 (34.78%)	6 (26.09%)
White	10 (43.48%)	12 (52.17%)

Description analysis of the ethnic groups included in the study by groups

Table 4.7, Median values of Weight by group

Variable	Group	
Body Mass	Intervention	Control
Min	63	56
median	74	74
max	101	103
IQR	12	16

Table Describing the body mass by group, body mass, minimum, medium, maximum and inter quartile range of participants

Table 4.8, median values of Age by group

Variable	**Group**	
AGE	Intervention	Control
Min	18	23
median	31	32
max	64	65
IQR	14	13

The Mann Whitney U test showed that body mass and age was the same between control and PNE group with P-value 0.6275 and 0.8402 respectively.

Table 4.9, Mean and S.D of Height by group

	Group	
Variable	Intervention	Control
Height		
Mean	2.99	2.99
S.D	0.07	0.08
C.I	(2.85, 3.13)	(2.78, 3.11)

T-test showed that mean of height was not statistically different between the control and Intervention group with P-value 0,6411. (Table 4.9).

4.5 STATISTICAL ANALYSIS

Participants were randomly assigned into the intervention or control group. Summary statistics of mean and standard deviation (SD) were performed for normally distributed variables. Normality of the variables was checked using the Shapiro-Wilk test. For those variables that are not normally distributed median, minimum value, maximum value and Inter quartile range was calculated for those variables that were not normally distributed.

To check the comparability of variables between groups, T-test was used to compare the mean between groups for normally distributed variables. The Mann-Whitney U test was used for abnormally distributed data. The proportion test was used to assess if there is difference in proportion between groups for Binary variables. A significance level of 0.05 was used.

A two-way repeated measure ANOVA model was used to assess the effectiveness of treatment for outcome variables (NRS, PCI, LEF) within participants over time. Profile plots were used to show the direction and trend of the intervention and control groups over time. A significance level of 0.05 was used.

4.6 RESULTS OF THE OBJECTIVES

4.6.1 Objective 1: To determine the effectiveness of PNE (initial and changes from initial to end) for the treatment of recreational marathon runners with chronic running related knee injuries using the Pain Catastrophising Scale (PCS).

Table 4.10, Summary statistics of pain catastrophizing scale by group.

GROUP		PCS1	PCS2
Intervention	mean	31.21739	20.86957
	S.D	12.39852	12.27453
	min	14	13
	max	62	71
Control	mean	31.34783	21
	S.D	8.870834	8.453079
	min	18	13
	max	52	51
Total	mean	31.28261	20.93478
	S.D	10.65971	10.42092
	min	14	13
	max	62	71

Table 4.10 showed that the average value of Pain Catastrophising scale (PCS) in both intervention and control groups are almost similar at baseline and end measurement time.

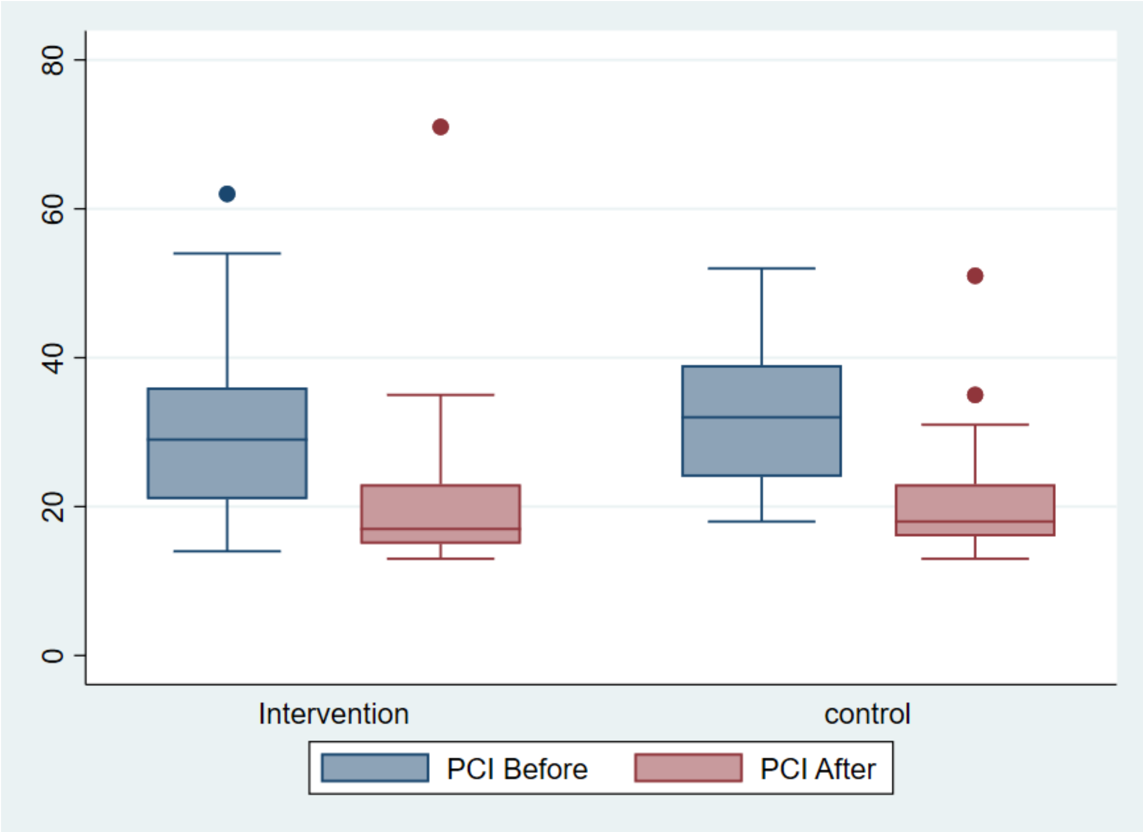


Fig. 4.2. Box and whisker diagram of PCI

The box plot highlights the mean value of both PCI before and PCI after are almost similar between intervention and control group. In contrast, the mean value of PCI before is higher compared to PCI after in both intervention and control groups.

4.6.1.1 Profile plot

Figure 4.3 shows that Pain Catastrophising Scale (PCS) was the same over time for both control and intervention group (Fig. 4.3).

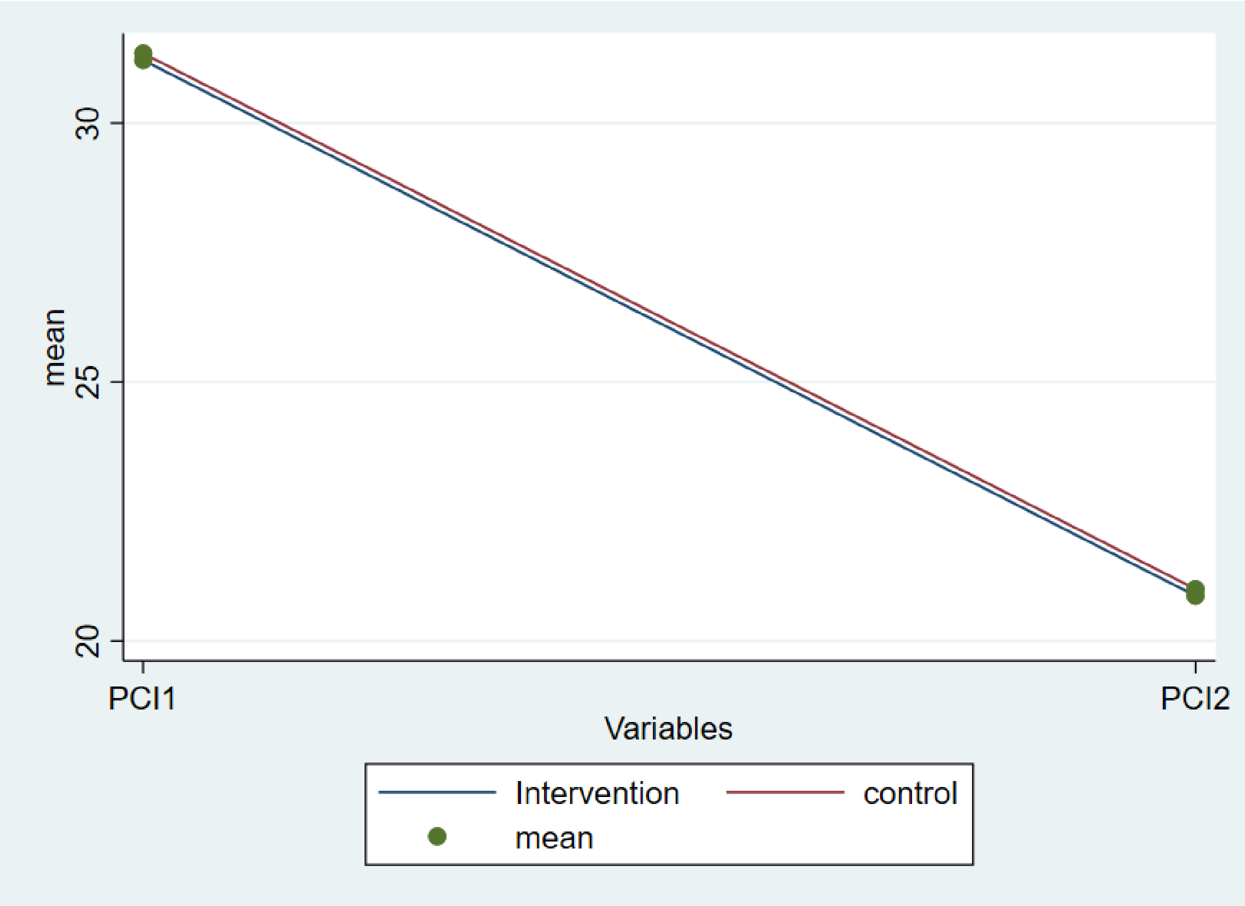


Fig. 4.3. Profile plot of PCS

Correlation Matrix PCS at two time points

A weak correlation is seen among PCS at two time points from the matrix analysis (Table 11).

Table 11, correlation matrix of PCI measurements over time

	PCS1	PCS2
PCS1	1.0000	
PCS2	0.2006	1.0000

A two-way repeated measures ANOVA was performed to evaluate the effect of PNE over time on PCS.

Table 4.12, Repeated measure ANOVA- Dependent variable PCS

Source	Partial SS	df	MS	F	Prob>F
Model	8465.6957	47	180.12118	1.98	0.0119
GROUP	.39130435	1	.39130435	0.00	0.9575
time	2462.7826	1	2462.7826	27.11	<0.0001
GROUP# time	1.035e-28	1	1.035e-28	0.00	1.0000

A two-way repeated measure ANOVA result revealed there was a non-significant statistically interaction between the effects of group (Intervention and Control) and time on PCS with F (1, 44) = 0, p-value = 1.00.

Main effects revealed that there is significant main effect of time on PCS with p-value <0.001. This implies that the mean score of PCS showed a statistically significant difference before and after treatment in both groups. Furthermore, the main effect of group did not have a statistically significant effect on PCS with (p = 0,95). This indicates that there was no difference between the treatment groups either before or after treatment.

4.6.2 Objective 2: To estimate the effectiveness of PNE, in the reduction of pain for the treatment of recreational marathon runners with chronic running related knee complex and joint injuries using Numerical pain rating scale (NRS).

Table 4.13, Summary statistics of Numerical pain rating scale (NRS) by GROUP

GROUP		NRS1	NRS2	NRS3	NRS4
Intervention	mean	5.782609	4.608696	3.391304	2.130435
	SD	1.756974	1.751341	1.559112	1.686965
	Min	2	1	0	0
	Max	9	8	7	6
Control	mean	6.869565	5.913043	4.956522	3.391304
	SD	1.099766	1.378835	1.397344	1.698639
	Min	5	4	2	0
	Max	9	8	8	6
Total		6.326087	5.26087	4.173913	2.76087
		1.549973	1.692267	1.664056	1.791148
		2	1	0	0
		9	8	8	6

The NRS score decreased over time in both groups (Control and Intervention) (Table 13).

4.6.2.1 Profile plot

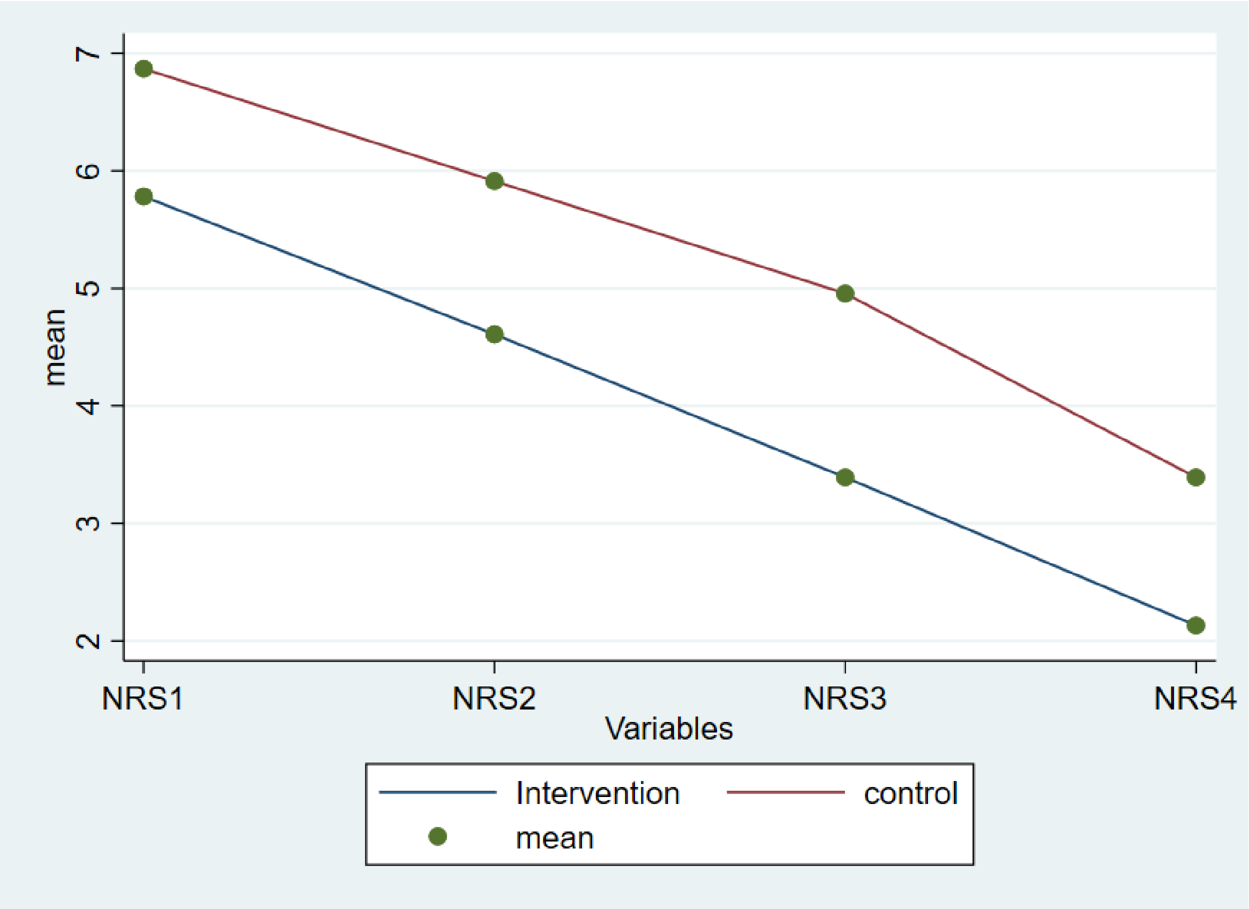


Fig. 4.4. Profile plot of NRS

Figure 4.4 and 4.5 shows that in both groups (Control and Intervention), the mean score of NRS decreased over time. However, the control group showed a higher mean score of NRS over time as compared to the intervention group.

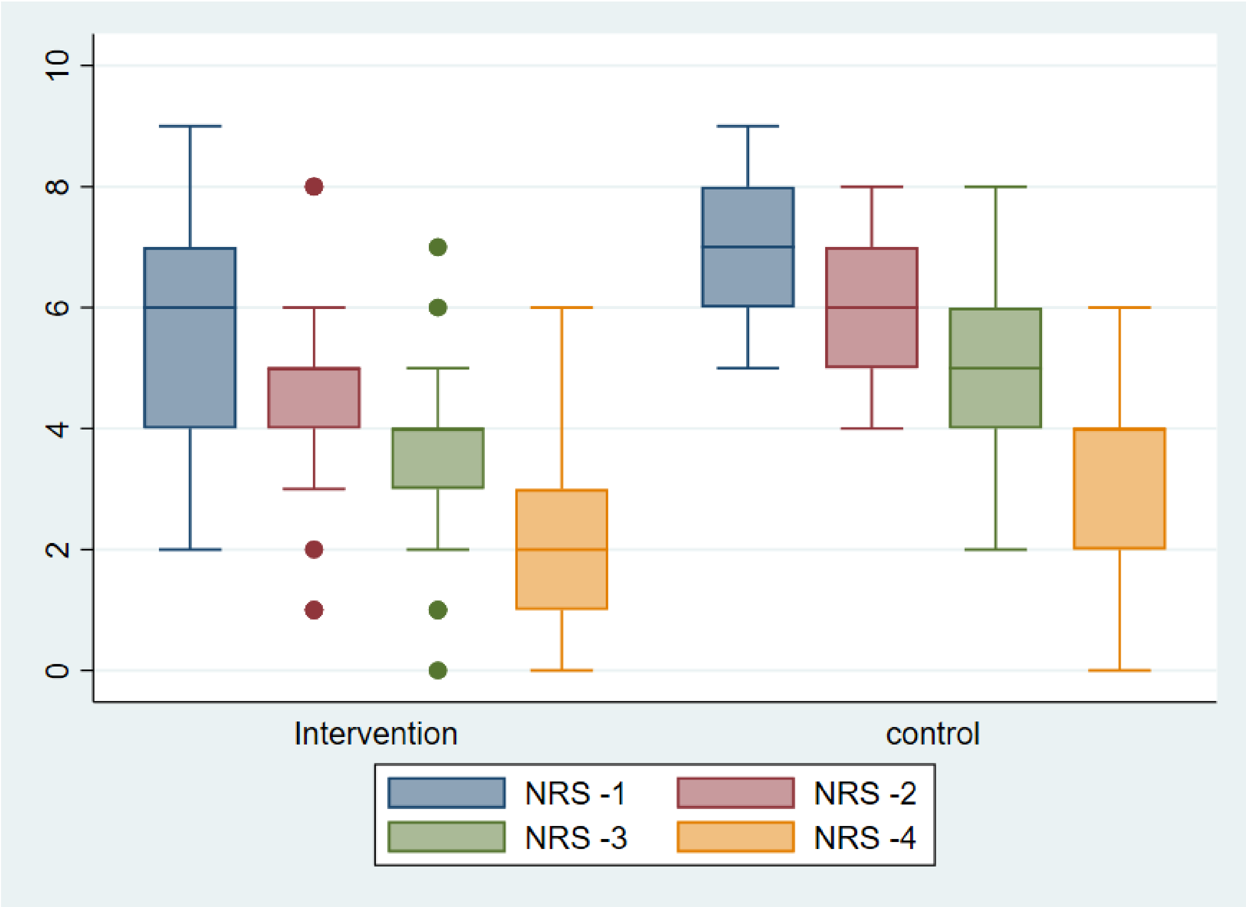


Fig. 4.5. Box and whisker diagram of NRS

The mean of NRS at time 1 is higher in both control and intervention group. While the mean of NRS at time 1 in control group is higher compared to in intervention group.

Correlation matrix of NRS at different time points

Table 4.14, correlation matrix of NRS measurements over time

	NRS1	NRS2	NRS3	NRS4
NRS1	1.0000			
NRS2	0.6870	1.0000		
NRS3	0.6065	0.8042	1.0000	
NRS4	0.4690	0.6002	0.6778	1.0000

To evaluate the effect of PNE over time on NRS, a two-way repeated measure ANOVA was performed. Table 14 highlights a medium to high correlation among measurements at different time points

Table 4.15, Repeated measure ANOVA- Dependent variable NRS

Source	Partial SS	df	MS	F	Prob>F
Model	691.13043	51	13.551577	13.18	0.0000
GROUP	78.26087	1	78.26087	11.85	0.0013
time	320.91304	3	106.97101	104.02	0.0000
GROUP#time	1.3478261	3	.44927536	0.44	0.7270

A two-way repeated measure ANOVA revealed that there was no statistically significant interaction effect between group and time on NRS score with F (3, 44) = 0,44 and p-value = 0,72. This meant that the change over time was not dependent on treatment group.

Main effect of group did have a statistically significant effect on numerical pain rating scale with (p = 0,0013). This meant that the treatment groups showed a significant difference at all time points. Similarly, there is significant main effect of time on NRS with F(3, 44)=104,02 and p-value <0.001. This indicated that the NRS scores changed over time in both treatment groups.

The effectiveness of PNE in reduction of pain is different between the intervention group and control group. Similarly, it differs over time, but the time change is not dependent on treatment.

4.6.3 Objective 3: To determine self-reported changes in functionality of the knee joint of the treatment of recreational marathon runners with chronic running-related knee injuries using the Lower Extremity Functional Scale (LEFS).

Table 4.16, Summary statistics of lower extremity functional scale (LEFS) by GROUPS

GROUP		LEFS Before	LEFS After
Intervention	Mean	54.17391	69
	S.D	18.02	15.29
	Min	8	13
	Max	75	80
Control	Mean	56.91	69
	S.D	12.78	11.38
	Min	25	23
	Max	74	80
Total	Mean	55.54	69
	S.D	15.59	13.40
	Min	8	13
	Max	75	80

4.6.3.1 Profile plot

Figure 4.6 profile plot highlights that the LEFS score increases over time (Fig4.1).

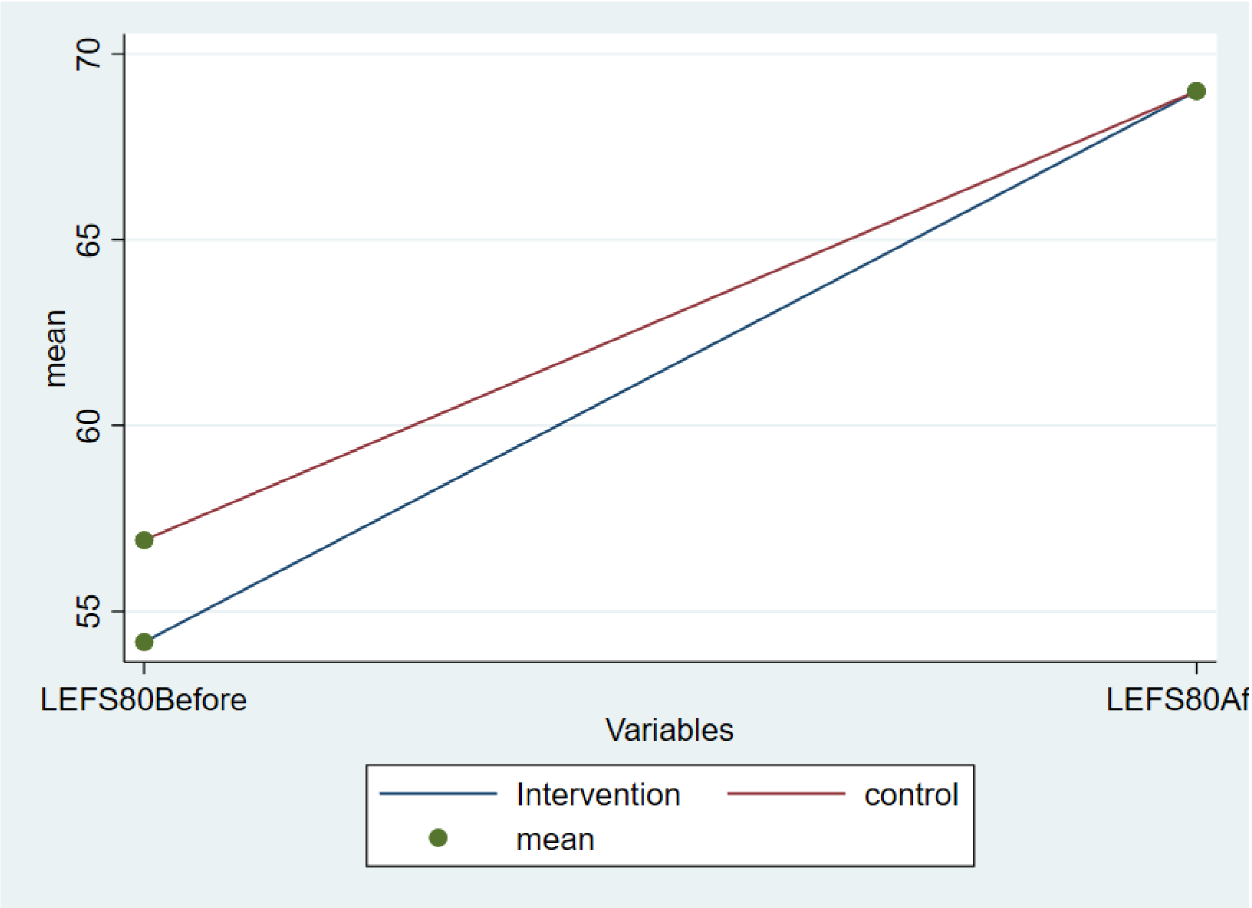


Fig. 4.6. Profile plot of LEFS

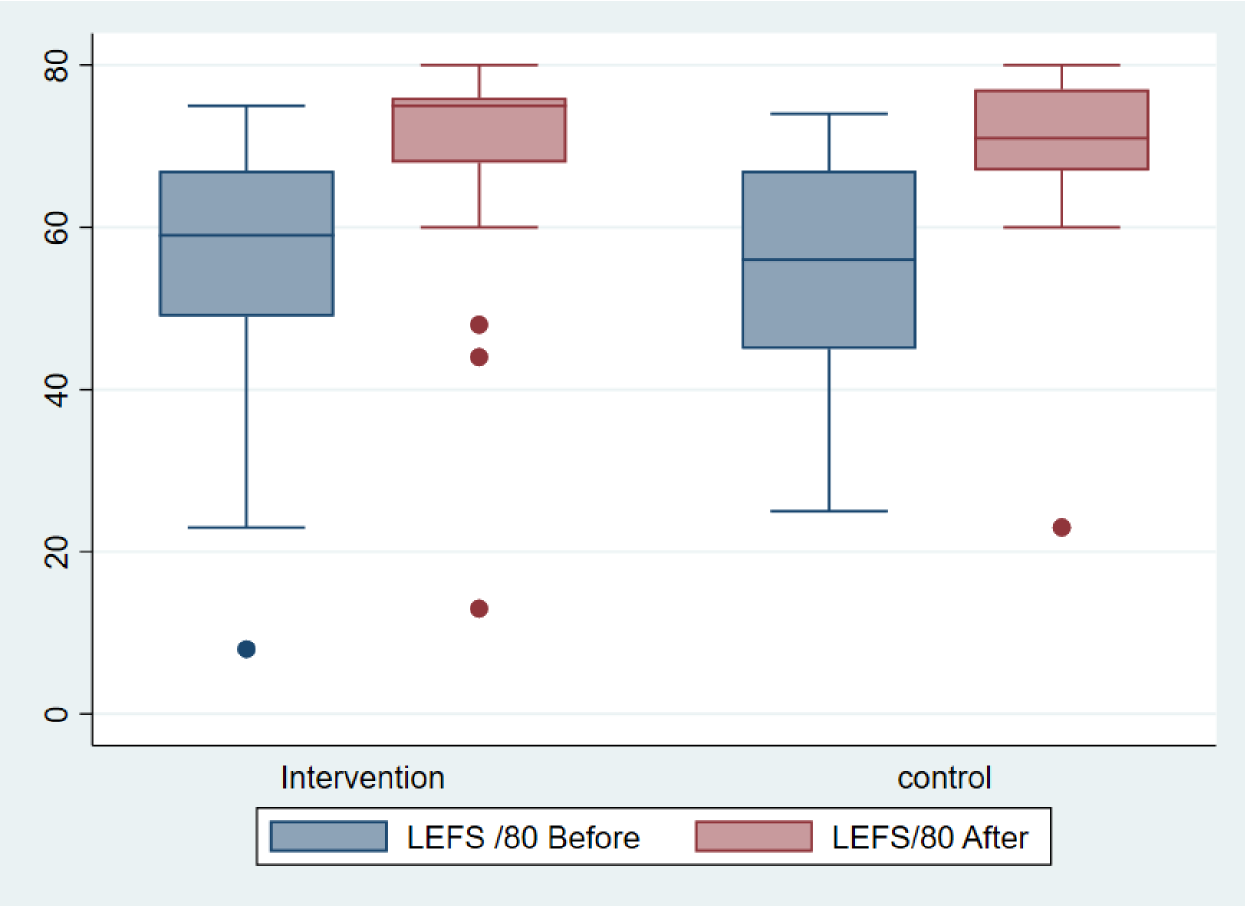


Fig. 4.7. Box and whisker diagram of LEFS

The box plot showed that the mean of LEFS after is higher in both control and intervention group compared to LEFS before group. While LEFS before shows a slight increase in intervention group compared to control group.

A two-way repeated measure ANOVA revealed that there was no statistically significant interaction effect between intervention group and time on P = 0,54. This meant that the change over time was not dependent on treatment group.

The main effects showed that treatment group did not have a statistically significant effect on LEFS with (p = 0.715). This implies that the mean of LEFS score is not significantly different between the control and intervention group.

In contrast, there was a significant main effect of time on LEFS with F(1, 44)=36,16 and P-value <0,001. Which implies that the mean of LEFS score differ significantly with time (before and after intervention) in both groups, as tabulated in Table 4.14.

Table 4.17, Repeated measure ANOVA-LEFS

Source	Partial SS	df	MS	F	Prob>F
Model	18336.641	47	390.1413	3.39	0.0000
GROUP	43.141304	1	43.141304	0.13	0.7153
time	4164.7935	1	4164.7935	36.16	0.0000
GROUP#time	43.141304	1	43.141304	0.37	0.5437

4.6.3.2 Profile plot

Gender vs Scores plot

1. The graph below shows that PCI score decreased over time for both male and female. However, males score of PCI was higher compared to females score.

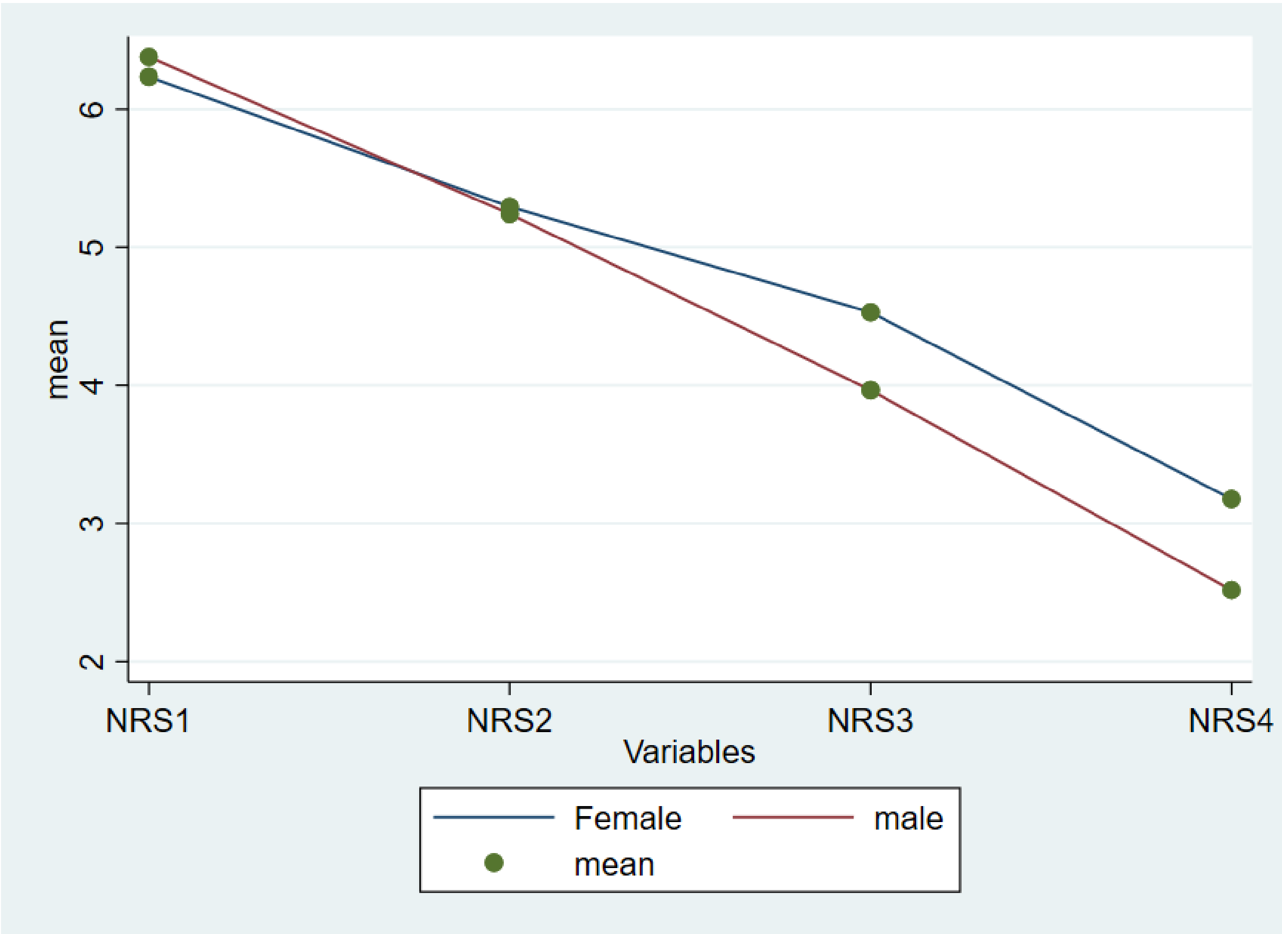


Fig. 4.8. Profile Plot of NRS and Gender

2. The graph revealed that the overall NRS score was decreased over time for both male and female participants. Measurement time 1 and 2 revealed that both males and females had similar NRS score. However, a comparison between measurement time 2 and time 4, females showed higher NRS score compared to males.

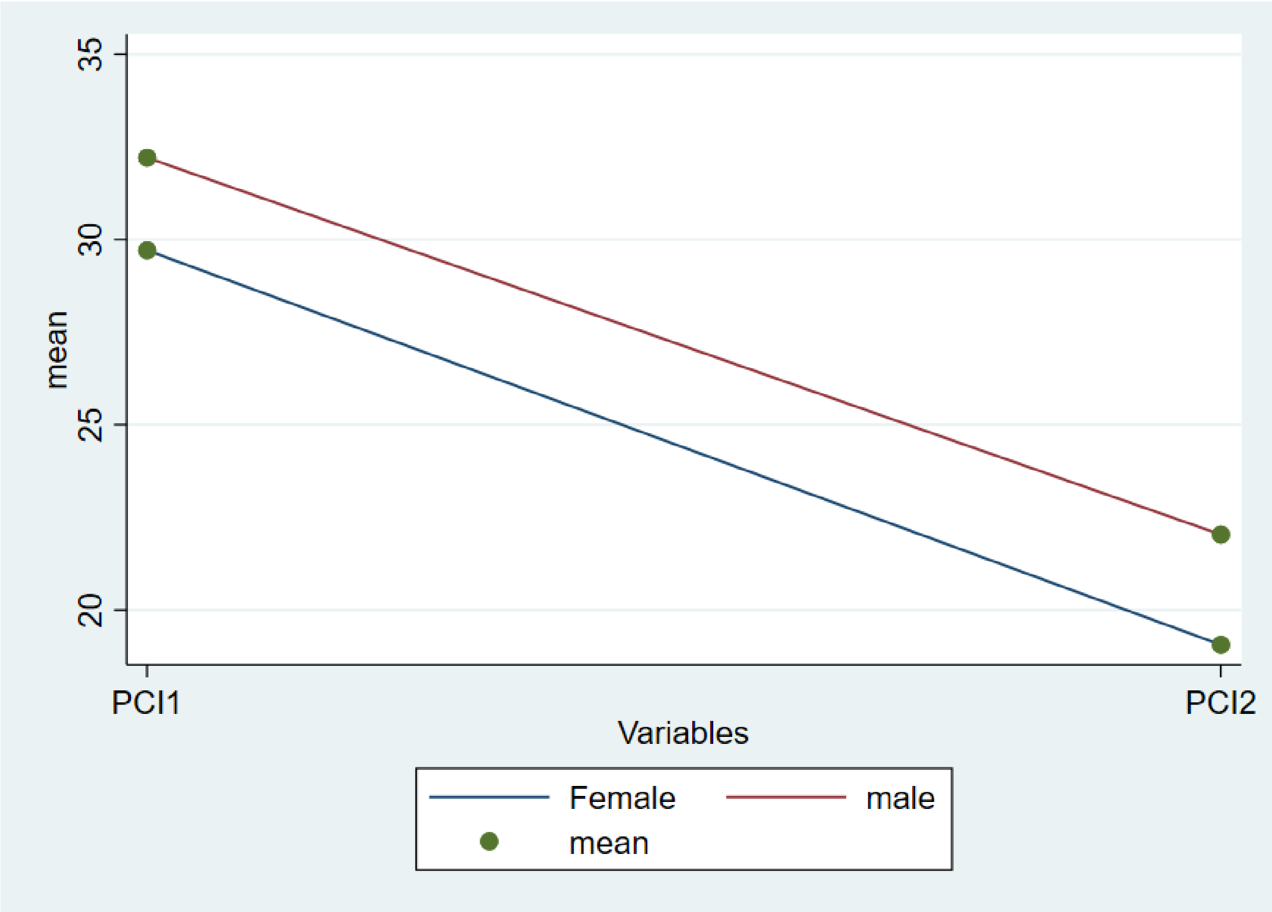


Fig. 4.9. Profile Plot PCS and Gender

3. The third plot below shows that the overall mean LEFS increases over time for male and female participants. However, females LEFS was shown to be higher than males scores.

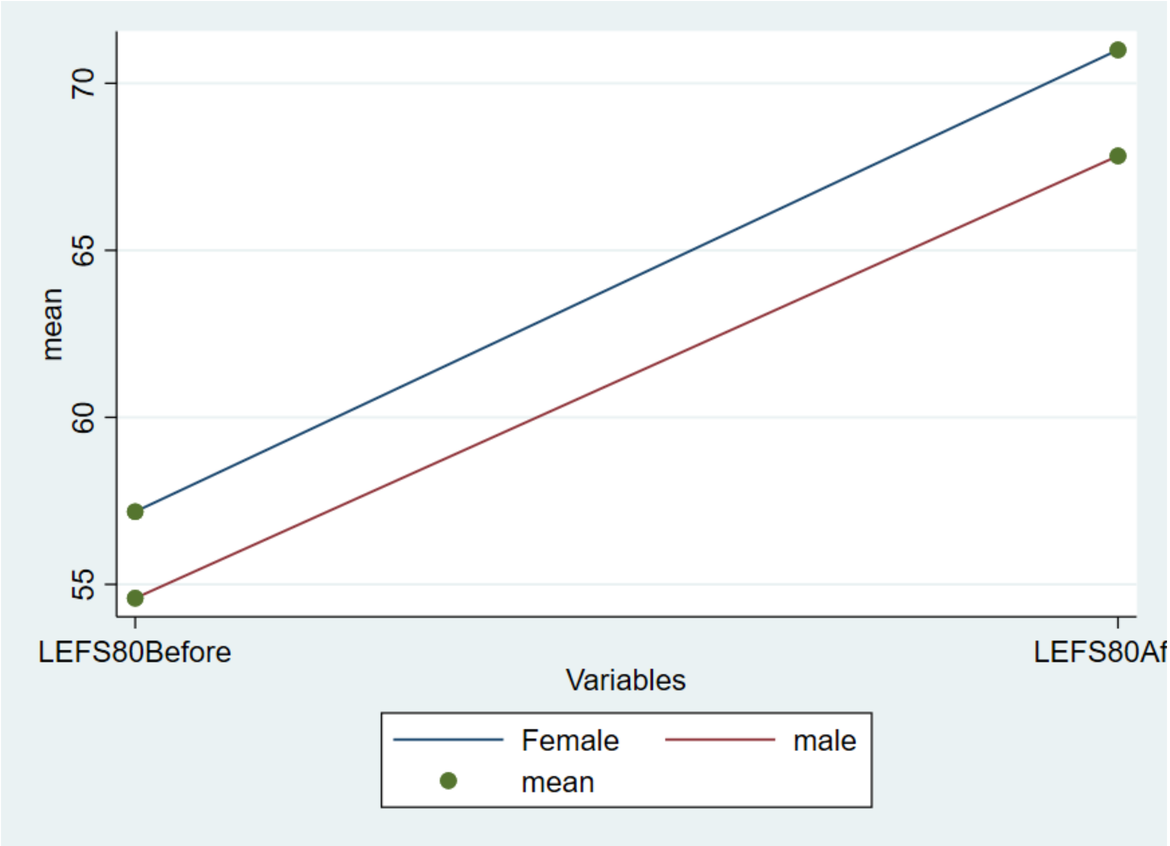


Fig. 4.10. Profile plot LEFS and Gender

4.7 CONCLUSION

This study investigated the effectiveness of PNE combined with chiropractic care versus chiropractic care alone for the reduction of pain due to chronic running-related knee pain in recreational marathon runners within the eThekwini Municipality.

The results showed that there was no significant difference between the intervention and the control group, with respect to PCS, and the LEFS recordings. However, both the Intervention and the control group under analysis showed a decrease in their NRS readings, where the control group showed a higher mean score (decrease) over time compared to the PNE (intervention group).

The discussion of these results will be presented in chapter five.

CHAPTER FIVE: DISCUSSION

5.1 INTRODUCTION

This chapter will focus on discussing the results found in this study in correlation to the objectives and comparing them with similar literature. These include determining the effectiveness of pain neuroscience education, determining self-reported changes in functionality of the knee joint and estimating the effectiveness of PNE in the reduction of pain of the treatment of recreational marathon runners with chronic running-related knee joint injuries. This chapter will further unpack the results in conjunction with the literature in chapter two.

The study revealed that PNE in combination with chiropractic manipulation (Intervention group) of the knee joint did not produce any significant superior effect in the reduction of running related knee injuries, compared to chiropractic manipulation without PNE (Control group).

However, the study revealed that there was a slight degree and difference in the PCS, LEFS and NRS measurements. Consequently, this finding concurs with previous literature (Louw et al. (2016); Foster (2021), whereby PNE combined with physical therapy produced a reduction in pain as opposed to PNE alone.

5.2 SAMPLE SIZE AND RESPONSE RATE

The sample size needed for the study was 46 recreational marathon runners (Esterhuizen, 2020). Response rates are calculated by dividing the number of eligible participants by the total number of eligible in the sample size. In total 46 participants were used, 23 each in the control and intervention group, giving the study a 100% participation rate.

The sample size for this study was in keeping and comparable with previous research. Mills et al. (2021) looked at the management of patients who had chronic plantar fasciitis with pain neuroscience education using a sample size of 20 participants. Zimney et al. (2019) compared which pain neuroscience educational metaphor worked best between 27 participants. Ram et al. (2022) compared exercise physiologists use of pain neuroscience education for treating knee osteoarthritis using a sample size of 25 participants. Lluch et al. (2018) investigated PNE combined with knee joint mobilisation for knee osteoarthritis: a randomised controlled trial and utilised a sample size of 22 participants per group.

Previous studies were conducted on a specific group and gender, focusing on varying aspects of running, spinal injuries, pre and post-surgical intervention, paediatric cases, and ACL related injuries. This study utilised a very similar sample size, as well as having no bias towards gender and ethnicity, providing a larger profile relating to running-related knee injuries sustained by recreational marathon running population.

The response rate for the current study was affected catastrophically by the Covid-19 pandemic. The data collection process commenced during the pandemic.

This study attained a sufficient response rate for it to be statistically acceptable when compared to the target areas and the total number of recreational road runners in the eThekwini Municipality of KwaZulu-Natal (Esterhuizen, 2020).

5.3 DEMOGRAPHICS

5.3.1 Age and Body Mass Index

The median age of the participants was 32 years of age, while the minimum and maximum age was 18 and 65, respectively **(**Table 4.4).

Recreational marathon runners, who had sustained running-related knee injuries were all found to have had one/more injurie/s per year due to long distance running and were well into their early thirties. This is in contrast with the findings of (Fields, 2011), who stated that 50% of long distance runners risk of injuries increases, in particular with road running marathons, at the mean average age of 40 years. The contrast could be due to the inclusion criteria and exclusion criteria being restricted to the age of 65 years, the minimum requirement of completing only two or more marathons, compared to running more marathons and being more prone to injury.

(Malliaropoulos, Mertyri and Tsaklis (2015) and Millar (2019) distinguished that there was no relationship between BMI and the possibility of sustaining an injury on trail/uneven surfaces. However, road running surfaces have a larger impact compared to trail and its variation of impact upon specific surfaces, i.e., gravel, cobblestones and sand. Buist *et al.* (2010) noted that larger BMI among road runners was seen as a risk factor to injury development, due to several influences such as; excess weight, loading of the joint, ligaments and tendons on the contact surface.

In accordance with these findings, it was determined that the mean body mass of the participants was 74kg, minimum 56kg and maximum 103kg, respectively (Table 4), which could possibly account for the BMI of the participants contributing to possible injury occurrence since the vast majority of the participants had higher than recommended BMI ranges.

5.3.2 Gender

The bulk of the participants in the study were male (63.04%), whereas (36.96%) participants were female (Table 4.1). This sample was considerably different from previous studies conducted with recreational marathon runners who had running-related knee pain (Lluch et al. 2018b; Zimney et al. 2019). However, distribution of injuries amongst both genders were congruent with other studies done by (Buist et al. 2010b), whereby males and females had different risk injury profiles, where female runners were found to be twice as likely to sustain running-related injuries compared to their male counterparts. The proportion test showed gender to be statistically significant difference between control and intervention groups with P-value 0.035. With a higher male proportion in the intervention group (78.26%) compared to (21.74%) of females.

(Figure 4.3) revealed that PCI score decreased over time for both male and female participants. However, male PCI scores were higher compared to female scores. (Figure 4.3) showed that the overall NRS score had decreased over time for both males and females. Measurement time one and two revealed that both males and females had similar NRS score. However, a comparison between measurement time two and time four, illustrated that females showed higher NRS score compared to males.

The development and utilisation of PNE is well established in the Western World. However, in the last two decades it has been reported that variation in gender issues need to be considered when developing educational tools for any population (Mukhtar et al. 2021).

5.3.3 Ethnicity

Various ethnic groups participated in the study; however, the predominant sample size had a high prevalence of Caucasian participants (47.83%) with 30.43% being Indian, 17.39% being African and 4.35% being Coloured (Table 4.2). This aligns with Aschmann et al. (2013), which found that endurance running events have become ever so popular, with an array of ethnic groups participating in the sport. In contrast to the ethnic distribution, the Caucasian group was dominant in this study, possibly due to demographic trends and distribution in the eThekwini region. Mukhtar et al. (2021) found that PNE was very well developed and suited to Caucasians. Therefore, there was an urgent need to research and develop culturally sensitive PNE material for other population groups globally, in order to increase accessibility to PNE interventions for patents suffering with chronic pain. Cultural and ethnic sensitivity is defined by two dimensions: surface and deep structures. These structures include matching intervention materials, content and messages to observable superficial characteristics of the target population, which may use people, locations, languages and even clothing and environmental factors (Mukhtar et al. 2021). Whereas deep structure encompasses the integration of cultural, social, environmental and psychosocial factors which change the target health behaviour in the target population (Mukhtar et al. 2021). Existing PNE material mainly developed in Australia, Europe and America have pictures, examples and metaphors that may not be appropriate for indigenous African languages. Since the translation nor the culturally sensitive versions of PNE are available (Mukhtar et al. 2021).

5.3.4 Pain Neuroscience Education

According to Wijma et al. (2016), pain that persists for three to six months or longer can be described as chronic. In the study, recreational marathon runners all reported incidence of chronic pain, caused by running-related knee injuries. In line with the study done by (Afzal et al. 2019) chronic pain and its treatment is a tremendously complex experience.

The findings from the study showed that male patients in the intervention group showed an overall greater decrease in pain, when compared to their female counterparts in the same group. This is possibly due to (Afzal et al. 2019), where PNE was utilised to help increase the patients' understanding of pain, affecting their NRS score (slightly higher), since their knowledge and understanding of chronic pain had increased. Additionally, (Afzal et al. 2019) noted that PNE has led to a contradiction of increased knowledge not, by definition, corresponding to improvements seen with pain. Figure 4 shows that not all participants scored a marginal NRS value and, despite experiencing pain and residual knee joint pain, their increased knowledge about the pain experience through their introduction of PNE may reduce the need for additional care i.e., testing and patient education (Afzal et al. 2019).

Figure 4 illustrates the pattern and decreasing trend seen with the NRS scores from both the intervention and control group. In which the intervention group displays a lower mean NRS score. These findings concur with previously conducted research by Louw et al. (2011), Puentedura and Louw (2012) and Afzal et al. (2019), since their findings showed compelling evidence of reduction in pain and improvement in physical movement.

According to Afzal et al. (2019), high-level randomised controlled trials as well as systematic reviews of PNE reported on various studies that utilise movement/manual approach with PNE. Clinical trials have shown that PNE alone can benefit a patient (Afzal et al. 2019), however, when combined with exercise or manual therapy, coinciding with this study, it is far superior in pain reduction compared to education alone.

5.3.5 Objective 1: To determine the effectiveness of PNE (initial and changes from initial to end) for the treatment of recreational marathon runners with chronic running related knee injuries using the Pain Catastrophizing Scale (PCS)

Louw et al. (2016) stated that there are many different outcome measurement tools used across studies. Pain is complex with very intensive documented issues such as central sensitisation, neuroplasticity and changes in mechanisms i.e., the knee joint complex. Using the NRS alone as a measure of improvement and effectiveness seems illogical. Therefore, the use of the PCS in the study was well-warranted, as it was related to outcomes, such as psychosocial factors.

PCS (Table 4.10) revealed that the average values in both intervention and control groups are almost similar at baseline and end measurement. According to Galán-Martín et al*.* (2016) and Malfliet et al. (2018) the minimal difference in the PCS measurements could possibly be as a result of a higher CSI score, which was gathered initially.

5.3.6 Objective 2: To estimate the effectiveness of PNE in the reduction of pain for the treatment of recreational marathon runners with chronic running related knee complex and joint injuries using Numerical pain rating scale (NRS)

The NRS was used to measure pain and the effectiveness of PNE i.e., NRS: 0=no pain and 10=highest pain to assess pain intensity and the effectiveness of PNE.

Figure 4.1 showed that in the intervention and control group, the mean score of NRS decreased over time. However, the control group showed a higher final mean score of NRS (3.94) over time, as compared to the intervention group (2.13), where the pain was not significantly reduced by the same degree.

According to Louw et al*.* (2016), it was found that combined PNE with physical intervention (manipulation) was able to produce a significant reduction in pain. Although the findings from this study does not concur with this statement by Louw et al. (2016) a reduction in pain is still seen, which was in keeping with the definition of PNE and the argument that PNE “biologises” pain, educating the participant about the biology and physiology of a painful injury.

5.3.6 Objective 3: To determine self-reported changes in functionality of the knee joint of the treatment of recreational marathon runners with chronic running related knee injuries using the Lower Extremity Functional Scale (LEFS)

The LEFS is a patient-rated outcome measurement tool, a score of 0-80 is achievable, whereby 80 is the maximum score indicating high function in comparison to 0, whereby this is the minimum score, indicating low functionality of the lower limb. The study utilised the LEFS to assess the participants function impairments of the lower limb, more specific to the knee joint complex (Foster, 2021).

The study revealed that intervention group did not have a statistically significant effect on LEFS with ($p = 0.715$). This implies that the mean of LEFS score is not significantly different between control and intervention groups.

In contrast, there was a significant main effect of time on LEFS with $F (1.44) =36.16$ and P-value <0.001. Which implies that the mean of LEFS score differs significantly with time (before and after intervention) in both groups as tabulated (Table 4.14).
The study supports other literature and studies done by Louw et al. (2011), Puentedura and Louw (2012) and Louw et al. (2016), in which PNE combined with physical therapy causes an increase in range of motion and reduction in pain relative to the joint and injury. Based on the findings, whereby the time had a significant effect on the LEFS measurements, the findings are in accordance with, and applicably and evidently support the use of PNE to decrease pain and better the function of the knee joint complex (Foster, 2021).

5.4 CONCLUSION

In this chapter, the results were discussed and compared to relevant literature pertaining to the study. The most significant finding in the study was that both intervention and control groups showed a reduction in knee pain. A more in-depth analysis revealed that the intervention group had a more significant effect on pain. Furthermore, that gender influenced the degree of pain reduction amongst the intervention group, whereby female participants reported a higher pain experience. Evidence supports the use of PNE, especially in chronic pain, and has the potential to provide favourable outcomes when combined with appropriate manual therapy and strategies. The conclusion, limitations, and recommendations of this study will be discussed in the following chapter.

CHAPTER SIX: LIMITATIONS, RECOMMENDATIONS AND CONCLUSION

6.1 INTRODUCTION

This chapter will discuss the limitations found in this study, as well as recommendations for future research and, finally, conclude this study.

6.2 LIMITATIONS

Participants over the age of 65 years were excluded from the study and, therefore, a larger number of participants with chronic running-related knee injuries were not included, which could possibly provide more insight between the relationship and effectiveness of PNE with chronic running-related knee injuries by recreational marathon runners.

The study negated both elite and professional marathon runners, whereas inclusion of elite and professional marathon runners would provide additional data that could be analysed comparatively.

Several limitations for this study were encountered. The fact that the PNE had to be delivered in a pace-specific 4-week format, which was limited to 40 to 50 minutes a session to minimise disruption and standardise the intervention group. The time format to deliver the PNE may have been too short a time for participants in the intervention group. In addition, a small sample size meant that some of the outcomes were underpowered.

The Covid-19 pandemic presented as a heavy limitation through a time period of 2 years, prohibiting all marathon running and hindering usual training programmes through lockdown levels respectively. The majority of the running community did not participate in any road running marathon races or training, which altered the diversities of injuries which recreational marathon runners could have sustained.

In addition, the city of Durban experienced severe looting, rioting and unease for several weeks. Thereafter, flooding in the city and greater surrounding districts forced the city into a state of emergency due to damage to infrastructure, loss of lives and destruction of people's homes and livelihoods, which shifted their focus away from marathon running and racing.

Collectively, the above-mentioned limitations caused a cascade effect, where participants were not able to participate in the study, attend follow up appointments or meet the inclusion and exclusion criteria successfully.

6.3 RECOMMENDATIONS

Future research and clinical trials should consider and focus more on other regions of KwaZulu-Natal and provinces in South Africa. This would be highly beneficial as there is a paucity with pain neuroscience education regarding chronic marathon running-related knee injuries.

Future studies should also aim to increase the sample size to n=100, potential longitudinal studies and the duration of the delivered intervention, to make further comparisons with the intervention and its effectiveness with regards to chronic running-related knee injuries with marathon runners. i.e., pain measurements, range of motion of the knee and function. Other future studies need to focus more to a homogenous age stratum of (30-39 years), possibly conduct a study exclusively on male or females as gender does play a role and additionally increase the number of PNE and chiropractic sessions to 10 in order to determine its efficacy rates.

Identifying the correct management protocol with PNE will be highly beneficial to both marathon runners and healthcare providers. Finally, PNE material should be researched and developed for the intervention group, specifically for the target population.

6.4 CONCLUSION

This study used the aims and objectives as a guideline to explain, interpret and discuss the findings. This study investigated the effectiveness of PNE combined with chiropractic care versus chiropractic care alone for the reduction of pain due to chronic running-related knee pain in recreational marathon runners within the eThekwini Municipality.

The findings of this study showed that there was no real significant difference between the intervention and control group, with respect to PCS, as well as the LEFS recordings. However, both the intervention and control group under analysis showed a decrease in their NRS readings, where the control showed a higher mean score (decrease) over the time compared to the intervention group (Schröder et al.).

Furthermore, while analysing gender with the measurement tools, it was found that PCI score decreased over time for both genders. Given the sizeable shift in spinal surgery studies (Louw et al. 2015) it was surprising that PCS did not change by a greater margin. Moreover, other PNE studies have shown high levels of PCS may in fact be strong indicators of the success of a PNE intervention as an approach (Louw et al. 2015; Lluch et al. 2018a; Zimney et al. 2019). However, the males' scores of PCI was higher compared to the females score.

Overall mean LEFS score increased over time by gender. However, females' LEFS score was higher than the males' score. NRS scores decreased over time for both genders. Starting from measurement time 1 till measurement time 2, males and females had similar NRS scores. However, from measurement time 2 over measurement time 4 females showed higher NRS scores compared to males.

The fact that chronic running-related knee pain did not change significantly coincides with the complexity of pain with previous PNE studies and, given the anatomical changes associated with running-related knee injuries, it was not surprising that running activities and range of motion did not change significantly either (Louw et al. 2014; Zimney et al. 2019).

Appendix A

LETTER OF INFORMATION

Title of the Research Study:
The effectiveness of pain neuroscience education and chiropractic care in the treatment of recreational marathon runners with chronic running related knee injuries.

Principal Investigator/s/researcher:
Tyren Naidoo, Btech chiropractic

Co-Investigator/s/supervisor/s:
Dr Keseri Padayachy, Mtech chiropractic, PhD anatomy
Dr Adriaan Louw, PT, PhD

Brief Introduction and Purpose of the Study: Running and marathon running has surged in popularity over the recent years. While regular low-impact exercise is thought to improve an individual's health, endurance exercise, such as marathon running, may be linked to associated running related injuries (RRI). Evidence, however, is suggestive that many runners presenting with physical signs — such as swelling, achy, stiffness, sharp pain, laterally, anteriorly, posteriorly and even deep inside the knee — have recovered from their injury yet will continue to experience pain, which emphasises the necessity for athletes to be treated more comprehensively through a biopsychosocial model (pain neuroscience education) component, where a greater understanding of how the nervous system processes injury and pain is utilised. The purpose of the study is to assess the effectiveness of PNE combined with manipulation versus chiropractic care alone for the reduction of pain due to chronic running-related knee pain in recreational marathon runners within the eThekwini Municipality region.

Outline of the Procedures: Participants will have appointments booked at the Durban University of Technology Chiropractic Day Clinic and a private practice — Dr Keseri Padayachy, Chiropractor, 233 Main Road Malvern, 4093. Bookings and all follow up consultations over 4 weeks will be coordinated by the researcher. Letters of information and informed consent will be required to be signed on the initial consult before the commencing of the study. For this randomised controlled single-blinded trial, in which the participants will be blinded, patients with chronic knee pain, will be recruited from the eThekwini Municipality region. Participants will be randomly assigned in a 1:1 ratio to one of the two groups. Each participant will receive 4 consultations in total, 1 per week for 4 weeks. The consultations are estimated to last 30 to 45 minutes each. Baseline assessments will be performed before the intervention and at the final consultation in the 3rd week, after the intervention respectively for each group.

Inclusion Criteria:

- Signed informed consent.
- Participants aged 18 to 65 years.
- Participants who can read and speak English.
- Participants who are or are not affiliated to an official running club with a registered Athletics South Africa (Jaenes et al.) licence.
- Participants who are male or female with symptomatic chronic knee pain (greater than 3 months duration).
- Participants with a weekly training volume between 30 and 80km/week.
- Participants who had completed 2 or more marathon events within the past 2 years (virtual and non-virtual).
- Participants with a score greater than 40 on the central sensitisation inventory scale (CSI).

Exclusion Criteria:

- Professional and elite marathon runners.
- Subjects who have had previous total knee replacement or any other lower limb surgery within the past six months of the affected knee, co-existing inflammatory, metabolic or neurologic disease.
- Subjects who have previously received chiropractic care and/or PNE before within 3 months.
- Participation in other pain trials prior (3 months) to recruitment.
- Lack of the ability to adhere to the protocol and cognitive impairment

Group 1 (intervention group): PNE and chiropractic care — on the first consult, the participant will be introduced to the intervention via a brief introductory level (pace-based) case history, short physical, measurements (baseline assessment) and special tests, as well as chiropractic care — that will include adjustments limited to the knee joint only. An educational tool *Understanding Pain and What to Do about it in Less Than Five Minutes* will be aired to the participant. The first session will be a longer session lasting 50 to 60 minutes, whereas the second, third and fourth follow-up sessions will be 40 to 50 minutes long. On the second, third and fourth consult, questions that arise will be answered and further PNE, in the form of metaphors and pictures, will be delivered with repeated chiropractic care. The fourth and final consultation will consist of recordings and measurements. Chiropractic care such as adjusting the knee joint will be done. Adjusting will be specific to the affected knee/s. Adjustments will be limited to the knee joint only.

Group 2 (control): chiropractic care only — on the first consult, the participant will have a case history, short physical, measurements (baseline assessment), special tests and chiropractic care. The second, third and fourth consult will be a repeat of the first consult, excluding the case history. The fourth and final consultation will consist of recordings and measurements.

Participants in both groups will receive the same chiropractic care, with the only difference being the PNE intervention. Adjustments will be limited to the knee joint only. No dry needling or other additional modalities will be used. Group 1 (Intervention) will receive 4 sessions with the proposed intervention since evidence is suggestive that 1 to 2 consultations per week is sufficient over 4 weeks.

Risks or Discomforts to the participant: There are no risks or risk of discomfort to the participants during this study.

Benefits: The results of this study may or may not have a reduction in fear and catastrophising, due to the immediate effect of PNE on improving attitudes and beliefs about your chronic running related knee injury. The benefits of the study may also have a positive effect on the disability and physical performance, improvements in both passive and active range of motion in the knee. Results of the study will be made available in the form of a dissertation at the Durban University of Technology library.

Reason/s why the Participant may be Withdrawn from the Study: If participants don't comply with the inclusion and exclusion criteria, non-compliant with the intervention. Participants are free to withdraw from the study at any stage. There will be no adverse consequences for a participant should they choose to withdraw from the study.

Remuneration: Participation in this study will be entirely voluntary and without remuneration. Participants are free to leave the research at any time.

Costs of the Study: There is no cost to you for your participation in this research.

Confidentiality: All research data will be submitted to the chiropractic programme for storage and disposal after 5 years will be shredded. During the duration of the study all information will be stored in the Durban University of Technology Chiropractic Clinic in a locked room and kept safe.

Research-related Injuries: Research-related injuries should not occur.

Persons to Contact in the Event of Any Problems or Queries:
Please contact the research student, Tyren Naidoo (072 491 0192), my supervisor Dr Keseri Padayachy, keserip@hotmail.com (031 464 4057), or the Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the DVC: Research, Innovation and Engagement Professor S Moyo on 031 373 2577 or moyos@dut.ac.za.

Thank you for participating in my study.

Tyren Naidoo

Appendix B

INFORMED CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, ______________ (name of researcher), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: __________,
- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

_____________________ __________ ______ ________________

Full Name of Participant **Date** **Time** **Signature / Right Thumbprint**

I, ______________ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

__________________ __________ ____________________

Full Name of Researcher **Date** **Signature**

__________________ __________ ____________________

Full Name of Witness (If applicable) **Date** **Signature**

________________ _________ __________________

Full Name of Legal Guardian (If applicable) **Date** **Signature**

Appendix C

Worksheet

CSI Inventory (Part A)

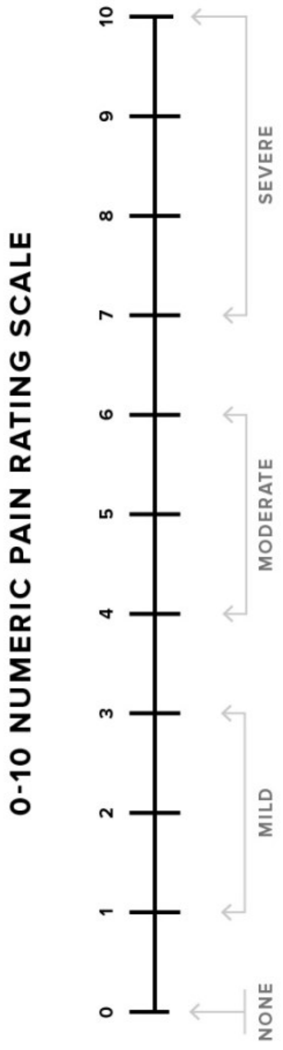
Name ______________________________ Date _______________

Please circle the best response to the right of each statement.
Key for Scoring: **Never** = **0**, **Rarely** = **1**, **Sometimes** = **2**, **Often** = **3**, **Always** = **4**

1. I feel tired and unrefreshed when I wake from sleeping.	Never	Rarely	Sometimes	Often	Always
2. My muscles feel stiff and achy.	Never	Rarely	Sometimes	Often	Always
3. I have anxiety attacks.	Never	Rarely	Sometimes	Often	Always
4. I grind or clench my teeth.	Never	Rarely	Sometimes	Often	Always
5. I have problems with diarrhea and/or constipation.	Never	Rarely	Sometimes	Often	Always
6. I need help in performing my daily activities.	Never	Rarely	Sometimes	Often	Always
7. I am sensitive to bright lights.	Never	Rarely	Sometimes	Often	Always
8. I get tired very easily when I am physically active.	Never	Rarely	Sometimes	Often	Always
9. I feel pain all over my body.	Never	Rarely	Sometimes	Often	Always
10. I have headaches.	Never	Rarely	Sometimes	Often	Always
11. I feel discomfort in my bladder and/or burning when I urinate.	Never	Rarely	Sometimes	Often	Always
12. I do not sleep well.	Never	Rarely	Sometimes	Often	Always
13. I have difficulty concentrating.	Never	Rarely	Sometimes	Often	Always
14. I have skin problems such as dryness, itchiness, or rashes.	Never	Rarely	Sometimes	Often	Always
15. Stress makes my physical symptoms get worse.	Never	Rarely	Sometimes	Often	Always
16. I feel sad or depressed.	Never	Rarely	Sometimes	Often	Always
17. I have low energy.	Never	Rarely	Sometimes	Often	Always
18. I have muscle tension in my neck and shoulders.	Never	Rarely	Sometimes	Often	Always
19. I have pain in my jaw.	Never	Rarely	Sometimes	Often	Always
20. Certain smells, such as perfumes, make me feel dizzy and nauseated.	Never	Rarely	Sometimes	Often	Always
21. I have to urinate frequently.	Never	Rarely	Sometimes	Often	Always
22. My legs feel uncomfortable and restless when I am trying to go to sleep at night.	Never	Rarely	Sometimes	Often	Always
23. I have difficulty remembering things.	Never	Rarely	Sometimes	Often	Always
24. I suffered trauma as a child.	Never	Rarely	Sometimes	Often	Always
25. I have pain in my pelvic area.	Never	Rarely	Sometimes	Often	Always
Total Each Column					

Overall Total ________

Appendix D


0-10 NUMERIC PAIN RATING SCALE
0
1
2
3
4
5
6
7
8
9
10
NONE
MILD
MODERATE
SEVERE

Appendix E

Lower Extremity Functional Scale

Appendix.
Lower Extremity Functional Scale

We are interested in knowing whether you are having any difficulty at all with the activities listed below because of your lower limb problem for which you are currently seeking attention. Please provide an answer for **each** activity.

Today, do you or would you have any difficulty at all with:

(Circle one number on each line)

Activities	Extreme Difficulty or Unable to Perform Activity	Quite a Bit of Difficulty	Moderate Difficulty	A Little Bit of Difficulty	No Difficulty
a. Any of your usual work, housework, or school activities.	0	1	2	3	4
b. Your usual hobbies, recreational or sporting activities.	0	1	2	3	4
c. Getting into or out of the bath.	0	1	2	3	4
d. Walking between rooms.	0	1	2	3	4
e. Putting on your shoes or socks.	0	1	2	3	4
f. Squatting.	0	1	2	3	4
g. Lifting an object, like a bag of groceries from the floor.	0	1	2	3	4
h. Performing light activities around your home.	0	1	2	3	4
i. Performing heavy activities around your home.	0	1	2	3	4
j. Getting into or out of a car.	0	1	2	3	4
k. Walking 2 blocks.	0	1	2	3	4
l. Walking a mile.	0	1	2	3	4
m. Going up or down 10 stairs (about 1 flight of stairs).	0	1	2	3	4
n. Standing for 1 hour.	0	1	2	3	4
o. Sitting for 1 hour.	0	1	2	3	4
p. Running on even ground.	0	1	2	3	4
q. Running on uneven ground.	0	1	2	3	4
r. Making sharp turns while running fast.	0	1	2	3	4
s. Hopping.	0	1	2	3	4
t. Rolling over in bed.	0	1	2	3	4
Column Totals:					

SCORE: ______/80

Error (single measure): ±5 scale points
MDC: 9 scale points
MCID: 9 scale points

Appendix F

Pain Catastrophization Scale

We are interested in the types of thoughts and feeling that you have when you are in pain. Listed below are thirteen statements describing different thoughts and feelings that may be associated with pain. Using the scale, please indicate the degree to which you have these thoughts and feelings when you are experiencing pain.

	Strongly Disagree	Disagree	Agree	Strongly Agree
1. I worry all the time about whether the pain will end.	1	2	3	4
2. I feel I can't go on.	1	2	3	4
3. It's terrible and I think it's never going to get any better.	1	2	3	4
4. It's awful and I feel that it overwhelms me.	1	2	3	4
5. I feel I can't stand it anymore.	1	2	3	4
6. I become afraid that the pain will get worse.	1	2	3	4
7. I keep thinking of other painful events.	1	2	3	4
8. I anxiously want the pain to go away.	1	2	3	4
9. I can't seem to keep it out of my mind.	1	2	3	4
10. I keep thinking about how much it hurts.	1	2	3	4
11. I keep thinking about how badly I want the pain to stop.	1	2	3	4
12. There's nothing I can do to reduce the intensity of the pain.	1	2	3	4
13. I wonder whether something serious may happen.	1	2	3	4

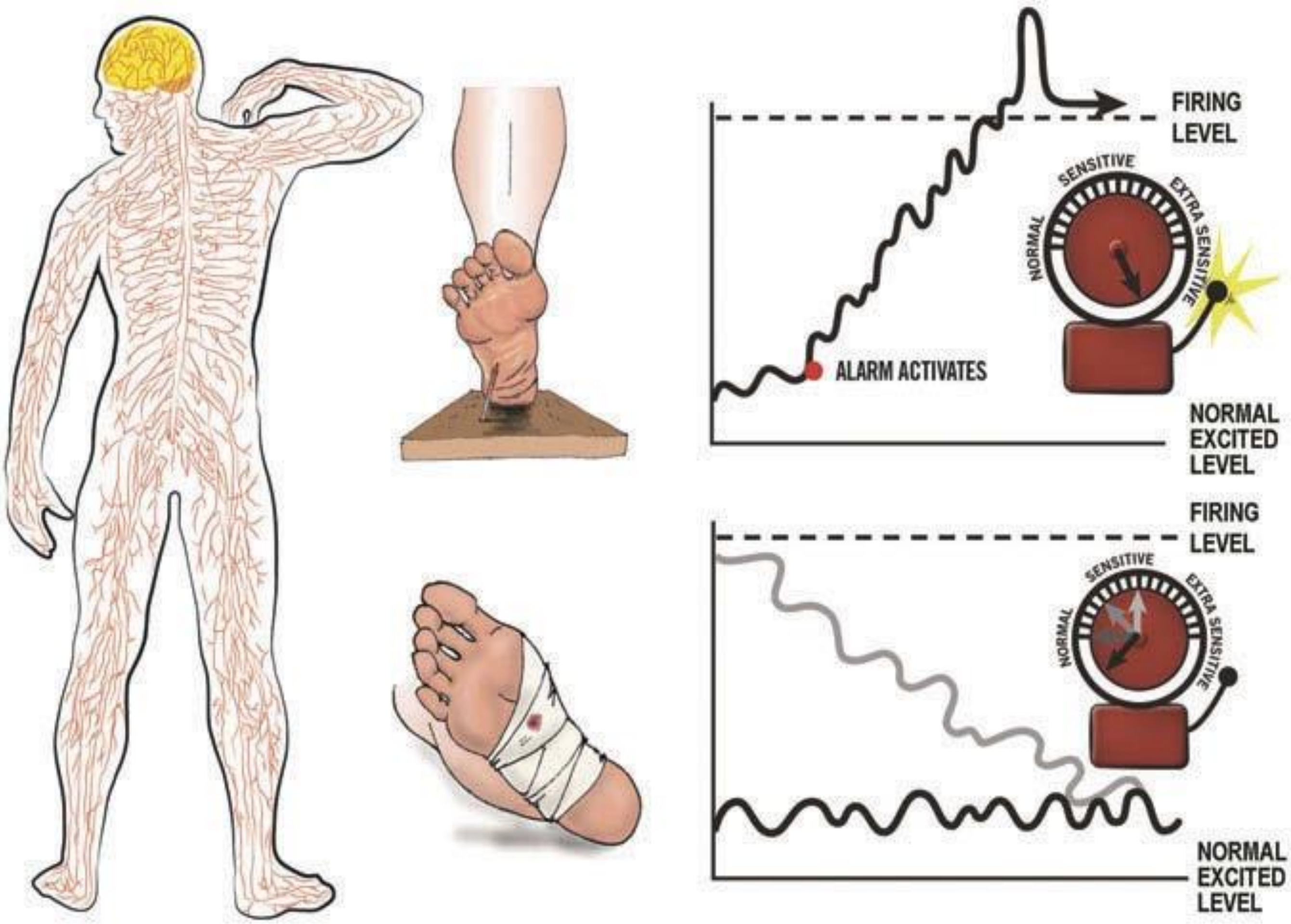
Total Score:

evidenceinmotion.com – info@eimpt.com – 888.709.7096

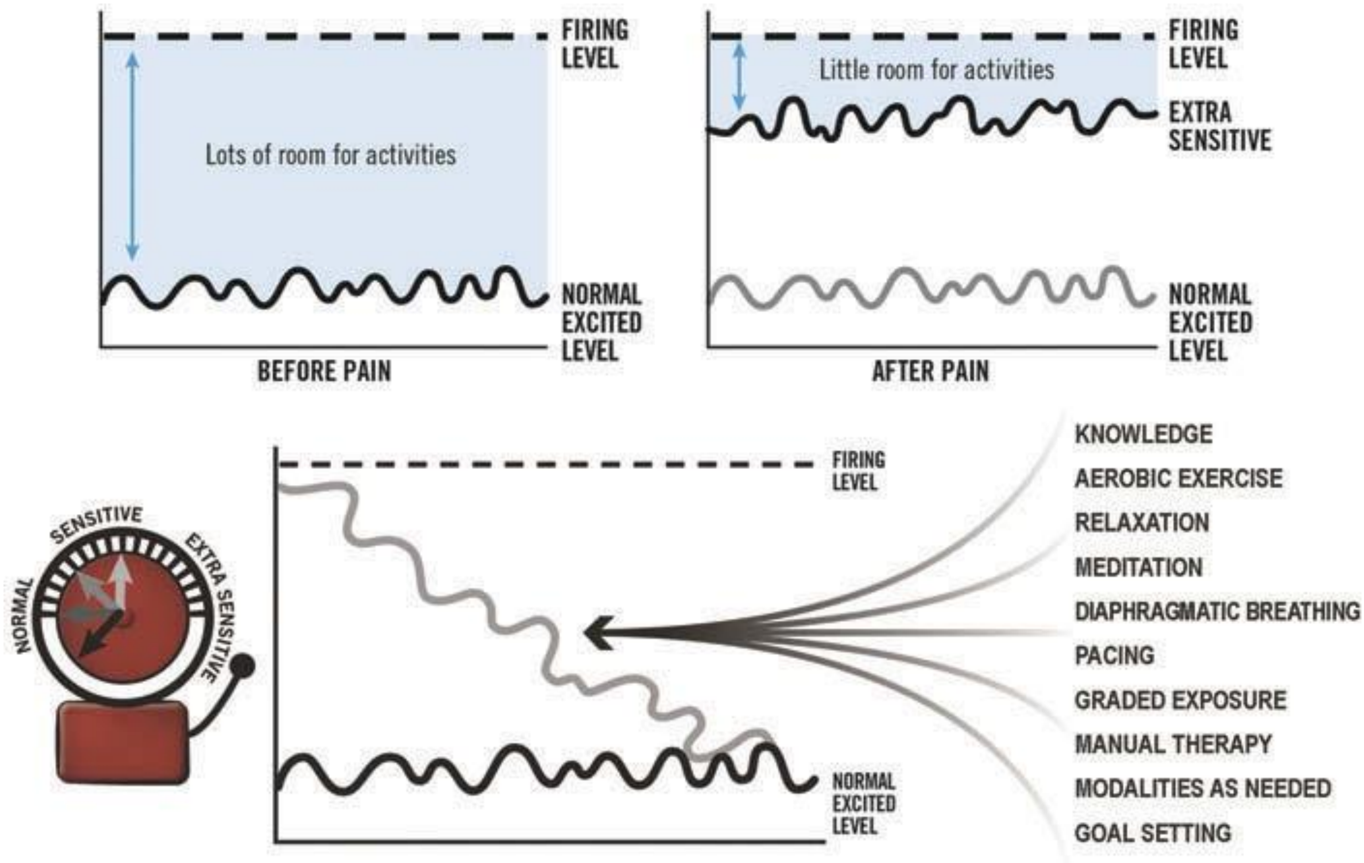
Appendix G


CALLING
ALL
MARATHON
RUNNERS
A research study
JOIN THE REVOLUTION IF:
- YOU HAVE CHRONIC KNEE PAIN
-YOU RUN 30+ KM P/W
-YOU HAVE COMPLETED 2 OR MORE MARATHONS
TYREN NAIDOO | (072) 491 0192 | PNEMARATHON@GMAIL.COM

Appendix H


FIRING
LEVEL
SENSITIVE
NORMAL
EXTRA SENSITIVE
ALARM ACTIVATES
NORMAL
EXCITED
LEVEL
FIRING
LEVEL
SENSITIVE
NORMAL
EXTRA SENSITIVE
NORMAL
EXCITED
LEVEL

Appendix I


FIRING LEVEL
Lots of room for activities
NORMAL EXCITED LEVEL
BEFORE PAIN
FIRING LEVEL
Little room for activities
EXTRA SENSITIVE
NORMAL EXCITED LEVEL
AFTER PAIN
NORMAL
SENSITIVE
EXTRA SENSITIVE
FIRING LEVEL
NORMAL EXCITED LEVEL
KNOWLEDGE
AEROBIC EXERCISE
RELAXATION
MEDITATION
DIAPHRAGMATIC BREATHING
PACING
GRADED EXPOSURE
MANUAL THERAPY
MODALITIES AS NEEDED
GOAL SETTING

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