# The Biomechanical Risk Factors Associated with Preventing and Managing Iliotibial Band Syndrome in Runners: A Systematic Review

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## Declaration

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## Abstract

**Introduction:** Iliotibial band syndrome (ITBS), an overuse injury, is the second most common running injury and the main cause of lateral knee pain in runners. Due to the increasing number of runners worldwide there has been an increase in its occurrence. Runners with ITBS typically experience symptoms just after heel strike at approximately 20°-30° of knee flexion (impingement zone) during the stance phase of running. A variety of intrinsic and extrinsic risk factors may be responsible for why some runners are more prone to developing symptoms during the impingement zone as opposed to others. Abnormalities in running biomechanics is an intrinsic risk factor which has been most extensively described in literature but little is known about its exact relationship to ITBS.

**Objectives:** The purpose of this systematic review was to provide an up to date evidence synthesis of the biomechanical risk factors associated with ITBS. These risk factors may need to be considered in the prevention or management of ITBS in runners. A clinical algorithm is also presented.

**Methods:** A systematic review with meta-analysis was conducted. An electronic search was performed in PubMed, PEDro, SPORTSDisc and Scopus of literature published up-until May 2014. Cross-sectional and cohort studies were eligible for inclusion if they evaluated the lower limb biomechanics of runners with ITBS or those who went onto developing it. All studies included in the review were methodologically appraised. Evidence was graded according to the level of evidence, consistency of evidence and the clinical impact. Data was described narratively using tables or narrative summaries where appropriate. A meta-analysis was conducted for biomechanical risk factors which were reported in at least two studies, provided that homogeneity in the outcomes and samples were present.

**Results:** A total of 11 studies were included (1 prospective and 10 cross-sectional). Overall the methodological score of the studies was moderate. Increased peak hip adduction and knee internal rotation during the stance phase may predict the development of ITBS in female runners. These biomechanical risk factors may need to be screened for ITBS prevention, despite the evidence base being limited to a single study. Currently there is no conclusive evidence that any of the biomechanical parameters need to be considered when managing runners with ITBS.

**Conclusion:** Biomechanical differences may exist between runners with ITBS and those who may develop ITBS compared to healthy runners. Although a large variety of biomechanical risk factors were evaluated, the evidence base for screening or managing these risk factors for runners with ITBS is limited. This is due to a small evidence base, small clinical effect and heterogeneity between study outcomes and findings. Further prospective and cross-sectional research is required to ascertain if abnormalities in running biomechanics may be related to why runners develop ITBS or to ascertain which risk factors may be involved when managing these runners.

## Opsomming

**Inleiding:** Iliotibiale-band-sindroom (ITBS), ’n besering vanweë oormatige gebruik, is die tweede algemeenste hardloopbesering en die hoofoorsaak van laterale kniepyn by hardlopers. Namate die getal hardlopers wêreldwyd toeneem, neem die voorkoms van hierdie toestand ook toe. Hardlopers met ITBS ervaar tipies simptome ná die hakslag met die knie ongeveer 20-30° gebuig (die wrywingsone of “impingement zone”) gedurende die staanfase van hardloop. Verskeie intrinsieke en ekstrinsieke risikofaktore kan ’n rol speel in waarom sommige hardlopers meer geneig is as ander om gedurende die wrywingsone simptome te ervaar. Abnormaliteite in hardloopbiomeganika is ’n intrinsieke risikofaktor wat reeds omvattend in die literatuur beskryf is. Tog is weinig bekend oor presies hoe dit met ITBS verband hou.

**Oogmerke:** Die doel van hierdie stelselmatige ondersoek was om ’n sintese te bied van die jongste bewyse van die biomeganiese risikofaktore van ITBS. Hierdie risikofaktore kan dalk oorweeg word om ITBS by hardlopers te voorkom of te bestuur. ’n Kliniese algoritme word ook aangebied.

**Metodes:** ’n Stelselmatige ondersoek is met behulp van meta-ontleding onderneem. PubMed, PEDro, SPORTSDisc en Scopus is elektronies deurgesoek vir literatuur wat tot en met Mei 2014 verskyn het. Deursnee en kohortstudies is ingesluit indien dit gehandel het oor die biomeganika in die onderste ledemate van hardlopers wat ITBS het of later ontwikkel het. Alle studies wat deel was van die ondersoek is metodologies geëvalueer. Bewyse is aan die hand van bewysvlak, bewyskonsekwentheid en kliniese impak beoordeel. Data is narratief beskryf met behulp van tabelle of narratiewe opsommings waar dit toepaslik was. ’n Meta-ontleding is onderneem waar biomeganiese risikofaktore in minstens twee studies aangemeld is, mits daar homogeniteit in die uitkomste sowel as die steekproewe was.

**Resultate:** Altesaam 11 studies is ingesluit (een prospektief en tien deursnee). Die metodologiese telling van die studies was oorwegend gemiddeld. Verhoogde spitsheupadduksie en interne knierotasie gedurende die staanfase kan op die ontwikkeling van ITBS by vrouehardlopers dui. Hierdie biomeganiese risikofaktore kan dalk nagegaan word vir ITBS-voorkoming, al was die bewysbasis beperk tot ’n enkele studie. Daar is tans geen afdoende bewys dat enige van die biomeganiese parameters oorweeg behoort te word in die bestuur van langafstandatlete met ITBS nie.

**Gevolgtrekking:** Daar bestaan dalk biomeganiese verskille tussen hardlopers wat ITBS het of kan ontwikkel en gesonde hardlopers. Hoewel ’n groot verskeidenheid biomeganiese risikofaktore beoordeel is, is die bewysbasis vir die toets of bestuur daarvan by atlete met ITBS beperk. Dít is vanweë die klein hoeveelheid bewyse, die klein kliniese impak, en heterogeniteit tussen studie-uitkomste en bevindinge. Verdere prospektiewe en deursneenavorsing word vereis om te bepaal of abnormaliteite in hardloopbiomeganika ’n rol kan speel in waarom langafstandhardlopers ITBS ontwikkel, of om vas te stel watter risikofaktore ter sprake kan wees in die bestuur van hierdie hardlopers.

## Dedication

To all my grandparents.

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## List of Abbreviations and Symbols

| | |
|---|---|
| ASIS | Anterior superior iliac spine |
| CAT | Critical appraisal tool |
| CI | Confidence intervals |
| CON | Control |
| CRP | Continuous Relative Phase |
| DNR | Did not report |
| F | Females |
| ITB | Iliotibial band |
| ITBS | Iliotitibial band syndrome |
| JA | Jodi Aderem |
| JOSPT | Journal of Orthopaedic and Sports Physical Therapy |
| Kg | Kilograms |
| Km | Kilometres |
| M | Males |
| M/F | Males and females |
| m | Meters |
| mo | Monthly |
| MRI | Magnetic resonance imaging |
| N | No |
| n | Total number of sample |
| N/A | Not applicable |
| NHMRC | National Health and Medical Research Council |
| NSAIDS | Non-steroidal anti-inflammatory drugs |
| PCA | Principal components analysis |
| QL | Quinette Louw |
| RCT | Randomized control trial |

| | |
|---|---|
| SD | Standard deviation |
| TOT | Total |
| TFL | Tensor fasciae latae |
| vs | Versus |
| W | Weekly |
| WHO | World Health Organization |
| Y | Yes |
| YRS | Number of years |
| 3D | Three dimensional |
| = | Equals |
| ° | Degrees |
| °/s | Degrees per second |
| %/ROP | Percent of roll over process |
| $m/s^{-1}$ | meters per second |
| Nm/kg | Newtons per kilogram |
| $^{S}$ | Small clinical impact |
| $^{M}$ | Medium clinical impact |
| $^{L}$ | Large clinical impact |
| ↑ | Increased |
| ↓ | Decreased |

## Definition of Terms

| | |
|---|---|
| Biomechanics: | The aspect of science related to the analysis of the mechanics of human movement. Biomechanics encompasses kinetics and kinematics.[1] |
| Extrinsic risk factor: | Factors which are related to the environment and training of the individual.[2] |
| Impingement zone: | 20°-30° range of motion where repetitive knee flexion occurs and runners experience symptoms of ITBS.[3] |
| Intrinsic risk factor: | Factors which are related to the anatomy and physiology of the individual.[2] |
| Kinematics: | The aspect of biomechanics which analyses the way the body moves[1], by looking at spatial and temporal components without considering force.[4,5] |
| Kinetics: | The aspect of biomechanics which analyses the forces which cause movement.[4,5] |
| Overuse inury: | Any injury of the musculoskeletal system resulting from 'combined fatigue effect' over a period of time beyond the boundaries that a specific structure has been stressed.[6] |
| Risk factor: | Any 'attribute, characteristic or exposure' that increases the chance of an individual acquiring a specific disease or injury.[7] |
| Running: | The act of one or no leg striking the ground during the gait cycle.[8] |
| Stance phase: | The period of time for which the foot is in contact with the running/walking surface during the gait cycle. In running the stance phase is less than 50% of the running cycle.[4,8] |
| Strain: | An 'overstretching or overexertion' of part of the musculature over time through overuse.[9] |
| Strain rate: | Change in strain over time from initial foot contact to mid-support during the stance.[10] |

## Outline of Study

The following study will be presented in a 'masters by publication' format according to the guidelines for the Journal of Orthopaedic and Sports Physical Therapy (JOSPT) which can be seen in Appendix 1.

- **CHAPTER 1:**
  Introduction to the study and literature overview.

- **CHAPTER 2:**
  Basis of study, aims and objectives.

- **CHAPTER 3:**
  Systematic review on, *'The Biomechanical Risk Factors Associated with Preventing and Managing Iliotibial Band Syndrome in Runners'*.

- **CHAPTER 4:**
  Conclusion of study, clinical recommendations, limitations and future research.

# CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

Running is one of the most popular forms of physical activity and is a key component of the majority of all recreational and professional sports globally.[11] It is enjoyed by people of all ages predominantly because it is an inexpensive form of exercise which is easily accessible and can be performed with little or no equipment.[12] Despite the numerous positive effects on the cardiopulmonary system, general mental and physical health, general well-being, as well as fitness and weight management, running does come with the risk of injury.[11,13,14] The main injury risk for runners is overuse, predominantly of the lower limb.[15] The excessive and increased loading of the tissues during the landing phase of the running cycle may be the reason why runners are prone to injury.[6] Additionally, increased weekly mileage, speed, training conditions, footwear, number of years of running and a history of previous running related injuries may be responsible for increasing the incidence of overuse injuries in runners worldwide.[2,16-18] The annual prevalence of injury to the lower limb in runners ranges from 19.4%-79.3% with the knee being reported as the most commonly affected joint with prevalence up to 50%.[18]

Iliotibial Band Syndrome (ITBS) is named one of the most common causes of lateral knee pain in runners.[12,19] The aim of this chapter is to provide background on ITBS.

## 1.1 Definition of Iliotibial Band Syndrome

ITBS has been described as an overuse injury to the knee which is unrelated to a traumatic event.[20] It was first described by Renne[21] as lateral knee pain, as a result of running or cycling and remains the definition used today. ITBS is characterized by a sharp burning pain over the lateral aspect of the knee, approximately 2cm superior to the lateral joint line.[22] This is the site where the distal iliotibial band (ITB), a tight band of fascia, inserts distally onto Gerdys tubercle on the anterior lateral tibia and the intermuscular septum of the distal femur.[23] The ITB is formed proximally from the fascia of the gluteus maximus and medius and tensor fasciae latae (TFL).[24] It originates from the anterior superior iliac spine (ASIS), the anterior border of the ilium and the external lip of the iliac crest.[24]

## 1.2 Prevalence of Iliotibial Band Syndrome

ITBS is prevalent in sports where participants are subjected to repetitive knee flexion and extension.[3,20,23,25,26] In runners, ITBS has been noted as the second most common knee injury[20] and one of the main causes of lateral knee pain.[12] It is also an overuse injury which is becoming more prevalent in cyclists and endurance athletes.[19] ITBS accounts for approximately one tenth of all running related injuries[12] with incidence ranging between 1.6%-52%[12,25,27] depending on the population.[28] In a recent systematic review by Ellis et al[20] the incidence of ITBS in women was reported to be between 16%-50% and in men between 50%-81%. A gradual increase in the occurrence of ITBS was noted over the past decade.[18] This increase in ITBS prevalence may be related to the increasing number of people participating in running and multi-disciplinary sports at a competitive level and as a form of physical activity to maintain good health.[12]

## 1.3 Pathogenesis of Iliotibial Band Syndrome

Runners with ITBS typically experience symptoms during the stance phase of running, just after heel strike at approximately 20°-30° of knee flexion.[3,10] Orchard et al[3] called this range the 'impingement zone' and stated that this is the point where irritation to the lateral structures of the knee occur. This irritation is believed to result in symptoms of ITBS.[3] During the stance phase of running the foot touches the ground and adapts to the ground surface, it is then in constant contact with the ground for the remainder of this phase.[4] The stance phase can be further broken down into the following phases; foot/heel strike, mid stance and take off.[4] Runners are most prone to an injury like ITBS during the stance phase as it is during this phase of the running cycle where there is increased load to the lower limb muscles and joints. The underlying pathology of ITBS and what occurs in the 'impingement zone' is poorly understood and there is much debate as to why runners may be prone to it.[3]

Initially it was proposed that ITBS results from excessive friction of the distal ITB as it moves over the lateral femoral epicondyle during repetitive knee flexion and extension.[29] When the knee is flexed, the ITB moves posteriorly over the lateral femoral epicondyle and with extension it moves anteriorly.[30] This repetitive motion of the knee in the 'impingement zone' was thought to cause irritation or inflammation of the distal ITB or the underlying bursa.[3] Fairclough et al[23] later challenged this theory by saying that

that the cause of ITBS was not as a result of friction but rather as a result of compression and felt it was impossible for friction to occur as various anatomical factors were not considered. Fairclough et al[23] reasoned that the ITB was a thickened zone within the lateral fascia rather than an anatomical structure and as a result the anterior/posterior motion of the ITB was only an illusion. This impression of movement of the ITB was as a result of changes in tension of the lateral fascia causing compression of an innervated and vascularized layer of fat and loose connective tissue which lies between the ITB and the lateral femoral epicondyle.[23]

The topic of whether friction or compression exists is controversial. There has been much debate as to what occurs at the distal ITB or whether or not a bursa actually exists. Ekman et al[31] conducted a study on cadavers where he compared their findings to the Magnetic Resonance Imaging (MRI) results of patients complaining of symptoms of ITBS. Ekman et al[31] found a fluid filled sac between the ITB and the lateral femoral epicondyle, referred to as a bursa. The theory that a bursa may be present was confirmed by Harriri et al[32] who surgically removed a bursa in the space between the ITB and the lateral femoral epicondyle and reported that these patients experienced a reduction in symptoms of ITBS.

Nemeth and Sanders[33] was not under the impression that a bursa exists and found that the tissue below the ITB is made up of synovium, described as being a lateral extension of the knee joint capsule rather than a bursa. Muhle et al[34] conducted a study on cadavers and humans using MRI. Muhle et al[34] did also not identify a bursa or cyst in the area nor identify any changes in the distal ITB. Due to the conflict in thoughts regarding the underlying pathology of ITBS on a MRI scan, the diagnosis is usually based on a thorough clinical evaluation.[19,35]

## 1.4 Diagnosis of Iliotibial Band Syndrome

The diagnosis of ITBS is usually made on presenting symptoms and a thorough clinical examination.[19,35] An MRI may be used for differential diagnosis and to exclude pathology of the lateral collateral ligament, lateral meniscus, biceps femoris tendon and patella femoral joint, and to rule out the possibility of a stress fracture.[36] If only a diagnosis of ITBS is suspected, an MRI is not usually indicated.[35] The clinical examination will begin with a detailed medical history. Runners with ITBS will typically report the area of pain to be on the lateral aspect of the knee approximately 2cm superior to the lateral joint line.[22] This pain may occasionally radiate proximally or distally.[35] The onset of these symptoms are often said to occur at a similar time and distance in a run.[26] Long distance running and running downhill are often reported to increase symptoms due to increased time that the knee is spent in the 'impingement zone'.[3] Cessation of running may be reported to reduce symptoms.[35] On physical examination runners may have acute tenderness over the lateral femoral epicondyle.[19] To confirm a diagnosis of ITBS the Obers and Nobles tests should be performed.[36] These tests can be used to differentiate ITBS from other conditions which may result in lateral knee pain. Both the Obers and Nobles tests have been used in previous studies to accurately diagnose ITBS[36], however their validity has not yet been investigated.[37,38]

### 1.4.1 Obers test

The Obers test can be used to evaluate flexibility of the ITB and the TFL. It has been reported to have good interrator reliability.[37] This test is performed in side lying where the clinician passively abducts and extends the affected leg, after which the affected thigh is adducted. If the runner's thigh does not descend beyond 10° of the horizontal plane the test is positive and is indicative of a tight ITB and TFL.[19]

### 1.4.2 Nobles Compression test

The Noble's compression test has also been found to be positive in subjects with ITBS, however it has moderate reliability.[26,37] The runner will be positioned in supine with their affected leg hanging off the side of a bed and the unaffected leg flexed to 90°.[19] The clinician will place their thumb over the lateral femoral epicondyle of the affected leg and will ask the runner to actively extend their knee to approximately 30°(impingement zone).[3,19] With extension, the ITB will move anteriorly under the clinicians thumb and posteriorly with flexion.[39] Runners with ITBS should experience reproduction of symptoms when the clinician compresses the distal ITB with the knee being held in approximately 30° of flexion.[19]

### 1.4.3 Grading the severity of Iliotibial Band Syndrome

Lindenburg et al[40] stated that the diagnosis of ITBS can be graded according to one of four grades, depending on the severity of the condition. 'Grade I', runner experiences symptoms after running but their distance or speed is not affected. 'Grade II', runner experiences pain during running but their distance and speed are not limited. 'Grade III', runner experiences symptoms during running affecting their distance or speed and Grade IV symptoms of ITBS prohibits running.[40]

## 1.5 Aetiology of Iliotibial Band Syndrome

The cause of ITBS is multifactorial and a topic of constant debate for clinicians treating runners who suffer from it. In the quest to identify the cause of ITBS in runners, many studies have been conducted to explore the intrinsic and extrinsic risk factors which may result in runners developing the condition. A risk factor has been described by the World Health Organization (WHO) as any, 'attribute, characteristic or exposure' that increases the chance of an individual acquiring a specific disease or injury.[7]

## 1.6 Intrinsic risk factors of Iliotibial Band Syndrome

A wide range of intrinsic risk factors have been discussed as potential reasons why certain runners are believed to be more prone to developing ITBS.

### 1.6.1 Anatomical risk factors

Anatomical factors include; leg length discrepancies, increased prominence of the lateral femoral epicondyles as well as decreased flexibility of the ITB.[3,12,22,25,26] Leg length discrepancies are thought to result in changes in pelvic and hip position which may result in unnecessary tension being placed on the ITB.[25] The Obers test is used to assess the flexibility of the ITB but to date no studies have determined if there is a correlation between reduced ITB length/flexibility and ITBS.[19,38,41] There are no recent studies to support these findings.

### 1.6.2 Biomechanical risk factors

Biomechanical factors (kinetics and kinematics) are believed to be a possible cause of ITBS in runners.[3,25,42] Numerous studies in motion analysis laboratories across the world have been conducted to determine if there is a difference in biomechanics between runners with ITBS compared to healthy/injury free runners. Biomechanical abnormalities are believed to exist at the hip and knee due to the origin and insertion of the ITB.[43] Runners with ITBS are thought to display increased amounts of peak hip adduction and knee internal rotation.[42] This knee position is believed to increase the strain and tension on the ITB, resulting in friction or compression of the ITB against the lateral femoral epicondyle.[3] Peak knee flexion is another biomechanical risk factor which has been discussed as being a risk factor of ITBS and this could be related to runners with ITBS experiencing symptoms in the 'impingement zone'.[3,44-46] Abnormal biomechanics at the foot and tibia may also play a role in causing ITBS.[42] This may be due to the anatomical connection of the ITB to the tibia and the inter relationship between the foot and the tibia.[38] Rearfoot eversion is another kinematic factor which is thought to be a contributing factor of ITBS.[25]

The ITB is required to resist large varus forces distally at the knee,[47] which may cause an increase in strain and tension on the ITB. Hamill et al[10] conducted a study on female runners who went onto developing ITBS to explore whether there is increased strain in the ITB of runners with ITBS. Musculoskeletal modelling was used to model the ITB. This model was used to calculate and quantify the amount of strain (tension) and strain rate, as well as the duration of impingement occurring at the ITB.[10] ITB strain was calculated by dividing the change in length of the ITB by its resting length and ITB strain rate was calculated by dividing the change in strain of the ITB by the change in time.[10] This study concluded that only strain rate was found to be a significant contributing factor of ITBS in runners.[10] To date this finding is only limited to one study.

### 1.6.3 Strength deficits

Decreased strength of the gluteal muscles, particularly the gluteus medius has been proposed as another reason why runners may develop ITBS.[27,42,44,48,49] This could be because running predominantly occurs in the sagittal plane.[27] Fredericson et al[27] found that when evaluating the hip abductor strength of runners with ITBS using a hand held dynamometer, runners with ITBS presented with hip abductor weakness compared to the asymptomatic controls. The function of the gluteus medius is to improve hip adduction, which both Noehren et al[42] and Ferber et al[44] found to be present in runners with ITBS. Increased amounts of hip adduction may increase tension on the ITB.[42] A hip abductor strengthening program was found to reduce symptoms of ITBS.[27] This theory was challenged by Grau et al[50], who did not believe that hip abductor weakness was the cause of ITBS. Further studies are required to determine the relationship of the hip abductor muscle to ITBS.

## 1.7 Extrinsic risk factors of Iliotibial Band Syndrome

Extrinsic risk factors include downhill running,[3,51] running at a slower pace,[3] sudden increase in mileage and frequency,[25] foot wear and step width.[3,25] An association has been found between these factors and ITB strain as they are believed to cause excessive friction of the ITB against the lateral femoral epicondyle due to the reduction of knee flexion at foot strike.[3] A sudden increase in mileage and frequency may result in the body not having adequate time to adjust to an increased load resulting in injury of the knee.[25] Running at a slower pace or running downhill are thought to increase the amount of knee flexion at heel strike, resulting in runners spending more time in the 'impingement zone'.[3,51] Changing the position of the foot will also have an effect on the amount of strain taking place at the site of the ITB.[3,25] The biomechanics of runners in shoes versus running barefoot have been found to be different. Mearden et al[52] found that there was an increased amount of ITB strain and strain rate in runners who ran with a narrower step width. Further research is required regarding the extrinsic risk factors of ITBS.

## 1.8 Conservative management of Iliotibial Band Syndrome

Fredericson and Wolf[26] described the conservative management of ITBS according to one of three phases; the acute, sub-acute, and the recovery and strengthening phase. Although these phases are not evidence based, there is evidence to support the management techniques which were advised.

### 1.8.1 Acute and sub-acute phase

During the acute phase the goal of treatment is to reduce inflammation at the site where the ITB moves over the lateral femoral epicondyle.[26] This can be achieved using a combination of treatment modalities such as; rest, ice, activity modification, non-steroidal anti-inflammatory drugs (NSAIDS) and in more severe cases corticosteroid injections.[26] In a randomized control trial (RCT) by Gunter and Schwellnus[53] it was found that an infiltration of local corticosteroid caused a reduction in symptoms of ITBS during running in the first two weeks. Once the pain and inflammation have subsided, myofascial restrictions in the ITB and TFL complex can be released with stretching and soft tissue release.[22] There is not high level evidence from RCT's to support these treatment techniques. The lack of evidence can be noted in the systematic review conducted by Ellis et al[20] who evaluated the conservative treatment of ITBS. This review comprised of four RCT's on the following conservative approaches for the management of ITBS; NSAID's, deep friction massage, phonopheresis versus immobilization and corticosteroid injection. Ellis et al[20] concluded that there is insufficient evidence to support the use of any of these forms of conservative management and also noted that in most of the studies, patients received a baseline of physiotherapy which included combinations of ice, massage, ultrasound and stretching. During the acute and sub-acute stage it is important for runners to modify their training and address the extrinsic risk factors. A step width altering program has been explored as a technique to reduce strain on the ITB.[52,54] Meardon et al[52] conducted a study on fifteen healthy runners where they measured and compared the ITB strain and strain rate during preferred step width, narrow step width as well as wide step width. Results showed statistical significance between ITB strain and strain rate to step width. ITB strain was approximately two times greater when runners ran with a reduced step width. From a wide condition to the narrow condition there was a 1.22 times greater strain rate on the ITB. Increasing the step width of runners with ITBS may reduce the amount of strain/tension on the ITB.[52]

### 1.8.2 Recovery and strengthening phase

During the recovery and strengthening phase Fredericson and Weir[22] recommended strengthening the hip abductors. Studies have shown that hip abductor strength parallels symptom improvement.[27] However one of these studies included additional treatment modalities and the researchers were not clear which modality was responsible for the improvement in symptoms.[27,55] Thus a combination of hip abductor strengthening and additional modalities such as ultrasound may be beneficial as management techniques in runners with ITBS.

## 1.9 Surgical management of Iliotibial Band Syndrome

In cases where conservative management is unsuccessful, a surgical approach may be required. Various surgical procedures have been conducted in the treatment of ITBS. These approaches were explored in a review by Beals and Flanigan[35]. The surgical approaches included; Arthroscopy for the resection of the lateral synovial reces,[56] Bursectomy[32] and Transection of the posterior half of the ITB.[57] All of these techniques appeared to be successful and the patients were satisfied with their outcome. Z lengthening is another procedure which has been explored in RCT's and found to be successful.[58,59]

### 1.10 Summary

ITBS, a common yet complicated overuse injury, remains a management dilemma for clinicians. There are many views regarding its aetiology, which makes it difficult to identify which of the intrinsic and extrinsic risk factors are its predominant cause in runners.

# CHAPTER 2: BASIS FOR STUDY, AIMS AND OBJECTIVES

In response to the differing views on the cause of ITBS in runners, a search of the available literature on the biomechanical risk factors associated with ITBS was conducted. This chapter highlights the findings and shortcomings of the two published systematic reviews identified on biomechanics, as well as the aims and objectives of this study.

These published systematic reviews were conducted by Van der Worp et al[41] and Louw and Deary[60]. Van der Worp et al[41] evaluated the literature available on the aetiology, diagnosis and treatment of ITBS in runners. Biomechanical findings were inconclusive as in many cases findings were conflicting. Louw and Deary[60] found that the cause of ITBS is most likely proximal and as a result of abnormal hip biomechanics rather than as a result of abnormal biomechanics of the foot or tibia. However, the abstract and conclusion had conflicting results.

These systematic reviews[41,60] only focused on identifying the significant and insignificant biomechanical differences and did not provide any further analysis of the findings. In many cases the findings of the included studies were found to be insignificant which could be due to their small sample sizes. The size of the evidence base, the consistency between studies for each finding and the effect size of the differences in risk factors, were not considered. In addition, findings of previous systematic reviews did not consider study population heterogeneity. This limits clinicians when applying these findings, as the risk factors, particularly the biomechanical risk factors of ITBS have not been clearly defined.

The aim of this systematic review is therefore to provide an up to date evidence synthesis which will also analyse the size of the evidence base, consistency in findings between studies as well as the size of the differences of risk factors between runners with ITBS and those who were healthy. In addition, both prospective cohort studies to identify factors which may predispose runners to ITBS and cross-sectional studies which may provide information about factors which should be considered when managing runners with ITBS, will be considered. This will assist in objectively clarifying whether or not biomechanical differences exist between these two groups. This was not clear in the previous review[60]. In order to facilitate knowledge translation for clinicians, a clinical algorithm for the prevention and management of ITBS will be developed. To our knowledge, this has not previously been done.

Chapter 3 presents a systematic review on the *‘Biomechanical Risk Factors Associated with Iliotibial Band Syndrome (ITBS) in Runners’.*

# CHAPTER 3: SYSTEMATIC REVIEW

The following chapter on *'The Biomechanical Risk Factors Associated with Preventing and Managing Iliotibial Band Syndrome in Runners: A Systematic Review'* has been submitted to the Journal of Orthopaedic and Sports Physical Therapy (JOSPT).

## The Biomechanical Risk factors Associated with Preventing and Managing Iliotibial Band Syndrome in Runners: A Systematic Review

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## 3.1 ABSTRACT

**Study design:** Systematic review of the literature.

**Objectives:** To explore the biomechanical risk factors associated with preventing and managing Iliotibial band syndrome (ITBS) in runners.
**Background:** ITBS is the second most common running injury. A gradual increase in its occurrence has been noted over the past decade. This may be related to the increasing number of runners worldwide.

**Methods:** An electronic search was conducted in PubMed, PEDro, SPORTSDisc and Scopus of literature published up until May 2014. The critical appraisal tool for quantitative studies was used to evaluate methodological quality of the eligible studies. Forest plots display biomechanical findings as well as mean differences and confidence intervals. Level and consistency of evidence and clinical impact were evaluated for each risk factor. A meta-analysis was conducted where possible.

**Results:** A total of 11 studies were included (prospective (n=1), cross-sectional (n=10)). Overall the methodological score of the studies was moderate. Female runners who went onto developing ITBS presented with increased peak; hip adduction and knee internal rotation during the stance phase. There are no biomechanical risk factors which must strongly be considered when managing runners with ITBS.

**Conclusion:** The evidence base for screening or managing risk factors for runners with ITBS is limited. *J Orthop Sports Phys Ther 2014;x:xxx-xxx*

*Level of evidence: Prognosis, level 2a*

**Keywords**: kinetics, kinematics, lateral knee pain, recommendations

## 3.2 INTRODUCTION

Iliotibial band syndrome (ITBS) is the second most common running injury.[12] It is the main cause of lateral knee pain in runners and accounts for approximately one tenth of all running injuries.[12] An increase in ITBS was noted over the past decade. This increase may be related to the increasing number of runners worldwide.[18]

The cause of ITBS is thought to be multifactorial and the underlying pathology is poorly understood.[55] Initially it was proposed that ITBS results from excessive friction of the distal Iliotibial band (ITB) as it moves over the lateral femoral epicondyle with repetitive flexion and extension of the knee.[29] Another causal theory is impingement of the ITB against the lateral femoral epicondyle at approximately 20-30° of knee flexion.[10,22] Anatomical factors such as; leg length differences and increased prominence of the lateral epincondyles have also been noted as possible causes of ITBS.[3,12,22,25,26] Decreased flexibility and weakness of the surrounding musculature, particularly the abductor muscles may also lead to ITBS.[27,42,44,48,49] Unfortunately, the evidence that any of these factors are associated with the development of ITBS remains limited and inconsistent.

Biomechanical abnormalities may be another potential cause of ITBS in runners. These factors were explored in two previous systematic reviews.[41,60] Both of these reviews identified biomechanical differences in runners with ITBS compared to healthy runners. These biomechanical differences were focused on the dichotomous identification of significant and insignificant biomechanical differences between the two groups. This may limit the clinical application of these potential risk factors since the number of studies (quantifying the size of the evidence base), consistency between studies for a specific risk factor and effect size of the differences in risk factors, were not considered. Published reviews have not facilitated the identification of potential ITB risk factors in clinical practice. To facilitate the translation of research evidence, clinicians must know for which risk factors there are convincing evidence. Analysis of the evidence base for each risk factor may direct clinical questions for future research.

Since the last systematic review[60] four new studies were published. The aim of this systematic review is to provide an up to date evidence synthesis which will also analyse the size of the evidence base (number of studies), consistency between studies as well as the size of the differences of risk factors between runners with ITBS and healthy runners. In addition this study will consider both prospective cohort studies to identify factors which may predispose runners to ITBS as well as cross-sectional studies which may provide information about biomechanical factors which should be considered in runners with ITBS. To facilitate knowledge translation, a clinical algorithm was developed for the screening/prevention and management of ITBS in runners. To the knowledge of the reviewer, a similar algorithm has not been published.

## 3.3. METHODOLOGY

Data from published cross-sectional and cohort studies written in English, Afrikaans or German languages reporting on the 3D biomechanical risk factors associated with ITBS in runners were considered for inclusion. Studies were included if they were conducted to determine whether lower limb biomechanical differences exist between runners with ITBS or those who went on to developing ITBS compared to healthy runners irrespective of gender. Studies were excluded if they were conducted on cadavers or animals.

### 3.3.1 Search strategy

The following medical electronic databases were searched from inception to May 2014; PubMed, Science Direct, Scopus and SPORTDiscus. A broad strategy search approach was used, using the search terms in Table 3.1. There was no restriction for language. The search terms were selected to maximize potential hits. In order to increase the search, Pearling (searching the reference lists of eligible and published systematic reviews) was conducted. Full text articles were retrieved for studies which were deemed potentially eligible, based on the eligibility criteria.

**TABLE 3.1. Final search strategy**

| Database | Initial key words searched |
|---|---|
| PubMed | (Iliotibial band syndrome OR Iliotibial band friction syndrome OR Iliotibial band strain) AND running |
| Science Direct | Iliotibial band AND runners |
| SPORTSDisc | Iliotibial band AND runners |
| Scopus | (Iliotibial band syndrome OR Iliotibial band friction syndrome OR Iliotibial band strain) AND running |

### 3.3.2 Review process

The reviewer (JA) and second reviewer (QL) independently screened the titles and abstracts of all initial hits and all potential full text papers according to the eligibility criteria described above. The findings of both reviewers were discussed to ensure that all possible articles were screened and identified for inclusion.

### 3.3.3 Methodological appraisal

The Critical Appraisal Form for Quantitative Studies was used to appraise the methodological quality of the selected papers.[61] The reviewer referred to the user guidelines to assist in interpretation of the critical appraisal tool (CAT). The second reviewer reviewed the results and discrepancies in findings were discussed. The CAT comprised of 16 dichotomous questions. All questions which were answered *'yes'* added to the total score except for questions 3 and 4 where *'no'* was positive and added to the total score. The best score for methodological quality was 16. Following the methodological appraisal, included studies were classified according to their methodological quality. Since there are no gold standards, a CAT score above 75% was considered good methodological quality, a score between 50%-75% was considered moderate quality and a score lower than 50% was deemed to be of poor methodological quality.

To assess consistency of diagnosis, a seven item scale diagnosis checklist was compiled by the researcher (Table 3.2). This was based on previously used inclusion and exclusion criteria for ITBS participants.[62] Each paper was given a total score out of seven. A higher score indicated relatively better application of the inclusion and exclusion criteria.

**TABLE 3.2. Diagnostic criteria for ITBS**

| Key inclusion and exclusion criteria | ✔ / X |
|---|---|
| 1. Clear definition of pain was reported | |
| 2. Reports a typical history of ITBS with symptoms consistent to the condition | |
| 3. Diagnosis was confirmed by a medical practitioner/physiotherapist/ trainer | |
| 4. A positive clinical test (Obers/Nobles)/ palpation | |
| 5. No previous knee surgery | |
| 6. No internal derangement or other sources of lateral knee pain present | |
| 7. No previous spine or lower limb injury | |

Abbreviations: ITBS, Iliotibial band syndrome
✔ yes; x no

### 3.3.4 Data extraction

Two customised excel spreadsheets, based on Cochrane forms were used for data extraction. These spreadsheets extracted information regarding the sample demographics as well as the study aims, gait analysis tool used, running condition, running speed and phase of the gait cycle analysed.

### 3.3.5 Evidence grading

The FORM framework was followed to grade available evidence and provide recommendations for clinicians to identify risk factors of ITBS.[63] The FORM framework was developed, trialed and refined between 2004-2009 to provide an expanded and revised version of the Australian NHMRC (National Health and Medical Research Council) standards to adapt to the rapid growth and diversification of clinical practice.[63] For the purpose of this study three out of the five components of the FORM framework were used. The three elements utilized included; the level of evidence, consistency of evidence and the clinical impact. These elements are aligned with the aims of this systematic review.

#### *3.3.5.1 Level of evidence*

The level of evidence refers to the quality of evidence available for each biomechanical risk factor.[63] The evidence level for each biomechanical risk factor was graded according to the NHMRC hierarchy for aetiology which can be seen in Table 3.3.

**TABLE 3.3. NHMRC grading of evidence levels for aetiology**

| Evidence level | Study design |
|---|---|
| I | Systematic review of prospective cohort studies |
| II | One prospective cohort study |
| III | One retrospective cohort study |
| IV | A case control study |
| V | A cross-sectional study or case series |

#### *3.3.5.2 Consistency of the evidence*

The consistency evaluates the extent to which the findings of the included studies were consistent.[63] The grading of the consistency can be seen in Table 3.4.

**TABLE 3.4. Grading of level of consistency**

| Yes | No | N/A |
|---|---|---|
| All studies have consistent findings | Evidence is inconsistent | Only one study reports on this risk factor |

#### *3.3.5.3 Clinical impact*

Clinical impact is a subjective measure of the likely benefit that applying a particular finding would have on a specific population.[63] This review used mean difference as a measure of clinical impact (effect size). For biomechanical outcomes for which there was a significant difference found between runners with ITBS and healthy runners, Cohen's D was calculated. Table 3.5 shows how clinical impact was measured.

**TABLE 3.5. Effect size for clinical impact**

| Small clinical impact | Medium clinical impact | Large clinical impact |
|---|---|---|
| Less than 0.39 | 0.4-0.74 | Greater than 0.75 |

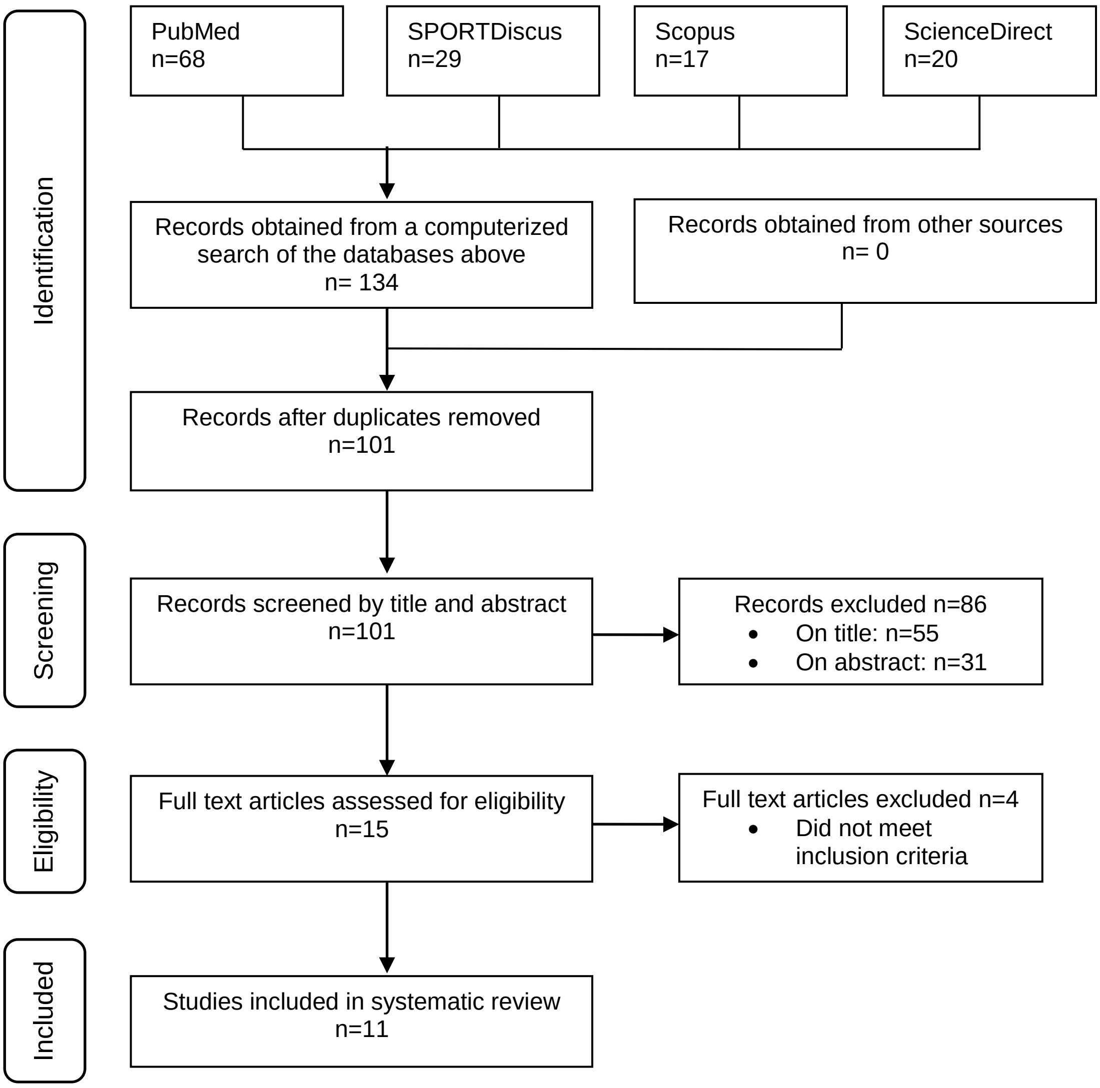
### 3.3.6 Data synthesis and analysis

Data were described narratively using tables or narrative summaries where appropriate. A random effects model in Revman version 5.2 was used to calculate mean differences and 95% confidence intervals (CI) provided that means and standard deviations (SD) were reported. Forest plots illustrating the mean difference and 95% CI were generated for graphic illustration. A meta-analysis was conducted for risk factors which were reported in at least two studies, provided that homogeneity in the outcomes and samples were present.

## 3.4 RESULTS

The initial search based on the search words described above yielded a total of 134 hits. Following the application of the inclusion and exclusion criteria to the titles and the removal of duplicates, 88 studies were excluded reducing the total number of potential studies for inclusion to 46. Thirty one studies were excluded after abstracts were read. The primary reason for excluding these studies was because they were conducted on participants who took part in sports other than running (cycling) and because they were not conducted on or compared to participants who currently had ITBS, had previously had ITBS or went on to developing ITBS during the study. After reading the full texts the number of studies to be included in this systematic review was reduced to 11. Results of the search strategy can be seen in Figure 3.1.

**FIGURE 3.1. PRISMA flow diagram of literature search**




Abbreviations: n,total number; =,equals

### 3.4.1 General description of the studies reviewed

*3.4.1.1 Study population*

The number of participants in each study varied from 16-126. None of the studies compared the kinetic and kinematic findings of males to females. All participants were runners who ran on a weekly basis. A sample description of the eleven eligible studies can be seen in Table 3.6.

*3.4.1.2 Study information*

A common aim among all studies was to determine whether there is a difference in the lower limb biomechanics of runners with ITBS or who went on to developing ITBS compared to a control group of healthy runners. In addition two of these studies also evaluated the trunk and pelvis.[64,65] Two studies included participants who ran barefoot,[45,66] the rest of the studies included participants who ran in a neutral running shoe. Two studies evaluated the full stride cycle,[46,67] the remainder evaluated the stance phase of running. A description of the study information including study aims as well as procedures can be seen in Table 3.7. Table 3.8 specifies which leg of the control group was used as a comparable to the affected leg of the ITBS group.

**TABLE 3.6. Sample description**

| | Sample size N | | | Gender M/F | | Mean Age yrs(SD) | | Mass kg(SD) | | Height m(SD) | | Running mileage km(w/mo) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TOT | ITB | CON | ITB | CON | ITB | CON | ITB | CON | ITB | CON | ITB | CON |
| Meisser et al[25] | 126 | 56 | 70 | 33M 17F | 53M 17F | 33.9 (1.2) | 35.0 (1.2) | 66.4 (1.9) | 70.2 (1.3) | 1.7 (0.13) | 1.74 (0.10) | 50.3 w | 42.5 w |
| Orchard et al[3] | 9 | 9 | N/A | 4M 5F | N/A | 27.0 (9.5) | N/A | DNR | N/A | DNR | N/A | DNR | N/A |
| Miller et al[46]* | 16 | 8 | 8 | DNR | DNR | 27.5 (9.0) | 26.4 (7.7) | 68.7 (15.9) | 71.3 (14.4) | 1.7 (0.06) | 1.72 (0.08) | 23.7 w | 11.8 w |
| Noehren et al[42] | 36 | 18 | 18 | 18F | 18F | 26.8 | 28.5 | DNR | DNR | DNR | DNR | 96.2 mo | 99.3 mo |
| Miller et al[67]* | 16 | 8 | 8 | DNR | DNR | 27.5 (9.0) | 26.4 (7.7) | 68.7 (15.9) | 71.3 (14.4) | 1.7 (0.06) | 1.72 (0.08) | DNR | DNR |
| Ferber et al[44] | 70 | 35 | 35 | 35F | 35F | 35.47 (10.35) | 31.23 (11.05) | 58.62 (3.97) | 61.30 (6.97) | 1.65 (0.06) | 1.67 (0.07) | 123.82 mo | 119.27 mo |
| Grau et al[45] | 36 | 18 | 18 | 13M 5F | 13M 5F | 36.0 (7.0) | 37.0 (9.0) | 71.0 (12.0) | 70.0 (10.0) | 1.77 (0.08) | 1.77 (0.09) | DNR | DNR |
| Hein et al[66] | 36 | 18 | 18 | 18F | 18F | 36.0 (7.0) | 37.0 (9.0) | 71.0 (12.0) | 70.0 (10.0) | 1.77 (0.08) | 1.77 (0.09) | DNR | DNR |
| Foch and Milner[65] | 34 | 17 | 17 | 17F | 17F | 26.6 (6.6) | 25.4 (6.2) | 57.9 (3.9) | 58.0 (4.6) | 1.67 (0.05) | 1.67 (0.06) | 44.9 w | 44.7 w |
| Foch and Milner[64] | 40 | 20 | 20 | 20F | 20F | 26.0 (5.6) | 23.7 (5.5) | 58.8 (7.4) | 58.9 (5.7) | 1.67 (0.04) | 1.68 (0.06) | 41.8 w | 38.6 w |
| Noehren et al[68] | 34 | 17 | 17 | 17M | 17M | 33.5 (6.6) | 28.1 (5.7) | 76.7 (5.7) | 69.9 (8.7) | 1.79 (0.06) | 1.80 (0.07) | 31.4 w | 30.8 w |

Abbreviations: n, number of participants; M, male; F, female; yrs, number of years; SD, standard deviation; kg, kilograms; m, meters; km, kilometres; w, weekly; m, monthly; TOT, total number of participants; ITB,group of participants with ITBS; CON, group of healthy participants; N/A, not applicable; DNR, did not report
*study conducted on runners who ran to fatigue

**TABLE 3.7. Description of study information**

| | Study Aim | Gait analysis tool | Running condition | Speed | Phase of running cycle |
|---|---|---|---|---|---|
| Meisser et al[25] | To determine whether there is a relationship between selected variables and runners affected by ITBS | High speed video camera, force plate was used | 22.75m runway neutral running shoe | Self-selected | Stance phase |
| Orchard et al[3] | To establish a model of the pathogenesis of ITBS in distance runners | Vicon 3D Motion analysis, force plate was used | 2 x 2 minute runs on a treadmill, second run was performed with a heel raise neutral running shoe | Constant pace | Stance phase |
| Miller et al[46]* | To expand the base of knowledge of ITBS biomechanics when comparing runners with ITBS to healthy runners during a run to voluntary exhaustion | 8-camera Vicon 3D motion analysis no force plate used | Quinton treadmill at a level grade neutral running shoe | Speed that would exhaust the runner within 20 minutes | Full stride cycle |
| Noehren et al[42] | To compare the pre-existing frontal and transverse plane lower extremity kinetics and kinematics between a group of female runners who develop ITBS compared to healthy controls | 6-camera Vicon 3D Motion analysis, force plate was used | 25m runway neutral running shoe | $3.7m/s^{-1}$ | Stance phase |
| Miller et al[67]* | To investigate the role of lower extremity coordination variability in runners with retrospective cases of ITBS during an exhaustive run | 8-camera Vicon 3D motion analysis, no force plate used | Quinton treadmill at a level grade neutral running shoe | Speed that would exhaust the runner within 20 minutes | Full stride cycle |
| Ferber et al[44] | To examine differences in running biomechanics between runners who previously sustained ITBS and runners with no knee-related running injuries | 6-camera Vicon 3D motion analysis, force plate was used | 25m runway neutral running shoe | $3.65m/s^{-1}$ | Stance phase |

| | | | | | |
|---|---|---|---|---|---|
| Grau et al[45] | Investigate differences between healthy runners and runners with ITBS with regards to kinematic characteristics in order to suggest treatment strategies for ITBS | 6-camera Vicon 3D motion analysis, force plate was used | 13m EVA foam runway<br>Barefoot | 3.3m/s$^{-1}$ | Stance phase |
| Hein et al[66] | To determine whether or not CRP variability is an effective and beneficial method for providing information about possible differences or similarities between injured and non-injured runners | 6-camera Vicon 3D motion analysis, did not state whether a force plate was used | 13m EVA foam runway<br>Barefoot | 3.3m/s$^{-1}$ | Stance phase |
| Foch and Milner[65] | To determine if biomechanics during running and frontal plane core endurance differ between female runners with previous ITBS and controls | 9-camera Vicon 3D motion analysis, force plate was used | 17m runway<br>neutral running shoe | 3.5m/s$^{-1}$ | Stance phase |
| Foch and Milner[64] | To determine whether women with previous ITBS exhibited differences in kinetics and kinematics during running compared to controls using a PCA approach | 9-camera Vicon 3D motion analysis, force plate was used | 17m runway<br>neutral running shoe | 3.5m/s$^{-1}$ | Stance phase |
| Noehren et al[68] | To assess the difference in abduction and external rotation strength, ITB length as well as frontal and transverse plane kinematics at the hip and knee in men with and without ITBS | 15-camera Vicon 3D motion analysis, no force plate was used | Treadmill<br>New Balance WR662 running shoe | 3.3m/s$^{-1}$ | Stance phase |

Abbreviations: m, meters; ITBS, Iliotibial band syndrome; 3D, three dimensional; m/s$^{-1}$, meters per second; PCA. Principal components analysis; ITB, Iliotibial band

*study conducted on runners who ran to fatigue

**TABLE 3.8. Comparison of legs used when comparing case to control**

| Case (ITBS) | | Control (healthy) | Source |
|---|---|---|---|
| ITBS side | vs | Right leg | Noehren et al[42]; Ferber et al[44] |
| ITBS side | vs | Same leg | Grau et al[45]; Hein et al[66]; Noehren et al[68] |
| ITBS side | vs | Random leg | Meisser et al[25] |
| ITBS side | vs | Non injured leg | Orchard et al[3] |
| ITBS side | vs | Did not state | Foch and Milner[65]; Foch and Milner[64]; Miller et al[46]*; Miller at al[67]* |

Abbreviations: ITBS, Iliotibial band syndrome; vs, versus

*study conducted on runners who ran to fatigue

### 3.4.2 Methodological quality appraisal

The methodological quality appraisal scores of the eleven eligible studies can be seen in Table 3.9. The mean methodological score was 64.1%. Based on the reviewers classification of methodological quality, one of the eleven studies was deemed good quality, scoring 75%, this study also happened to be the only prospective cohort study (Level II evidence).[42] The rest of the studies were considered to be of moderate quality scoring between 56.25% - 68.75% and were all cross-sectional (Level V evidence).

**TABLE 3.9. Methodological quality appraisal**

| | | Meisser et al[25] | Orchard et al[3] | Miller et al[46]* | Noehren et al[42] | Miller at al[67]* | Ferber et al[44] | Grau et al[45] | Hein et al[66] | Foch and Milner[65] | Foch and Milner[64] | Noehren et al[68] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | The purpose of the study was clearly stated | + | + | + | + | + | + | + | + | + | + | + |
| 2 | The study design was appropriate | + | + | + | + | + | + | + | + | + | + | + |
| 3 | The study detected sample biases (No adds to the total score) | + | + | + | + | + | + | + | + | + | + | + |
| 4 | Measurement biases were detected in the study (No adds to the total score) | + | + | + | + | + | + | + | + | + | + | + |
| 5 | The sample size was stated | + | + | + | + | + | + | + | + | + | + | + |
| 6 | The sample was described in detail | + | + | + | + | + | + | + | + | + | + | + |
| 7 | The sample size was justified | - | - | - | + | - | + | - | - | + | - | + |
| 8 | The outcomes were clearly stated and relevant to the study | + | + | + | + | + | + | + | + | + | + | + |
| 9 | The method of measurement was described sufficiently | + | + | + | + | + | + | + | + | + | + | + |
| 10 | The measures used were reliable | - | - | - | - | - | - | - | - | - | - | - |
| 11 | The measures used were valid | - | - | - | - | - | - | - | - | - | - | - |
| 12 | The results were reported in terms of statistical significance | + | + | + | + | + | + | + | + | + | + | + |
| 13 | The analysis methods used were appropriate | + | + | + | + | + | + | + | + | + | + | + |
| 14 | Clinical importance was reported | + | + | + | + | + | + | + | - | - | - | + |
| 15 | Missing data was reported where appropriate | - | - | - | + | - | - | + | - | - | - | - |
| 16 | Conclusions were relevant and appropriate given the methods and resuts of the study | + | + | + | + | + | + | + | + | + | + | + |
| | Study Results | | | | | | | | | | | |
| | Total CAT score /16 | 10 | 10 | 10 | 12 | 10 | 11 | 11 | 9 | 10 | 9 | 11 |
| | Total CAT % | 62.5 | 62.5 | 62.5 | 75.0 | 62.5 | 68.75 | 68.75 | 56.25 | 62.5% | 56.25 | 68.75 |

Abbreviations: CAT,Critical appraisal tool

*study conducted on runners who ran to fatigue

### 3.4.3 Diagnostic criteria

Table 3.10 outlines the key diagnostic criteria used by the eligible studies to determine which participants were eligible to take part. Eligible studies used these criteria to determine participant inclusion.

**TABLE 3.10. Diagnostic criteria results for ITBS**

| | **Key inclusion and exclusion criteria** | Meisser et al[25] | Orchard et al[3] | Miller et al[46*] | Noehren et al[19] | Miller at al[67*] | Ferber et al[44] | Grau et al[45] | Hein et al[66] | Foch and Milner[65] | Foch and Milner[64] | Noehren et al[18] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Clear definition of location of pain was reported | ✓ | ✓ | x | x | x | ✓ | ✓ | ✓ | x | x | ✓ |
| 2 | Reports a typical history of ITBS with symptoms consistent to the condition | x | ✓ | ✓ | x | x | ✓ | ✓ | ✓ | x | x | ✓ |
| 4 | Diagnosis was confirmed by a medical practitioner/physiotherapist/ trainer | ✓ | ✓ | x | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 4 | A positive clinical test (Obers/Nobles)/ palpation | ✓ | ✓ | ✓ | x | x | x | ✓ | ✓ | x | x | ✓ |
| 5 | No previous knee surgery | x | ✓ | x | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 6 | No internal derangement or other sources of lateral knee pain present | ✓ | ✓ | x | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 7 | No previous spine or lower limb injury | ✓ | ✓ | x | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | x | ✓ |
| | | 5 | 7 | 2 | 4 | 4 | 6 | 7 | 7 | 4 | 3 | 7 |

Abbreviations: ITBS, Iliotibial band syndrome
*study conducted on runners who ran to fatigue

### 3.4.4 Biomechanical findings during the stance phase of running

Nine of the eleven studies evaluated the stance phase of running.[3,25,42,44,45,64-66,68] Seven reported on means and standard deviations (results are displayed in the forest plots below in Figures 3.2-3.6),[3,25,42,44,45,65,68] one used continuous relative phase (CRP)[66] to describe the relationship of one joint to another and one used principal components analysis (PCA).[64]

#### *3.4.4.1 Hip*

Figure 3.2 illustrates the hip risk factors identified during the stance phase of running. A total of 12 risk factors were studied. Findings of five factors were found to be significant. Male and female runners with ITBS were found to have significantly decreased; total hip frontal range of motion in abduction and adduction,[45] peak hip flexion velocity,[45] time of maximum hip flexion[45] as well as decreased peak hip abduction velocity.[45] Two studies found peak hip adduction to be a significant risk factor;[42,45] one study found that female runners who later developed ITBS had significantly increased range of motion[42] and the other found that male and female runners with ITBS had decreased range of motion.[45]

*3.4.4.2 Knee*

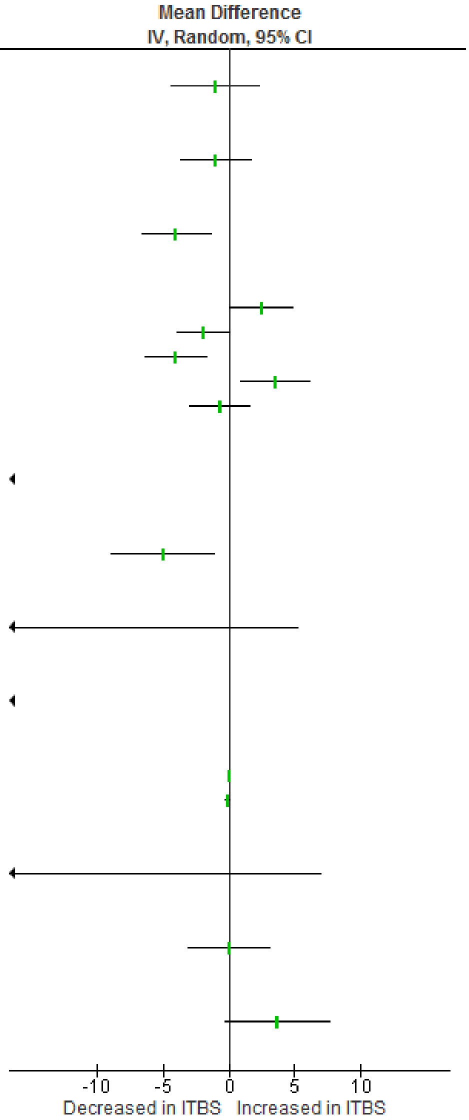
Figure 3.3 illustrates the knee risk factors identified during the stance phase of running. A total of 13 risk factors were studied. Findings of four risk factors were found to be significant. Female runners with ITBS were found to have significantly increased peak knee internal rotation,[42,44] male runners were found to have significantly increased peak knee adduction[68] where male and female runners were found to have significantly decreased peak knee flexion velocity[45] and decreased time of peak knee flexion.[45]

*3.4.4.3 Ankle and foot*

Figure 3.4 illustrates the ankle and foot risk factors during the stance phase of running, a total of 16 risk factors were studied. Nine of these factors were found to be significant. Male and female runners with ITBS were found to have significantly decreased; total rearfoot eversion range of motion,[25] total rearfoot pronation range of motion,[25] peak ankle flexion velocity[45] and peak rearfoot pronation velocity.[25] Male and female runners with ITBS were also found to have significantly increased; peak rearfoot eversion,[25] peak rearfoot pronation,[25] peak rearfoot supination velocity[25] as well as increased time to maximum rearfoot pronation[25] and increased time to maximum rearfoot pronation velocity.[25]

**FIGURE 3.2. Hip risk factors during the stance phase of running**

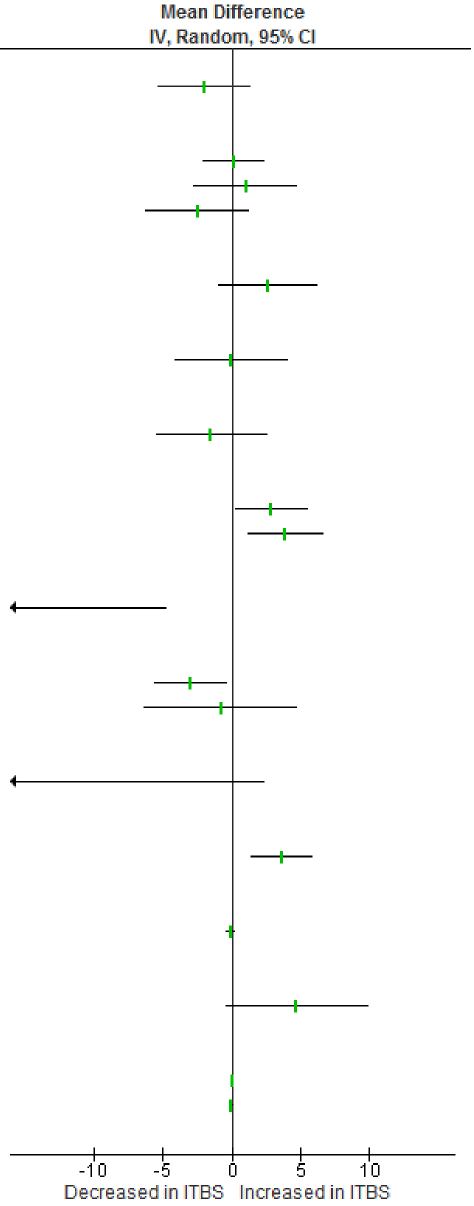
| Study or Subgroup | ITBS Mean | ITBS SD | ITBS Total | Control Mean | Control SD | Control Total | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|
| **1.1.1 Maximum hip flexion (°)** | | | | | | | |
| Grau et al., 2011 | 31 | 4 | 18 | 32 | 6 | 18 | -1.00 [-4.33, 2.33] |
| **1.1.2 Range of motion of hip in flexion and extension (°)** | | | | | | | |
| Grau et al., 2011 | 44 | 3 | 18 | 45 | 5 | 18 | -1.00 [-3.69, 1.69] |
| **1.1.3 Total hip frontal range of motion in abduction and adduction (°)** | | | | | | | |
| Grau et al., 2011 | 9 | 4 | 18 | 13 | 4 | 18 | -4.00 [-6.61, -1.39] |
| **1.1.4 Peak hip Adduction (°)** | | | | | | | |
| Ferber et al., 2010 | 10.39 | 4.36 | 35 | 7.92 | 5.84 | 35 | 2.47 [0.06, 4.88] |
| Foch and Milner, 2013 | 13.1 | 2.6 | 17 | 15 | 3.3 | 17 | -1.90 [-3.90, 0.10] |
| Grau et al., 2011 | 9 | 3 | 18 | 13 | 4 | 18 | -4.00 [-6.31, -1.69] |
| Noehrenn et al., 2007 | 14.1 | 2.5 | 18 | 10.6 | 5.1 | 18 | 3.50 [0.88, 6.12] |
| Noehrenn et al., 2014 | 7.9 | 2.6 | 17 | 8.6 | 4.1 | 17 | -0.70 [-3.01, 1.61] |
| **1.1.5 Peak hip flexion velocity (°/s)** | | | | | | | |
| Grau et al., 2011 | 30 | 76 | 18 | 119 | 93 | 18 | -89.00 [-144.48, -33.52] |
| **1.1.6 Time of maximum hip flexion (%/ROP)** | | | | | | | |
| Grau et al., 2011 | 12 | 6 | 18 | 17 | 6 | 18 | -5.00 [-8.92, -1.08] |
| **1.1.7 Peak hip extension velocity (°/s)** | | | | | | | |
| Grau et al., 2011 | 299 | 30 | 18 | 324 | 58 | 18 | -25.00 [-55.17, 5.17] |
| **1.1.8 Peak hip abduction velocity (°/s)** | | | | | | | |
| Grau et al., 2011 | 132 | 41 | 18 | 190 | 53 | 18 | -58.00 [-88.96, -27.04] |
| **1.1.9 Peak hip abductor moment (Nm/kg)** | | | | | | | |
| Ferber et al., 2010 | 1.33 | 0.24 | 35 | 1.33 | 0.18 | 35 | 0.00 [-0.10, 0.10] |
| Noehrenn et al., 2007 | -1.4 | 0.37 | 18 | -1.3 | 0.19 | 18 | -0.10 [-0.29, 0.09] |
| **1.1.10 Peak hip adduction velocity (°/s)** | | | | | | | |
| Grau et al., 2011 | 197 | 79 | 18 | 244 | 86 | 18 | -47.00 [-100.95, 6.95] |
| **1.1.11 Time of maximum hip adduction (%/ROP)** | | | | | | | |
| Grau et al., 2011 | 32 | 6 | 18 | 32 | 3 | 18 | 0.00 [-3.10, 3.10] |
| **1.1.12 Peak hip internal rotation(°)** | | | | | | | |
| Noehrenn et al., 2014 | 13.3 | 6.6 | 17 | 9.6 | 5.2 | 17 | 3.70 [-0.29, 7.69] |




Abbreviations: SD, standard deviation; CI, confidence interval; °, degrees; °/s, degrees per second; %/ROP, percent of the roll over process; Nm/kg, newtons per kilogram; ITBS, Iliotibial band syndrome

**FIGURE 3.3. Knee risk factors during the stance phase of running**

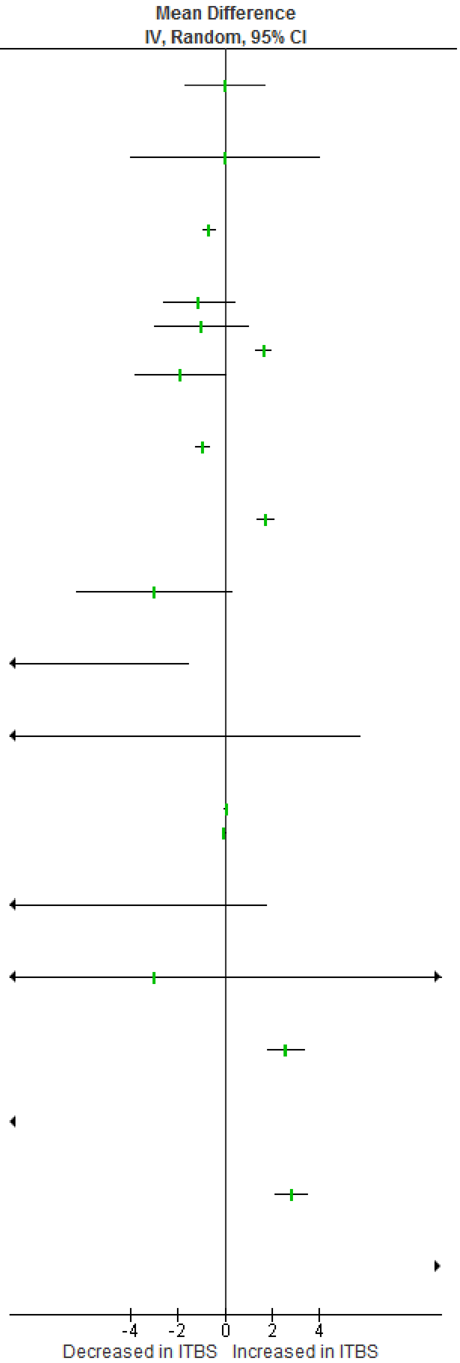
| | ITBS | | | Control | | | Mean Difference |
|---|---|---|---|---|---|---|---|
| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | IV, Random, 95% CI |
| **1.2.1 Range of motion of knee in flexion and extension (°)** | | | | | | | |
| Grau et al., 2011 | 24 | 4 | 18 | 26 | 6 | 18 | -2.00 [-5.33, 1.33] |
| **1.2.2 Peak knee flexion (°)** | | | | | | | |
| Ferber et al., 2010 | 45.3 | 4.5 | 35 | 45.21 | 5 | 35 | 0.09 [-2.14, 2.32] |
| Grau et al., 2011 | 38 | 4 | 18 | 37 | 7 | 18 | 1.00 [-2.72, 4.72] |
| Orchard et al., 1996 | 53.8 | 4 | 9 | 56.3 | 4 | 9 | -2.50 [-6.20, 1.20] |
| **1.2.3 Peak knee flexion at heel strike (°)** | | | | | | | |
| Noehrenn et al., 2007 | -11.8 | 4.78 | 18 | -14.4 | 6.03 | 18 | 2.60 [-0.95, 6.15] |
| **1.2.4 Peak knee flexion at foot strike (°)** | | | | | | | |
| Orchard et al., 1996 | 21.4 | 4.3 | 9 | 21.5 | 4.5 | 9 | -0.10 [-4.17, 3.97] |
| **1.2.5 Peak knee flexion at toe off (°)** | | | | | | | |
| Orchard et al., 1996 | 29.8 | 4.8 | 9 | 31.3 | 3.8 | 9 | -1.50 [-5.50, 2.50] |
| **1.2.6 Peak knee internal rotation (°)** | | | | | | | |
| Ferber et al., 2010 | 1.75 | 5.94 | 35 | -1.14 | 4.96 | 35 | 2.89 [0.33, 5.45] |
| Noehrenn et al., 2007 | 3.9 | 3.7 | 18 | 0.02 | 4.6 | 18 | 3.88 [1.15, 6.61] |
| **1.2.7 Peak knee flexion velocity (°/s)** | | | | | | | |
| Grau et al., 2011 | 455 | 105 | 18 | 524 | 91 | 18 | -69.00 [-133.19, -4.81] |
| **1.2.8 Time of peak knee flexion (%/ROP)** | | | | | | | |
| Grau et al., 2011 | 28 | 4 | 18 | 31 | 4 | 18 | -3.00 [-5.61, -0.39] |
| Orchard et al., 1996 | 45.6 | 3.9 | 9 | 46.4 | 7.5 | 9 | -0.80 [-6.32, 4.72] |
| **1.2.9 Peak knee extension velocity (°/s)** | | | | | | | |
| Grau et al., 2011 | 236 | 40 | 18 | 273 | 75 | 18 | -37.00 [-76.27, 2.27] |
| **1.2.10 Peak knee adduction (°)** | | | | | | | |
| Noehrenn et al., 2014 | 7.3 | 2.8 | 17 | 3.7 | 3.6 | 17 | 3.60 [1.43, 5.77] |
| **1.2.11 Peak knee adduction moment (Nm/kg)** | | | | | | | |
| Foch and Milner, 2013 | 1 | 0.3 | 17 | 1.1 | 0.5 | 17 | -0.10 [-0.38, 0.18] |
| **1.2.12 Peak knee external rotation (°)** | | | | | | | |
| Noehrenn et al., 2014 | 12.2 | 7.8 | 17 | 7.5 | 7.4 | 17 | 4.70 [-0.41, 9.81] |
| **1.2.13 Peak knee external rotation moment (Nm/kg)** | | | | | | | |
| Ferber et al., 2010 | 0.09 | 0.06 | 35 | 0.09 | 0.05 | 35 | 0.00 [-0.03, 0.03] |
| Noehrenn et al., 2007 | -0.12 | 0.12 | 18 | -0.09 | 0.05 | 18 | -0.03 [-0.09, 0.03] |




Abbreviations: SD, standard deviation; CI, confidence interval; °, degrees; °/s, degrees per second; %/ROP, percent of the roll over process; Nm/kg, newtons per kilogram; ITBS, Iliotibial band syndrome

**FIGURE 3.4. Ankle and foot risk factors during the stance phase of running**

| Study or Subgroup | ITBS Mean | ITBS SD | ITBS Total | Control Mean | Control SD | Control Total | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|
| **1.3.1 Peak ankle flexion (°)** | | | | | | | |
| Grau et al., 2011 | 20 | 2 | 18 | 20 | 3 | 18 | 0.00 [-1.67, 1.67] |
| **1.3.2 Range of motion of ankle in flexion and extension (°)** | | | | | | | |
| Grau et al., 2011 | 53 | 5 | 18 | 53 | 7 | 18 | 0.00 [-3.97, 3.97] |
| **1.3.3 Total rearfoot eversion range of motion (°)** | | | | | | | |
| Meisser et al., 1995 | 9.08 | 0.71 | 42 | 9.76 | 0.44 | 54 | -0.68 [-0.92, -0.44] |
| **1.3.4 Peak rearfoot eversion (°)** | | | | | | | |
| Ferber et al., 2010 | 8.94 | 3.16 | 35 | 10.04 | 3.22 | 35 | -1.10 [-2.59, 0.39] |
| Grau et al., 2011 | 11 | 3 | 18 | 12 | 3 | 18 | -1.00 [-2.96, 0.96] |
| Meisser et al., 1995 | 3.84 | 0.78 | 42 | 2.19 | 0.79 | 54 | 1.65 [1.33, 1.97] |
| Noehrenn et al., 2007 | 9.7 | 3.3 | 18 | 11.6 | 2.5 | 18 | -1.90 [-3.81, 0.01] |
| **1.3.5 Total rearfoot pronation range of motion (°)** | | | | | | | |
| Meisser et al., 1995 | 12.11 | 0.78 | 42 | 13.08 | 0.58 | 54 | -0.97 [-1.25, -0.69] |
| **1.3.6 Peak rearfoot pronation (°)** | | | | | | | |
| Meisser et al., 1995 | 12.94 | 0.86 | 42 | 11.19 | 0.89 | 54 | 1.75 [1.40, 2.10] |
| **1.3.7 Range of motion of rearfoot in eversion/inversion (°)** | | | | | | | |
| Grau et al., 2011 | 29 | 5 | 18 | 32 | 5 | 18 | -3.00 [-6.27, 0.27] |
| **1.3.8 Peak ankle flexion velocity (°/s)** | | | | | | | |
| Grau et al., 2011 | 297 | 51 | 18 | 330 | 45 | 18 | -33.00 [-64.42, -1.58] |
| **1.3.9 Peak ankle extension velocity (°/s)** | | | | | | | |
| Grau et al., 2011 | 663 | 72 | 18 | 730 | 140 | 18 | -67.00 [-139.73, 5.73] |
| **1.3.10 Peak rearfoot invertor moment (Nm/kg)** | | | | | | | |
| Ferber et al., 2010 | 0.14 | 0.13 | 35 | 0.09 | 0.08 | 35 | 0.05 [-0.00, 0.10] |
| Noehrenn et al., 2007 | -0.15 | 0.1 | 18 | -0.13 | 0.09 | 18 | -0.02 [-0.08, 0.04] |
| **1.3.11 Peak rearfoot inversion velocity (°/s)** | | | | | | | |
| Grau et al., 2011 | 414 | 87 | 18 | 480 | 118 | 18 | -66.00 [-133.73, 1.73] |
| **1.3.12 Peak rearfoot eversion velocity (°/s)** | | | | | | | |
| Grau et al., 2011 | 233 | 97 | 18 | 236 | 67 | 18 | -3.00 [-57.46, 51.46] |
| **1.3.13 Time to maximum rearfoot pronation** | | | | | | | |
| Meisser et al., 1995 | 42.98 | 2.1 | 42 | 40.4 | 1.75 | 54 | 2.58 [1.79, 3.37] |
| **1.3.14 Peak rearfoot pronation velocity (°/s)** | | | | | | | |
| Meisser et al., 1995 | 336.75 | 23.9 | 42 | 360.25 | 21.03 | 54 | -23.50 [-32.65, -14.35] |
| **1.3.15 Time to maximum rearfoot pronation velocity** | | | | | | | |
| Meisser et al., 1995 | 4.85 | 2.14 | 42 | 2.06 | 0.46 | 54 | 2.79 [2.13, 3.45] |
| **1.3.16 Peak rearfoot supination velocity (°/s)** | | | | | | | |
| Meisser et al., 1995 | 270.04 | 29.05 | 42 | 222.51 | 13.65 | 54 | 47.53 [38.02, 57.04] |

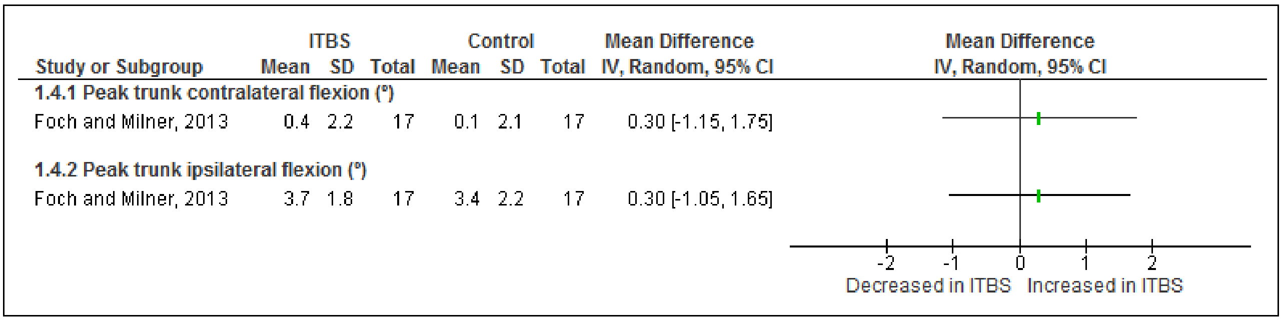



Abbreviations: SD, standard deviation; CI, confidence interval; °, degrees; °/s, degrees per second; Nm/kg, newtons per kilogram; ITBS, Iliotibial band syndrome

### *3.4.4.4 Trunk*

Figure 3.5 illustrates the two trunk risk factors studied during the stance phase of running, neither of these risk factors were found to be significant in female runners.

**FIGURE 3.5. Trunk risk factors during the stance phase of running**

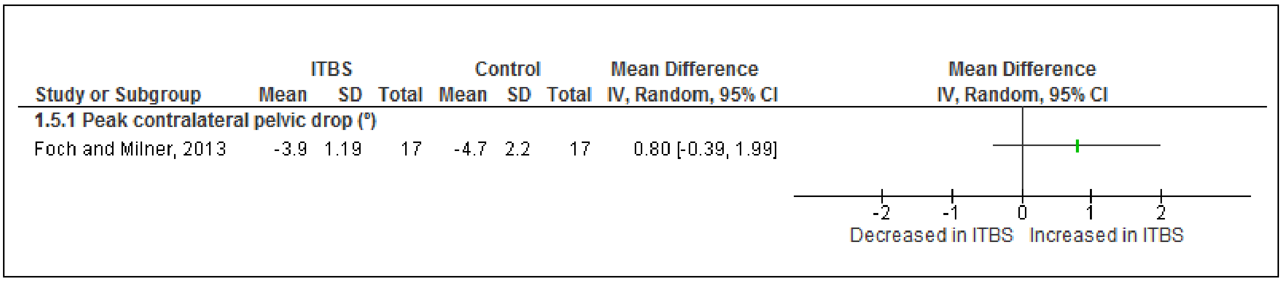



Abbreviations: SD, standard deviation; CI, confidence interval; °, degrees; ITBS, Iliotibial band syndrome

### *3.4.4.5 Pelvis*

Figure 3.6 illustrates the one pelvic risk factor analysed during the stance phase of running. This risk factor was not found to be significant in female runners.

**FIGURE 3.6. Pelvic risk factor during the stance phase of running**




Abbreviations: SD, standard deviation; CI, confidence interval; °, degrees; ITBS, Iliotibial band syndrome

### *3.4.4.6 Continuous relative phase (CRP)*

One study by Hein et al[66] was conducted on CRP variability for four coupling pairs. No difference was found in CRP between female runners with and without ITBS concluding that CRP variability may not be considered a risk factor for ITBS.

### *3.4.4.7 Principal components analysis (PCA)*

One study by Foch and Milner,[64] was conducted on PCA in female runners. Female runners with previous ITBS were found to have decreased hip adduction throughout the stance phase of running (PC1). This is the only study that has been conducted on PCA therefore the evidence is limited.

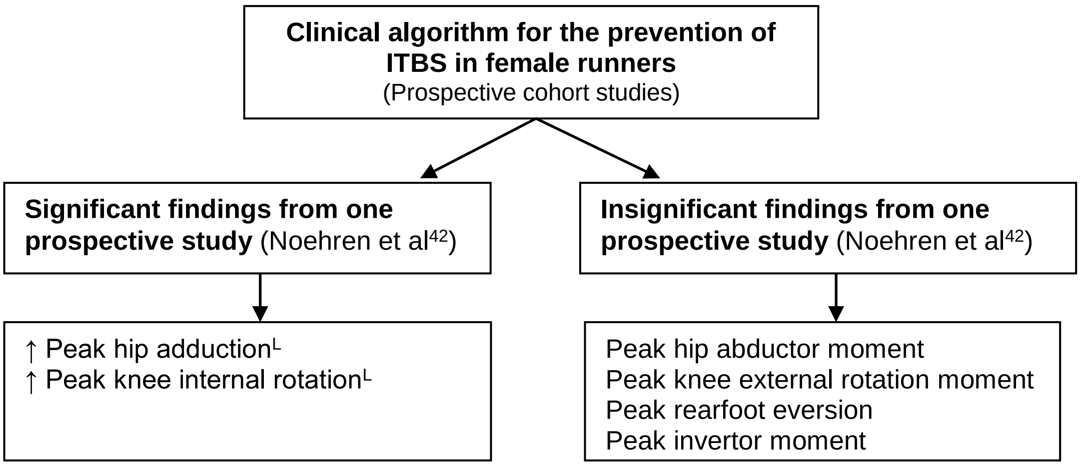
### 3.4.5 Evidence grading of the studies conducted during the stance phase of running

Evidence grading of the seven studies included in the forest plots above have been characterized according to their level of evidence.[3,25,42,44,45,65,68] All studies were cross-sectional with level V evidence apart from one study of level II evidence.[42] Grading the evidence allowed for a clinical algorithm to be developed for the screening/prevention (Figure 3.7) and management (Figure 3.8) of ITBS in runners. This algorithm acts as a guide for clinicians to identify the biomechanical risk factors which may be at fault in runners already presenting with ITBS or in runners who may be at risk of developing ITBS.

*3.4.5.1 Development of the clinical algorithm*

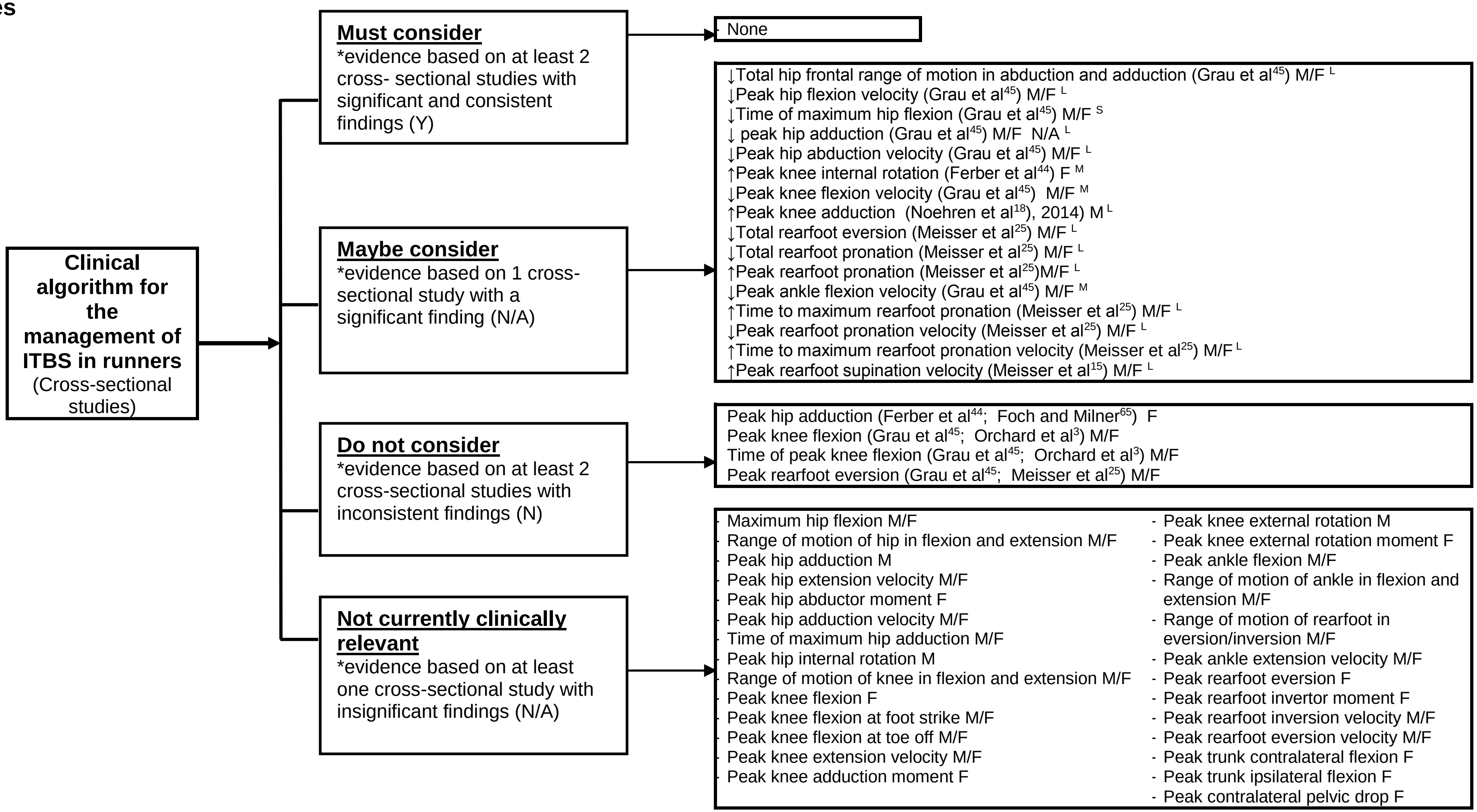
All risk factors from previous studies were identified. These risk factors were classified into two categories: runners who went onto developing ITBS (prospective) and runners currently presenting with ITBS (cross-sectional). The gender for each risk factor was specified. Prospective findings (Figure 3.7) were then classified into whether they were significant or insignificant. Clinical impact was determined for significant findings. Cross-sectional findings (Figure 3.8) were classified according to one of four categories which were based on whether the findings were 'significant', 'insignificant' and 'consistent'. The clinical impact for the 'must consider' and 'maybe consider' categories were determined.

**FIGURE 3.7. Clinical algorithm for the prevention of ITBS in female runners based on evidence from prospective cohort studies**




Abbreviations: ITBS; Iliotibial band syndrome; ↑, increased L, Large clinical impact

**FIGURE 3.8. Clinical algorithm for the management of ITBS in runners based on evidence from cross-sectional studies**



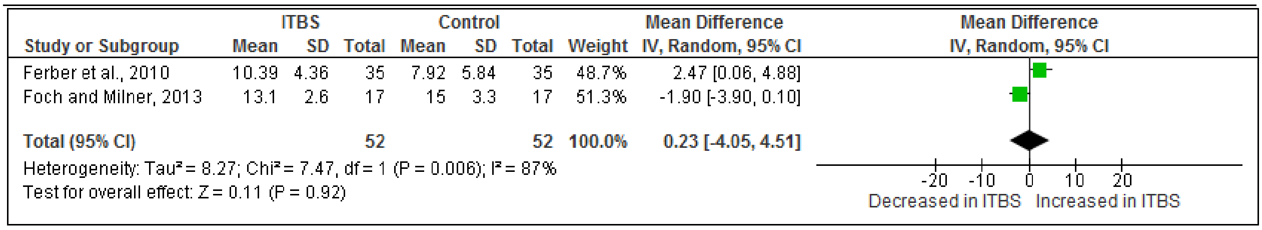

Abbreviations: ITBS; Iliotibial band syndrome; M/F,applicable to males and females; M, males; F,females; $^{S}$, small clinical effect; $^{M}$, medium clinical effect; $^{L}$, large clinical effect; (Y), findings are consistent; (N), findings are inconsistent; (N/A), not applicable; ↓, decreased; ↑, increased

### *3.4.5.1 Cross sectional studies*

Six of the seven studies conducted on the stance phase of running were cross-sectional and were conducted on runners who already had ITBS.[3,25,44,45,65,68] The management algorithm (Figure 3.8) identified; no risk factors which clinicians '*must consider*', fifteen risk factors which clinicians should '*maybe consider*' and four risk factors which clinicians '*do not need to consider*' when managing runners presenting with ITBS. These findings were categorized based on the consistency of the significant and insignificant biomechanical findings. Twelve risk factors were found to have a large clinical impact, three were found to have a medium clinical impact and one was found to have a small clinical impact (Figure 3.8).

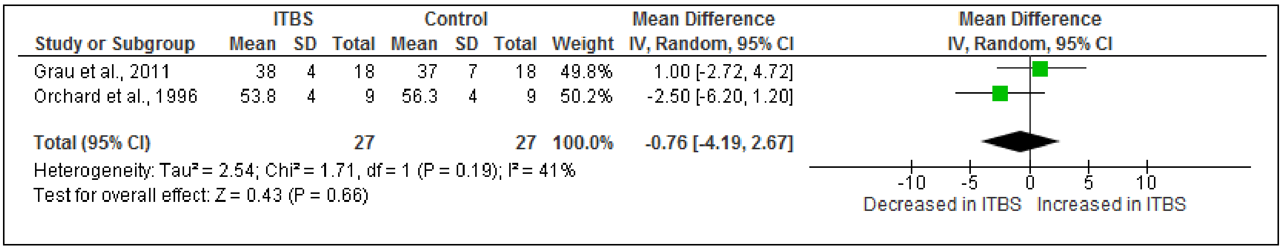
A meta-analysis was conducted to determine the clinical impact for peak hip adduction in females (Figure 3.9) as well as peak knee flexion (Figure 3.10), time of peak knee flexion (Figure 3.11) and peak rearfoot eversion (Figure 3.12) in males and females during the stance phase. These were risk factors which were conducted on runners of the same gender and were identified as not needing to be screened as two or more studies had inconsistent findings. These were therefore classified as risk factors which clinicians 'do not need to consider' in the management algorithm (Figure 3.8). Peak hip adduction (Figure 3.9) was found to be an insignificant risk factor for ITBS in female runners. Peak knee flexion (Figure 3.10) and peak rearfoot eversion (Figure 3.12) were also found to be insignificant risk factors for ITBS in male and female runners. Time of peak knee flexion (Figure 3.11) was found to be significant, however due to the inconsistency in findings it may not need to be considered as a risk factor for ITBS in male and female runners.

**FIGURE 3.9. Meta-analysis of peak hip adduction in female runners during the stance phase of running**



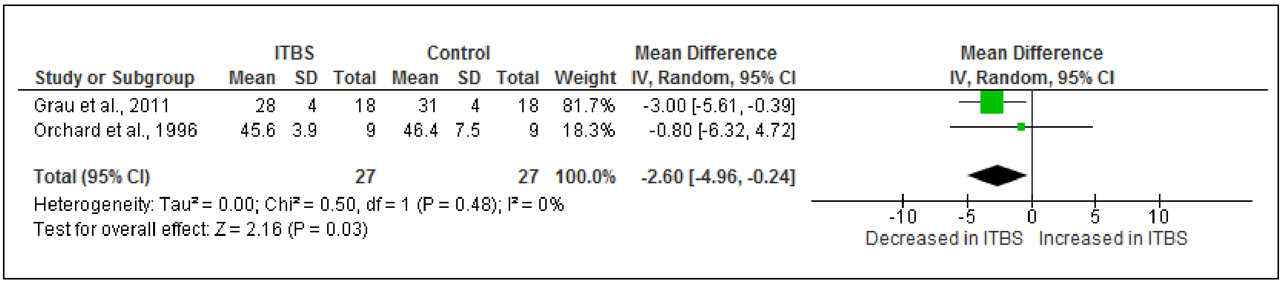

Abbreviations: SD, standard deviation; CI, confidence interval; ITBS, Iliotibial band syndrome

**FIGURE 3.10. Meta-analysis of peak knee flexion in male and female runners during the stance phase of running**



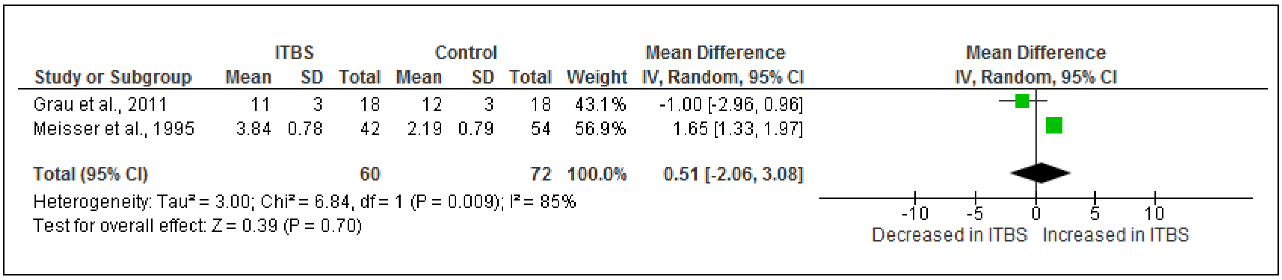

Abbreviations: SD, standard deviation; CI, confidence interval; ITBS, Iliotibial band syndrome

**FIGURE 3.11. Meta-analysis for time of peak knee flexion in male and female runners during the stance phase of running**




Abbreviations: SD, standard deviation; CI, confidence interval; ITBS, Iliotibial band syndrome

**FIGURE 3.12. Meta-analysis of peak rearfoot eversion in male and female runners during the stance phase of running**




Abbreviations: SD, standard deviation; CI, confidence interval; ITBS, Iliotibial band syndrome

### *3.4.5.2 Prospective cohort studies*

Based on one study by Noehren et al[42] peak hip adduction and peak knee internal rotation should be screened to determine runners who may be at risk for developing ITBS (Figure 3.7). Female runners who may be at risk of developing ITBS may present with increased peak hip adduction and increased peak knee internal rotation.[42]

### 3.4.6 Biomechanical findings during the full stride cycle

Two studies were conducted on the full stride cycle and compared the biomechanics of runners with ITBS to healthy runners' pre and post fatigue.[46,67] One of these studies evaluated CRP.[67] Significant differences were found with regards to maximum knee flexion, maximum foot adduction and peak ankle extension velocity at the beginning of the run as well as maximum knee flexion, maximum knee internal rotation velocity, maximum foot inversion and maximum ankle extension velocity at the end of the run.[67] Miller et al[67] suggested that runners prone to ITBS may use abnormal segmental coordination patterns particularly with couplings involving thigh adduction/abduction and tibial internal/external rotation.

## 3.5 DISCUSSION

The findings of this systematic review indicate the dearth of evidence for biomechanical differences between healthy runners and runners with ITBS or those who went on to developing ITBS. There is limited evidence for the prevention (or screening) and management (or treatment) of ITBS in runners. This may explain why it is such a difficult condition for clinicians to prevent and manage.

Prospective cohort studies present the highest level of evidence for factors which predispose the development of a condition. The findings of these studies thus indicate factors which could be considered in screening programmes aimed at prevention. One prospective cohort study showed that female runners who went onto developing ITBS had increased peak hip adduction and increased peak knee internal rotation during the stance phase of running.[42] Due to the proximal origin of the ITB at the hip and its distal insertion onto Gerdys tubercle at the knee,[24] patterns of increased hip adduction and knee internal rotation may increase the amount of strain and tension on the ITB.[10] The ITB assists in hip abduction and is stretched in adduction.[47] Female runners should be screened to determine if they have increased amounts of peak hip adduction or peak knee internal rotation to ascertain if they may be at risk of developing ITBS. There are a number of possible reasons why female runners may present with increased hip adduction and knee internal rotation. These may include the following; weak, poorly controlled or incorrect activation of the hip abductor muscles (particularly the gluteus medius), stiffness within the hip/knee joints, myofascial restrictions of surrounding musculature or abnormal running biomechanics. However, due to the lack of evidence the underlying reasons for increased hip adduction and knee internal rotation in female runners remains poorly understood. Female runners at risk of developing ITBS could be managed by clinicians by means of a hip abductor (gluteus medius) rehabilitation program to reduce the amount of hip adduction, thereby minimizing the amount of tension placed on the ITB. Additionally, gait re-education could be implemented to improve running biomechanics and incorrect joint patterning. Manual therapy could also be conducted to mobilize potential hip or knee joint stiffness as well as surrounding myofascial restrictions. Additional prospective cohort studies are required to increase the evidence base, allowing us to further understand the possible reasons why runners may be at risk of developing ITBS.

This systematic review clarifies prospective findings which were unclear in the conclusion of the previous systematic review.[60] Louw and Deary[60] concluded that ITBS is unlikely the result of abnormal biomechanics at the foot or tibia, but is more likely the result of proximal cause. Prospective findings of this recent systematic review are in agreement with the findings of the previous review[60] in relation to the hip and the foot. However, the findings of this review differ in relation to the tibia. This review found that female runners who went onto developing ITBS presented with increased peak knee internal rotation, thus indicating that the tibia may also be a contributing factor to the development of ITBS in female runners. This review indicates that current prospective findings are only applicable to female runners. At this stage no prospective research has been conducted on male runners.

Ten cross-sectional studies were identified.[3,25,44-46,64-68] Findings from cross-sectional studies provide information about factors to be addressed in runners with ITBS. However, these factors could have manifested before or as a result of the condition. This systematic review noted biomechanical differences between runners with ITBS and those who were healthy, but the evidence base for the majority of risk factors was limited to a single study. Figure 3.8, an algorithm for the management of ITBS in runners, highlights the biomechanical risk factors which may/may not need to be considered when managing runners with ITBS. This algorithm highlights biomechanical risk factors identified in previous studies and classifies them according to one of four categories. These categories are based on the amount of evidence available as well as the consistency of the evidence. None of the risk factors identified in the management algorithm are supported by a strong and consistent evidence base. Due to the lack of evidence, none of the risk factors were identified as factors which ‘must be considered’ when managing runners with ITBS. Sixteen risk factors were identified to ‘maybe consider’ when managing runners with ITBS, however these factors were only based on one study with a significant finding. Numerous risk factors were identified as not being ‘currently clinically relevant’ as the evidence was based on one cross-sectional study with an insignificant finding.

Contradictory evidence was found for peak knee flexion, time of peak knee flexion and peak rearfoot eversion during the stance phase in males and females with ITBS as well as peak hip adduction in the stance phase in females with ITBS (Figure 3.8). A possible reason for differences in findings (in male and female runners) is that runners ran barefoot in the study by Grau et al[45] and runners in the other two studies ran with shoes.[3,25] This indicates that shoes may also need to be considered when analysing the movement. Less peak hip adduction was noted in female runners with ITBS (Figure 3.9), but not in males. A possible reason could be the variation in pelvic size between males and females. Peak knee flexion was another risk factor which was found to be insignificant in female runners[44] and inconsistently insignificant in combined gender groups.[3,45] The combination group of males and females makes it impossible to extrapolate if gender is a confounder.[45] Gender may not play a role in runners already presenting with ITBS. This is noted when comparing the biomechanical risk factors studied in a group of males and females to a group of only males or only females. Peak hip adduction was significantly less in male and female runners with ITBS.[45] The contrary was noted in a group of only females[44,65] and a group of only males.[68] Both the females only[44,65] and males only[68] groups wore shoes where the group of males and females ran barefoot.[45] The management algorithm highlights the need for further research to identify which factors are important to consider when managing ITBS in runners. Future studies should discern between genders when designing their research. Additionally future research should include larger samples as most of these studies did not justify the sample size, potentially compromising statistical power.

In clinical practice, management techniques for ITBS are currently focused on the following; improving gluteus medius strength,[22] releasing myofascial restrictions,[22] improving gait patterning using real time retraining[54] and reducing inflammation at the site of the ITB attachment. The lack of concrete evidence regarding the underlying risk factors of ITBS emphasises why it is often not successfully treated. This therefore provides challenges to clinicians who may not be basing their management on the current evidence base. An example thereof is with a gluteus medius strengthening program, a strategy often used by clinicians to manage runners with ITBS to improve hip adduction. A previous study by Fredericson et al[27] found that improvement in hip abductor strength paralleled symptom improvement. However, it was also noted in this study that additional modalities (stretching, strengthening, ice or NSAID's) may have been used concurrently with the strengthening program. Thus, it is unclear whether improvement in symptoms was as a result of the strengthening. Runners in this systematic review presenting with ITBS for management were not found to have increased hip adduction indicating that weakness of the hip abductor musles may not be a factor. Clinicians should base their management/treatment of ITBS on up to date evidence. This review also suggests that clinicians should explore all avenues in addition to biomechanical analysis to determine why runners may present with ITBS.

Peak knee internal rotation was identified as the only risk factor which may be relevant for both prevention (Figure 3.7) and management (Figure 3.8) of ITBS in female runners. The physiological rationale may be due to the ITB'S attachment on the tibia. Increased torsion to the knee will result in increased load to the ITB.[44] The ITB assists in stabilization of the lateral aspect of the knee,[47] increased knee internal rotation will overload the ITB.[29] The size of the knee internal rotation difference is up to 4 degrees. Knee rotation is notorious for measurement error if the knee axis is not well estimated.[42,44] The measurement error of knee rotation could be bigger than the physiological range. Future studies should report reliability and measurement errors to understand the attributable role of this potential risk factor to ITBS.

The key methodological shortcomings of the included studies were similar across eligible studies. The risk of bias was high. Convenient sampling limits generalizability of findings. Sample sizes were also not justified and consequently statistical power were arguably too low to detect statistical significant differences. This review can be used to calculate sample sizes, depending on the key factor investigated. Another methodological shortcoming is no reporting of reliability and validity of testing procedures. Since the ITB may not be the sole reason for differences between runners with ITBS or healthy, reporting measurement issues will enhance interpretation of differences noted.

This review showed that many biomechanical risk factors were analysed in the eligible studies. A total of 47 risk factors were reported. It is proposed that future studies should consider published risk factors in order to compare across studies and allow meta-analyses. In addition, when designing a new study, selected risk factors to be investigated must be based on physiological plausible theories. Sample heterogeneity could account for the inconsistency in findings, limiting generalizability of findings. The wide range of SD's could also indicate that there was large variation in performance, which should be explored in future studies. This review was limited to English, Afrikaans and German languages which could have introduced bias.

## 3.6 CONCLUSION

The evidence base for screening or managing risk factors for runners with ITBS is limited due to a small evidence base and inconsistency between study findings. The single prospective cohort study included in this review showed that female runners who went onto developing ITBS presented with increased peak hip adduction and increased peak knee internal rotation during the stance phase of running.[42] Underlying reasons for increased hip adduction and knee internal rotation may include; weak, poorly controlled or incorrect activation of the hip abductor muscles (particularly the gluteus medius), stiffness within the hip/knee joints, myofascial restrictions of surrounding musculature or abnormal running biomechanics. Current prospective findings are only applicable to female runners. At this stage no prospective research has been conducted on male runners. There is therefore no evidence to determine which factors should be screened in male runners to prevent them from developing ITBS.

The cross-sectional studies indicated that there are no biomechanical risk factors which clinicians '*must consider'* when managing runners with ITBS. The evidence base of hip, knee, ankle/foot, trunk and pelvic biomechanical risk factors which are different between runners with or without ITB is limited to a single study. It is important for clinicians to know the status of the current evidence base.[42] It is thus difficult to make clinical recommendations for management at this stage, except that an individual approach should be attempted and regularly evaluated. There are many opportunities for research which could improve our understanding of ITBS. The methodological rigour of future studies should be addressed by justification of sample size and reporting of measurement issues which may confound the findings.

**Key points:**

**Findings:** Certain key biomechanical risk factors should be examined when screening runners to determine who may be at risk of developing ITBS and should be examined when evaluating runners who already present with ITBS. Further research is required to determine their long term effect on preventing and managing ITBS in runners.

**Implications:** There is insufficient evidence to state that biomechanical abnormalities play a role in preventing and managing ITBS in runners. Clinicians should explore avenues other than gait analysis to determine why runners may be prone to developing ITBS.

**Caution:** There is a lack of strong evidence to support the biomechanical risk factors associated with preventing and managing ITBS in runners, this is due to the fact that few studies evaluated the same biomechanical risk factors or the sample populations used were not heterogeneous. There should be rationale behind the biomechanical risk factors and sample population chosen to increase the evidence and consistency of findings.

# CHAPTER 4: CONCLUSION OF STUDY, CLINICAL RECOMMENDATIONS, LIMITATIONS AND FUTURE RESEARCH

## 4.1 Conclusion

The aim of this study was to provide clinicians with an up to date evidence synthesis on the biomechanical risk factors associated with preventing and managing ITBS in runners. To date no previous study has examined the evidence base in such detail. In order to update the evidence; the size of the evidence base, the consistency of findings between studies and the size of the differences of risk factors between runners with ITBS and those who were healthy were analysed. Both prospective cohort and cross-sectional studies were considered. Prospective cohort studies identify risk factors which may predispose runners to ITBS where cross-sectional studies provide information regarding the risk factors which should be considered when managing runners already presenting with ITBS.

The main finding was that biomechanical differences may exist between both runners presenting with ITBS and those who may develop ITBS, compared to healthy runners. These findings, however, were derived from a small evidence base. Although a large variety of biomechanical risk factors were evaluated, the evidence base for screening/preventing and managing these factors in runners with ITBS is limited. The examination of the evidence base in the systematic review (Chapter 3) allowed for the development of the clinical algorithm for the screening/prevention (Figure 3.7) and management of ITBS (Figure 3.8).

The systematic review on which this study was based, included a thorough search of the available literature from inception to May 2014 of four major databases. The critical appraisal tool for quantitative studies was used to appraise the quality of the methodologies of the included studies.[61] The single prospective cohort study included in the systematic review was rated as having the highest level of methodological quality.[42] The FORM framework was used to evaluate the; level and consistency of evidence as well as its clinical impact.[63] Forest plots were used to show significant and insignificant biomechanical findings and a meta-analysis was conducted where possible.

Prospective cohort and cross-sectional findings were displayed separately in the algorithm. The algorithm was designed to assist clinicians in identifying which biomechanical risk factors are important to consider when screening/preventing or managing ITBS in runners.

The one prospective cohort study in the clinical algorithm only included female runners.[42] If female runners present with increased peak hip adduction or increased peak knee internal rotation, they may be at risk of developing ITBS in the future. Increased hip adduction and knee internal rotation may increase the amount of strain and tension on the ITB.[42] Strengthening the gluteus medius, improving hip abductor/gluteal control and muscle firing, mobilization of the hip/knee joint to improve physiological range of motion as well as running gait re-education could help prevent female runners from developing ITBS. However, future research is required to determine their effect. No prospective cohort studies have been conducted on male runners therefore it is not known at this stage which biomechanical risk factors should be screened in males.

The clinical algorithm gives recommendations on the biomechanical risk factors which should be considered by clinicians when managing runners with ITBS. Previous studies have examined a wide range of biomechanical risk factors when comparing runners with ITBS to those who were healthy, however study population heterogeneity was not considered. As a result of differences in population heterogeneity, the results of only four of the biomechanical risk factors could be compared between studies. These include; peak hip adduction in females as well as peak knee flexion, time of peak knee flexion and peak rearfoot eversion in males and females. Due to the inconsistency in findings with regards to these four biomechanical risk factors, the algorithm (Figure 3.8) has identified that they do not need to be considered when managing ITBS in runners in these population groups. This is indicated in the algorithm as risk factors which clinicians *'do not need to consider'*.

The management algorithm did not identify any biomechanical risk factors which clinicians *'must consider'* when managing runners with ITBS. This is due to the majority of factors only being evaluated by a single study. There was no evidence where there were at least two cross-sectional studies with significant and consistent findings. The biomechanical risk factors identified by the single studies should *'maybe be considered'* when managing runners with ITBS as reflected in the algorithm (Figure 3.8).

At this stage it is impossible to determine whether gender is a confounder for ITBS as many of the studies were conducted on a combination group of male and female runners with ITBS, making it impossible to extrapolate to which gender the findings are most applicable.

Peak knee internal rotation was identified as both a biomechanical risk factor which may contribute to female runners developing ITBS, as well as a factor which 'may need to be considered' when managing their condition. Strain and tension on the ITB may be increased with knee internal rotation and thus may be the reason why it should be considered in both the prevention and management of ITBS.

## 4.2 Clinical recommendations

- Strengthening the gluteus medius muscle may help prevent ITBS in female runners, however there is no current evidence to support this theory.
- Strengthening the gluteus medius may not be effective in managing female runners already presenting with ITBS.
- Avenues in addition to gait analysis should be explored to determine why runners may develop ITBS.
- Testing runners wearing shoes versus running barefoot may affect results. This should therefore be considered when assessing running biomechanics in clinical practice.
- Opinion papers need to be reflected on to determine if there is evidence to support the current routine prevention and management of ITBS in runners.
- Clinicians need to embrace physiotherapy evidence based practice. In order to do this the clinical algorithm (Figure 3.7 and Figure 3.8) developed in the systematic review should be considered.
- Clinicians need to frequently monitor and reassess the effectiveness of their techniques to ensure that they are appropriate and effective.

## 4.3 Limitations of the systematic review

A number of limitations were identified while completing the systematic review (Chapter 3).

- **Language:** Studies conducted in only English, Afrikaans and German were considered for inclusion. This may limit the inclusion of significant findings from studies conducted in other languages.
- **Motion analysis:** One study (conducted prior to 1996) used high speed video cameras to capture the running biomechanics, whereas the rest of the studies used Vicon motion analysis. This was not factored into the results.
- **Sample heterogeneity:** The majority of the included studies were samples of convenience and the age of the runners, their weekly mileage, running style, whether or not they wore shoes and method of data collection were not considered.
- **Legs comparison:** The comparison of the leg used when comparing case to control (Table 3.7) were not taken into account when compiling the results.
- **Extrinsic risk factors**: Running wearing shoes versus barefoot was the only extrinsic risk factor considered. Extrinsic factors such as; step width, speed, downhill running and mileage have been found to be relevant in runners with ITBS but were not included in this review.
- **Aetiological pathways in addition to biomechanical factors:** Additional aetiological pathways like hip abductor strength, ITBS strain and strain rate, leg length discrepancies and ITB flexibility were not considered.
- **CRP, PCA and fatigue studies:** The algorithm was based only on the seven studies conducted on the stance phase of running. The studies conducted on CRP, fatigue and PCA were not included in the algorithm due to limited evidence and lack of comparability.

## 4.4 Limitations of current research and recommendations for future research

- Future research should focus on using the clinical algorithm (Figure 3.7 and Figure 3.8) developed in the systematic review (Chapter 3) to determine which risk factors require further research. This will allow additional meta-analysis.

Based on the algorithm of studies to May 2014, the following areas have been identified as requiring additional research:

- Prospective cohort research on both females and males (Figure 3.7)
- Cross-sectional research with a particular focus on the risk factors which should '*maybe be considered'* (Figure 3.8)
- In the '*should maybe be considered*' category, specific consideration should be given to the gender used in previous studies to allow for comparison of findings and to prevent research waste. This may then indicate whether a particular risk factor can be moved into the *'must consider'* or '*do not consider'* categories in the algorithm.
- Larger sample sizes may need to be used to increase the statistical power of studies. Increasing the sample size would allow smaller differences to be detected. The sample sizes of the included studies in the systematic review (Chapter 3) may have been too small resulting in a large amount of insignificant findings assigned to the *'not currently clinically relevant'* category in the algorithm (Figure 3. 8).

- To facilitate additional meta-analysis and heterogeneity, future studies should compare gender specific population groups (males or females) or differentiate between genders in combination groups.
- Within gender groups a distinction needs to be made between runners wearing shoes versus those running barefoot.
- In the future, motion analysis and other testing protocols should follow previous studies, and methodologies should be standardized to ensure effective comparison and consistency of results.
- Further studies need to be conducted on CRP, PCA and fatigue to allow for further analysis and comparison with existing studies.

### 4.5 Summary

Biomechanical differences may exist between runners with ITBS or those who may develop ITBS, compared to healthy runners. Although a large variety of biomechanical risk factors were evaluated, the evidence base for screening or managing these risk factors in runners with ITBS is limited to a small evidence base, small clinical effect and heterogeneity between study outcomes and findings. Further prospective cohort and cross-sectional research is required to ascertain if abnormalities in running biomechanics may be related to why runners develop ITBS or to ascertain which risk factors may need to be considered when managing these runners. This will help to reduce the number of runners from developing ITBS in the future.

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## APPENDIX 1: JOSPT formatting guidelines

JOSPT

### Manuscript Formatting Guide

The following is a guide to the way in which the *JOSPT* formats articles in MS Word. The closer an author can approximate the below formatting, the easier it is for the *JOSPT* to prepare the article for the printer.

I. Title Page: Arial 12 pt, single space, no indent, 1 return separating the following sections
   A. Title
      1. Title case
         a. All prepositions, conjunctions, and articles under 4 letters lowercase
         b. Do not capitalize second part of hyphenated compound if it is a prefix or suffix
   B. Author names
      1. Title case
      2. Period after initials
      3. Commas separating degrees
      4. "PT" first in list of degrees
      5. Superscript number referring to affiliation footnote
   C. Affiliations
      1. Title case
      2. Order: superscript number, institution, city, state (2-letter abbreviation), period
   D. Study information
      1. IRB approval, notice of author title changes after completion of study, military disclaimer, financial disclaimer
   E. Correspondence information
      1. Author address and email

II. Abstract: Arial 12 pt, double-space, no indent
   A. No section title
   B. Structured abstract: section headings in title case, bold, and separated by a colon at the start of each paragraph
   C. *JOSPT* publication reference at the end of the last paragraph in italics eg, *J Orthop Sports Phys Ther 2004;34(4):xxx-xxx.*
   D. Key words
      1. Key words in lower case, list in alphabetical order
      2. Whole section in italics

III. Introduction: Arial 12, .5" indent, double space

IV. Section Headings

A. Level 1 heading, Arial 12 pt, bold, no indent, uppercase, double-space

B. Level 2, Arial 12 pt, bold, no indent, title case, double-space

C. Level 3, Arial 12 pt, italic, run into paragraph, title case, double-space

V. References

A. Journals

Author. Title. Publication. year;vol:pp-pp. DOI

Austin AB, Souza RB, Meyer JL, Powers CM. Identification of abnormal hip motion associated with acetabular labral pathology. *J Orthop Sports Phys Ther*. 2008;38:558-565. http://dx.doi.org/10.2519/jospt.2008.2790 B. Books

Authors. Title. City, State: Publisher; year.

Afifi A, Clark V, May S. *Computer-Aided Multivariate Analysis*. 4th ed. New York, NY: Chapman and Hall; 2004.

C. Organization as author and publisher

Organization. Title. City, State: Publisher; year.

World Health Organization. *International Classification of Functioning, Disability and Health: ICF*. Geneva, Switzerland: World Health Organization; 2009. D. Book chapter

Authors. Title. In: Editor(s), ed(s). Book Title. City, State: Publisher; year:pp-pp.

Loland S. Alpine skiing technique – practical knowledge and scientific analysis. In: Müller E, Lindinger S, Stöggl T, eds. *Science and Skiing IV*. Maidenhead, UK: Meyer & Meyer Sport; 2009:43-57.

E. Master's or doctoral thesis

Author. Title [thesis]. City, State: University or Institution; year.

Charles ST. *Genetic and Environmental Influences on Osteoarthritis* [thesis]. Los Angeles, CA: University of Southern California; 1997.

F. Published abstract of a paper presented at a conference

Authors. Title [abstract]. Conference Title. City, State/Country: Publisher or Sponsoring Institution; year.

Ferreira PH, Ferreira ML, Maher C, Refshauge K, Latimer J, Herbert R. Clinical ultrasound test for transversus abdominis thickness:

investigation of reliability [abstract]. *Musculoskeletal Physiotherapy Australia 13th Biennial Conference*. Sydney, Australia: Musculoskeletal Physiotherapy Australia; 2003.

G. Universal Resource Locator (URL)

Publisher. Title. Available at: http://address.of.the.URL.htm. Accessed month day, year.

Uniform Data System for Medical Rehabilitation. About the FIM System.

Available at: http://www.udsmr.org/WebModules/FIM/Fim_About.aspx. Accessed April 20, 2009.

H. Paper presented at a conference

Authors. Title of paper. Conference; date, year; location.

Ng L, Burnett A, O'Sullivan P. Spino-pelvic kinematics and trunk muscle activation in prolonged ergometer rowing: mechanical etiology of nonspecific low back pain in adolescent rowers. *26th International Conference on Biomechanics in Sports*; July 14-18, 2008; Seoul, South Korea.

I. Report

Authors. Title. City, State: Publisher/Organization; year.

Adams PF, Heyman KM, Vickerie JL. *Summary Health Statistics for the US Population: National Health Interview Survey, 2008*. Hyattsville, MD: National Center for Health Statistics; 2009.

VI. Tables

A. Table designator bold, all caps and separated by a period
B. Table caption sentence case following designator
C. Font: Arial 12 pt, normal
D. Borders on top, bottom and under column headings
E. Column headings centered
F. Text left aligned with a .25-inch hanging indent
G. Numbers decimal aligned
H. Abbreviations placed before the footnotes, punctuated as follows: Abbreviations: AB1, abbreviation 1; AB2, abbreviation 2; etc.
I. Footnote symbols in the following order: * † ‡ § ‖ # ** †† ‡‡

VII. Figures

A. Figure designator bold, all caps and separated by a period
B. Graphs and/or charts
   1. Make data available either by clicking the chart or by providing spreadsheet
C. Photos
   1. At least 300 dpi resolution