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REVIEW

The Prevalence of Lower Extremity Injuries in Running and Associated Risk Factors: A Systematic Review

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Introduction: Running is an extremely popular pastime and competitive sport. There is a general consensus that runners present a high incidence of injury. This study aims to discover the prevalence of injury to the lower extremity among runners and any associated risk factors which correlate with the development of lower extremity injuries.

Methods: An inclusion and exclusion criteria were used to screen search results. From an original 184 search results, 24 research papers were selected for the final study. The PRISMA checklist was adhered to in the research process. EndnoteX9 was used to filter through all search results and to achieve the final study selections, in line with the appropriate criteria.

Results: Overall, a mean incidence of 37% was displayed for running related injuries to the lower extremity. Females displayed a greater mean incidence of injury than males, 39.7% vs 34.3%. Injury prevalence presented greatest at the knee region (24.3%), but this differed when results were split into male and females. Females presented the greatest prevalence of injury at the calf/lower leg, whilst males presented greatest incidence of injury at the hip/pelvis/upper leg region. Risk factors for developing injury which were identified throughout the research included; having <5 years running experience, being previously injured in the last 12 months and running >3 times per week.

Conclusion: This systematic review is in agreement with the literature which has repeatedly illustrated that female runners present a greater incidence of injury than male runners.

Keywords: Running Related Injury; Lower Limb Injury; Injury Risks; Runners; Injury Prevalence

Introduction

There are a variety of running related injuries discussed in recent literature. For example, there has been mentions of injuries such as patellofemoral pain syndrome, Achilles' tendinopathy, medial tibial stress syndrome, ankle-foot injury, knee injury and several more lower extremity injuries within current research (Francis, Whatman, Sheerin, Hume, & Johnson, 2019). Further research studies discuss generic lower extremity running related Musculo-skeletal injuries, such as sprains and strains (Mehl, Nelson, & McKenzie, 2011). Iliotibial band syndrome is said to be one of, if not the, most common injury of the lateral side of the knee, in runners with an estimated prevalence of between 5–14% (van der Worp, van der Horst, de Wijer, Backx, & Nijhuis-van der Sanden, 2012). In addition to this, overuse type injuries have been shown to be commonly associated with running, with the incidence of overuse injury being 7.1% (Toresdahl et al., 2020).

One study suggested that the risk factors for running related injuries (RRI) are not clear, despite there being an array of research regarding RRI (Mei et al., 2014; Saragiotto et al., 2014). Despite this, however, the same research article stated that previous injury, within the last twelve months, was the greatest predictor of developing RRI (Saragiotto et al., 2014). One suggested risk factor for runners developing injury, within training, post-training and during competition, is the shoe type worn during running activity; particularly

lateral torsional stiffness in shoe type has been shown to impact upon injury incidence (Helton et al., 2019). Another suggestion which has been made in research is that minimalistic shoes or barefoot running also impacts upon prevalence of lower extremity injury within runners (Goss & Gross, 2012). Thus, particular line of research suggesting that shoe type influences foot strike patterns in runners which subsequently effects incidence of injury within the hip, knee, lower leg and ankle areas.

A further area of risk which has been suggested to impact upon lower extremity is leg length inequalities in runners (Rauh, 2018). In addition to this, factors such as body mass index (BMI), how many years of running experience subjects have, and whether or not interval training was undertaken, have been shown to also have an association with the risk and prevalence of running related injuries (van Poppel, de Koning, Verhagen, & Scholten-Peeters, 2016). BMI was also discussed as a suggested risk factor in first time marathon runners in a further research study (Vadeboncoeur et al., 2012). Moreover, it was further stated that training load (distance of run), gender, age and running experience were associated with incidence of lower extremity injury (McKean, Manson, & Stanish, 2006). Furthermore, previous injury status, training characteristics and running exposure were all said to correlate with the incidence of running related injuries in subjects (Hespanhol Junior, Pena Costa, & Lopes, 2013).

The prevalence of lower extremity injuries in running has long been a subject of interest in many research articles. In this systematic review, various literature on this topic will be reviewed to discover the incidence of injuries in the lower extremity among runners with different levels of expertise. In addition, the risk factors associated with running will also be discussed. Running, with respect to all levels and abilities, is a highly popular pass time and competitive sport for many individuals, primarily because of its well-known health benefits and the enjoyability as a leisure activity. The popularity of running marathons has been increasing over the last 10–15 years. In addition to this, the same study illustrated that in some cases, there is a 90% incidence in injury for those running marathons (Fredericson & Misra, 2007). Therefore, it is important and highly relevant that the incidence of running related lower extremity injuries is investigated in order to gather valuable information about how to prevent such injuries in future runners. The importance of establishing the etiology of RRI is crucial in highlighting the identification of risk factors that can be used to provide information for future research questions, hypotheses and future injury prevention programmes (Bertelsen et al., 2017). Overall, the running injury incidence yearly has been shown to be between 37% and 56%: dependent on factors such as level of running, amount of running miles covered weekly, and the age of subjects. Research has suggested that between 20–70% of injuries associated with running require medical attention and often 0–5% of those injured as a result of running are forced to take absences from employment (van Mechelen, 1992). To advance further on this point, an additional journal article stated that the incidence of running related injuries to the lower extremity ranged from between 19.4% up to 79.3% (van Gent et al., 2007). Thus, highlighting the importance for studies to investigate the incidence and risk factors for lower extremity injuries in running in order for coaches and sport and exercise scientists to implement their knowledge into training programmes designed to prevent such ailments from occurring.

The aim of this study was to determine the prevalence of lower extremity injuries among runners generically via the outlined objectives:

1. To establish the prevalence of lower extremity injuries in running through a systematic review.
2. To compare the prevalence of lower extremity injuries within male and female runners.
3. To establish the anatomical areas in which lower extremity injuries are most frequent and how this varies between genders.
4. To report risk factors associated with developing RRI, through the review of previous literature.

Two hypotheses have been framed. Firstly, we hypothesize that previous literature will illustrate a high prevalence of lower extremity injuries in runners across both genders. Secondly, we hypothesize that females will display a higher prevalence of injury than male runners.

Methods

The PICO Framework method was utilized in order to be able to identify a specific research question to investigate for the purposes of this systematic review (**Table 1**). Effective research strategies are generally greatly planned and formulated around a framework, such as PICO (Sayers, 2008). As a result of using this framework it was very straightforward to establish a relevant research question and consequently identify appropriate search terms to use across the databases.

Table 1: PICO Framework.

Population	Male and Female Runners- of all ages and abilities.
Intervention	A review of literature discussing the incidence of lower extremity injuries in running.
Comparison	Gender variations in prevalence of injury in running and anatomical regions at which injuries occur. Extracting risk factors and establishing any population variations in risk factors.
Outcome	Established mean incidence of RRI, overall and in male and females independently.

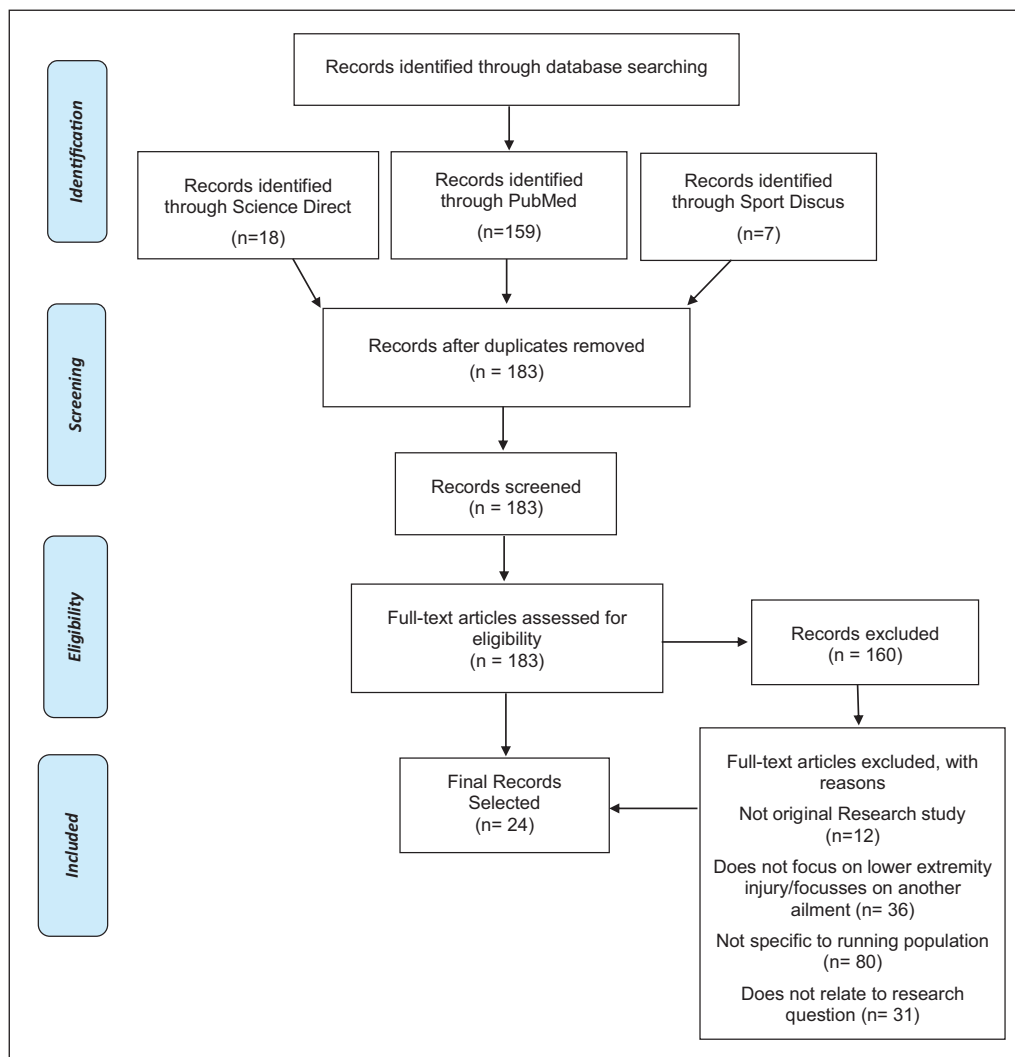


Figure 1: PRISMA Flow Diagram.

Eligibility Criteria

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was the method used to conduct the review of literature and screening process for the search results which were brought up within the initial database searches (Figure 1). PRISMA assists in improving the transparency, accuracy and completeness for systematic reviews and meta-analyses (Shamseer et al., 2015). The inclusion criteria were set as follows; 1. Studies including lower extremity/lower limb injury/injuries, 2. Articles discussing prevalence or incidence of such injuries, 3. Articles investigating or concluding risk factors for lower extremity and/or lower limb injuries, 4. Articles which were available to read in English language and 5. Articles which were running specific (and at any running level). The exclusion criteria were set as; 1. Any systematic review, 2. Any article which was focused on upper body injuries, 3. Studies which were not available in the English language, 4. Studies which were not relevant to the research question, 5. Studies which were not specific to the running population.

Sources of Information

A total of 3 databases were screened for relevant articles to this research study. The databases selected were; Science Direct, PubMed and Sport Discus. The searches were performed on the 20th of November 2020. The common search term which was used within all databases was as follows; "Prevalence of lower extremity injuries in running". In the "advanced search" option within the databases the search options were offered as; Prevalence (OR) Incidence (AND) Lower Extremity (OR) Lower Limb (AND) Injuries (OR) Injury (AND) Running (OR) Runners. Articles up until 31st December 2020 were included within the search criteria. An overview of the selected publications arranged in alphabetical order are displayed in **Table 2**.

Table 2: Summary of Final Research Articles.

Author Details (name and year)	Purpose of Study	Participants	Injuries Discussed
(Goss & Gross, 2012).	To compare and identify differences in running injuries with shoe type worn.	1254 male runners and 1255 female runners aged 18–50 years.	Generic running injuries.
(Helton et al., 2019).	To investigate running shoe and lower extremity/musculoskeletal injury risk.	1025 subjects.	Stiffness and overuse injuries in the lower extremities.
(Hespanhol Junior et al., 2013).	To establish the incidence of running related injuries in recreational runners.	200 Recreational runners.	Running related lower limb injuries- mainly musculoskeletal injury.
(Kluitenberg et al., 2015).	To determine the prevalence and risk factors for running related injuries in novice runners.	1696 novice runners aged 18–65 years.	Running related injuries.
(Macera, 1992).	To investigate the associations between different factors (i.e., weekly distance, age, running experience, gender, height, and weight) on lower extremity injury incidence.	Population based study.	Various generic lower extremity injuries.
(Macera et al., 1989).	To investigate the correlation between a number of perceived risk factors and the occurrence of lower extremity injuries in running.	583 habitual runners.	Lower extremity injuries caused by running which were severe enough to impact running performance, invoke a visit to the doctor/hospital, or required the use of medication.
(McKean et al., 2006).	To discover if there were differences in injury pattern and risk factors varied between master runners (aged 40 years or older) and younger runners.	2886 runners. Master runners consisted of 34% of population.	Various lower extremity injuries.
(Mehl et al., 2011).	To discover the cases of running related injuries in school aged children.	225344 children and adolescents aged 6–18 years old.	Lower extremity injuries such as sprains and strains.
(Messier et al., 2018).	To discover which risk factors are responsible for splitting non-injured and injured recreational runners in a 2-year period.	300 recreational runners whom were running a minimum of 5 miles per week and were injury free for the previous 6 months.	Generic lower extremity injuries.

(Contd.)

Author Details (name and year)	Purpose of Study	Participants	Injuries Discussed
(R. Nielsen et al., 2019).	To determine if a “dose-response” relationship occurs with training load variations and running injury incidence.	20,000 consenting runners grouped into 1. No injury, 2. A problem, 3. Injury.	Running related injuries.
(R. O. Nielsen et al., 2013).	To classify demographic and behavioral risk factors for running related injuries.	930 runners.	Running related injuries.
(Parker, Weitzenberg, Amey, & Nied, 2011).	To discover the association of group training programmes and risk factors for injury incidence in female marathoners.	78 female marathon runners.	Running related injuries.
(Pierpoint, Williams, Fields, & Comstock, 2016).	To determine the pattern of injuries in high school track and field male and female subjects.	Epidemiology study.	Injuries apparent in school aged track and field subjects.
(Rauh, 2014).	To discover the correlation between injury risk in the first month of high school country season and summer training habits.	421 athletes; 186 girls and 235 boys competed in multi-school cross country events.	Generic running injuries.
(Rauh, 2018).	To depict differences in leg length within female and male cross-country, high-school aged, runners and to subsequently discover if such variations in leg length between genders correlated with increased risk for running related injuries.	393 runners; 222 males and 171 females competed in high school cross country competitions.	Various running related injuries.
(Rauh, Koepsell, Rivara, Margherita, & Rice, 2006).	To discover the prevalence of lower limb injuries in high-school aged runners and to determine risk factors for such injuries.	421 runners from 23 cross country teams in Seattle, Washington.	Lower extremity running injuries.
(Teixeira, Lunardi, da Silva, Lopes, & Carvalho, 2016).	To determine the incidence, anatomical location and severity of running related Musculo-skeletal pain in elite marathon runners over 12 months and to then assess if there are any training characteristics which increase Musculo-skeletal pain.	199 elite marathon runners.	Musculo-skeletal pain associated with running.
(Toresdahl et al., 2020).	To discover if a 12-week training intervention would decrease overuse injury incidence which results in incompleteness of marathon and determine if this would improve overall finishing time.	720 first time marathon runners aged 18 and over-randomised trial.	Overuse injuries.
(Vadeboncoeur et al., 2012).	To assess if high body mass index (BMI) influences half-marathon and marathon runners to lower limb injuries.	194 runners; 139 females and 55 males with median BMI of 23.7 kg/m ² for females and 26.2 kg/m ² for males.	Running related lower extremity injuries.

(Contd.)

Author Details (name and year)	Purpose of Study	Participants	Injuries Discussed
(van der Worp et al., 2016).	To discover the prevalence and characteristics such as site and recurrence of running related injuries in females training for either a 5 or 10 km race. Then to subsequently determine specific risk factors.	435 women were registered for an upcoming 5 or 10 km race.	Hip/groin, knee and lower leg running related injuries.
(Van Middelkoop, Kolkman, Van Ochten, Bierma-Zeinstra, & Koes, 2008).	To assess the incidence of lower extremity injuries in male marathon runners before and during the race and then to subsequently scrutinize the effect of such injuries.	725 male runners taking part in the Rotterdam marathon.	Lower extremity running related injuries.
(van Poppel et al., 2016).	To discover risk factors for running injuries in the Lage Landen Marathon Eindhoven 2012.	943 runners.	Generic running injuries.
(van Poppel, Scholten-Peeters, van Middelkoop, & Verhagen, 2014).	To determine the 12 -month prevalence and course of lower extremity injuries.	713 participants.	Lower extremity injuries.
(Williams, McClay, & Hamill, 2001).	To discover if runners with high arch and low arch display dissimilar injury patterns.	20 high arched and 20 low arched runners.	Running related injuries grouped into; medial/lateral, bony/soft-tissue, knee/foot and ankle.

Study Selection

Following completion of the initial database searches, all articles which were brought up as search results were exported to EndnoteX9, which was the chosen reference manager. All imported articles were then screened to discover which results met the inclusion and exclusion criteria. The articles were then grouped accordingly based on if they would be included or excluded from the research. After screening with reference to the appropriate inclusion and exclusion criteria, a total of 24 studies were selected as the final records to be included within this research. As a result of the relevance, no articles from Sport Discus were included in the final 24 selected studies. Descriptive statistics was incorporated. The mean percentage of RRI was determined and reported in terms of anatomical location. The data reported on gender differences incorporated male and female representative datasets extracted from the search outputs presented.

For reference, in the table above the term “generic running injuries” is inclusive of, but not limited to, commonly occurring injuries in running to the lower extremity, such as; patellofemoral syndrome, hamstring injuries, stress fractures, iliotibial band syndrome and sprains. The term “running related injuries” is inclusive of any injury that may have occurred in subjects as a direct result of running, this is not limited to lower extremity injuries only.

Results

Upon reviewing the literature a mean (SD) of 37% ($\pm 11.8\%$) incidence for running related injuries was calculated. The results also showed that there is a slightly higher prevalence of injury among female runners in comparison to male runners (39.7% ($\pm 23.1\%$) vs 34.3% ($\pm 23.3\%$)), albeit not a significant difference ($P > 0.05$) between the genders.

The mean percentage of RRI by anatomical location was determined. **Figure 2** illustrates the differences in the frequency of injuries at generic locations of the lower extremities. Based on the search outputs, the knee was the most commonly injured site with an average of 24.3% of all lower extremity running related injuries occurring here. This was followed by the calf/lower leg with a mean 15.9% of injuries occurring in this region and then the ankle/foot area closely tailed with an average of 15% of RRI occurring here. The thigh/upper leg region had a 9.2% mean Incidence for Running Related Injuries and the hip/pelvis/groin closely followed with 7.2% average Incidence of RRI occurring in this region. The locations described as

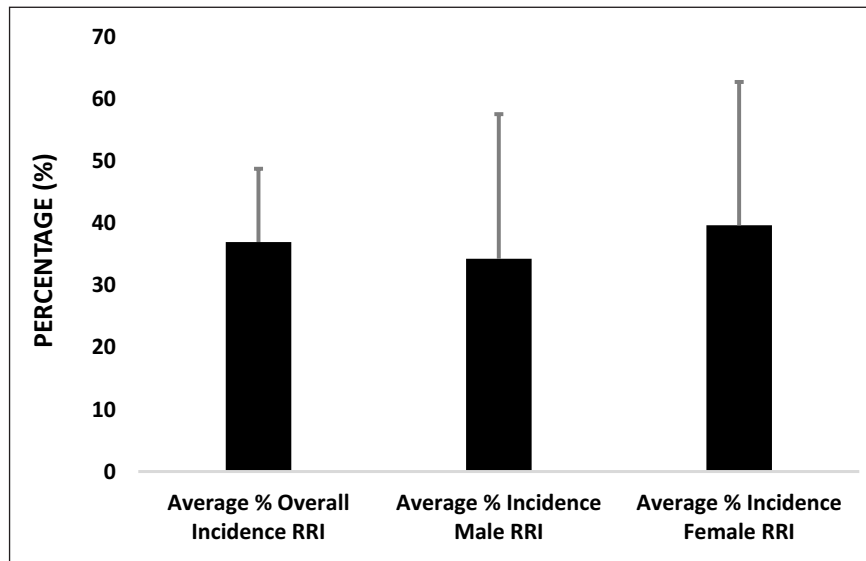


Figure 2: Mean Incidence of Running Related Injuries. RRI = Running Related Injury.

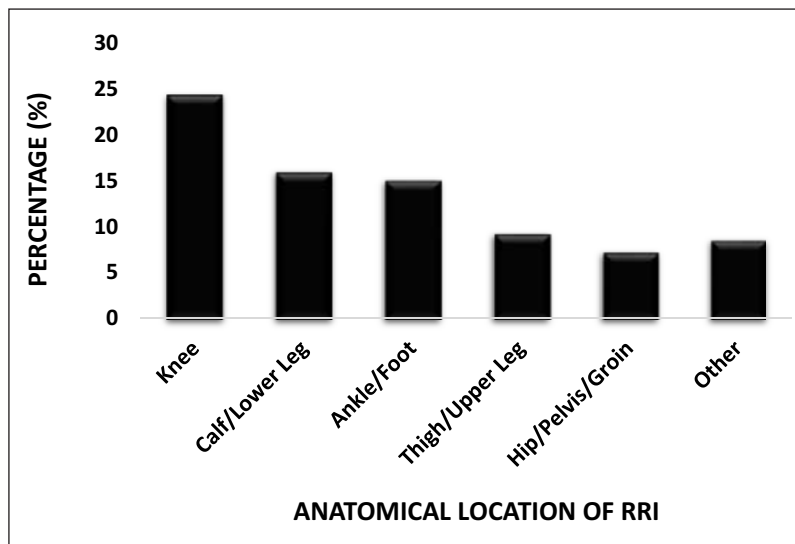


Figure 3: Mean Injury Prevalence by Anatomical Region.

'other' in **Figure 3** are inclusive of, but not limited to, various lumbar and cervical back injuries and there was an average of 8.5% Incidence RRI in these regions. **Figure 3** has been extracted from the results sections of selected studies and synthesized to form an average percentage value for RRI per anatomical location.

The mean incidence of RRI in females, by anatomical locations in the lower extremity showed that the calf/lower leg injuries were dominant with an average incidence of 9.9%. However, the knee very closely followed (9.3%) together with the hip/pelvis/upper leg regions (9%). The ankle/foot region presented the lowest mean incidence of injury in female runners (7.2%). Among the male runners the average incidence of injury was greatest in the hip/pelvis/upper leg region (14%). The knee region presenting with a lower mean prevalence of injury (8.5%), followed by the ankle/foot region (8.1%). Among male runners, the calf/lower leg presented the lowest mean incidence of injury (5.8%). **Table 3** summarizes the main findings in regards to risk factors for developing RRI.

Discussion

Key Findings

The aim of this study was to conduct a systematic review using the search outputs in order to discover the prevalence of lower extremity injuries in running and associated risk factors for developing such injuries.

Table 3: Risk Factors for Running Related Injury.

Author(s) and Study Name	Risk Factors for RRI Discussed and any Recommendations
Macera et al., (1989). Predicting lower extremity injuries among habitual runners.	Male risk factors for RRI; lower extremity injury in previous 12 months, running regularly for <3 years, running 6–7 days/week, running at least 1 marathon in previous 12 months, running average 32 km/week or more in last 3 months. Female risk factors for RRI; Ran at least 1 marathon in previous 12 months, running primarily on concrete, running average 48–63.8 km/week.
Mckean et al., (2006). Musculoskeletal injury in the masters runners.	Runners <40 years old risk factors; male gender (1.28 greater risk than females), running >3 times/week. Runners >40 years old risk factors; running >6 times/week. In both age groups, wearing orthotics posed a greater risk compared to runners who did not wear orthotics.
Goss and Gross (2012). Relationships among self-reported shoe type, foot strike pattern, and injury incidence.	Runners who wore traditional shoes were 3.41 times more likely to report injuries than experienced minimalist shoe wearers (46.7% vs 13.7%). Rearfoot strike pattern had greatest injury incidence (52.4%). Runners who ran 30 km/week had greatest injury incidence (41.4%). Runners with 1–5 years running experience had highest injury incidence (55%).
Parker et al., (2011). Group training programs and self-reported injury risk in female marathoners.	Inexperienced marathon runners were more likely to be injured during a marathon than experienced runners. Runners who had suffered injury in the previous 12 months were more likely to be injured in training.
Van Poppel et al., (2016). Risk factors for lower extremity injuries among half marathon and marathon runners of the large landen marathon Eindhoven 2012: A prospective cohort study in the Netherlands.	Risk factors; <5 years running experience, >10 years running experience and interval training.

The hypothesis was that there would be a high prevalence of lower extremity injuries among runners of all levels, and that there would be a higher incidence of injury in female runners as a result of biomechanical variations in female athlete's lower extremities.

The results from the research undertaken in this systematic review illustrate that the incidence of lower extremity injuries in running is 37%. Female runners were shown to present a slightly higher injury prevalence (39.7%) than males (34.3%), however there was no significant differences with respect to gender as had previously been hypothesized. The knee was the most frequently injured anatomical location overall (24.3% incidence), however the prevalence of running related injuries at anatomical locations varied between genders. Males presented the greatest incidence of injury at the hip/pelvis/upper leg region, whereas females presented the greatest injury prevalence in the lower leg/calf areas. Contrastingly also, females least common area for incidence of RRI was within the ankle/foot area. Furthermore, the results indicated that the male runners least injured area was the calf/lower leg, despite female runners presenting the greatest proportion of RRI in this region. In addition to this, studies which discussed risk factors were detailed and any observed similarities in results were reported.

Various risk factors are discussed within the studies above, however there are some general themes which can be extracted. Generally, <5 years running experience, being injured in the previous 12 months, and running >3 times/week or >30 km/week, were all shown to increase the risk of developing RRI. Although the previous factors were discussed in more than one article, these are not the only risk factors which have been detailed. Further articles independently discussed factors such as foot strike patterns, shoe type, the use of orthotics, interval training, surface of running activity and having ran at least one marathon in the previous 12 months as presenting an association with increased risk of developing RRI.

Incidence of Running Related Lower Extremity Injury

The results of this review aligned with the hypothesis reasonably closely. The results achieved illustrated an average injury incidence as being 37% and also showed a slight variation in gender incidence of RRI. It was established that although female runners present a slightly elevated injury prevalence compared to their male counterparts, this was not notably significant. The literature supports this finding within our results as one study concluded that there were no significant differences in injury rate between male and female runners (Macera, 1992). A further study states that females are more likely than males to sustain overuse injuries in running (73% vs 62%), which also aligns with the findings in our results (Messier et al., 2018). On the contrary however, one research paper stated within their conclusions that in younger runners (<40 years old), male runners presented a 1.28 times greater risk of injury than their female counterparts- this is contrasting with the results presented in this review (McKean et al., 2006). Therefore, due to the contrasting nature of the findings, between this review and previous research, regarding incidence of injury between the two genders this could perhaps grant an area for further research to be conducted in future studies. It would be worthwhile to establish if factors such as age or running experience/level of expertise correlated with gender variations in incidence of running related injuries or if gender variations were independent of other factors. Thus, granting an area for future research to be conducted.

Incidence of RRI per Anatomical Locations

As previously illustrated in the results, overall, the knee was shown to present the greatest incidence of injury for runners (24.3% average incidence). This is supported with data from various studies, one of which highlights that 24% of lower extremity running injuries occur at the knee (Macera et al., 1989). This aligns very closely with the figures displayed in the results in this review. Moreover, independent research studies (Messier et al., 2018), (Hespanhol Junior et al., 2013) and (Kluitenberg et al., 2015) all conclude the knee area as presenting the greatest incidence of injury for runners. Again, further supporting the results within this review article. In addition to this, a further research study highlights that within both short distance and long distance running, the knee is the most frequently injured anatomical site (van Poppel et al., 2014). Additionally, it has been stated that knee pain was the most frequent ailment in a study of 893 runners, with an occurrence of 32.5% (Chang, Shih, & Chen, 2012). However, it is important to note that there are studies which present contrasting findings and one of these studies concludes that the greatest injury incidence is noted within the ankle area (31.4% incidence), which conflicts with the results in this review (Mehl et al., 2011). Despite this however, the vast majority of research does suggest that the knee is the most frequently injured anatomical site in running which therefore agrees with our findings. Although it is important to account for and take note of contrary research findings, it is also important to understand that there are numerous reasons why such variations may occur and this therefore highlights the importance of continued research in this topic, to ensure that valid and up to date studies are utilized in evidence-based practice, research proposals, and scientific reviews.

Gender Variations in Incidence of RRI per Anatomical Locations

The results of our systematic review illustrated variations in the incidence per anatomical location between male and female runners. As has been previously outlined, female runner's injuries occurred the most within the calf/lower leg regions, however male runners were shown to be least likely to injure the calf/lower leg regions. However, male runner's injuries occurred mainly within the hip/pelvis/upper leg region. An investigation stated that within US high school track and field athletes, boys suffered mainly with thigh/upper leg strain injuries, presented as 32.7% incidence (Pierpoint et al., 2016). This aligns with the findings within this study as it was illustrated that male runners present the greatest injury occurrence within the hip/pelvis/upper leg region. Contrary, a further research paper stated within investigations that 70% of all injuries occur below the knee. In addition to this, the same paper also stated that injury per anatomical location did not vary between genders (Francis et al., 2019). This research provides for an interesting viewpoint as it supports our own research findings in one part as it states the majority of injuries occur below the knee. This aligns with our findings for overall injury incidence per anatomical location, and also the findings for female injury incidence per anatomical location, as both had greatest prevalence of injury below the knee. However, this contrasts with the findings for male incidence of injury, as our results illustrated males had the greatest prevalence of injury within the hip/pelvis/upper leg region. This particular research article contrasted further with our own findings as gender variations were established between injury incidence in anatomical locations, unlike Francis et al., (2019) research findings. Again, as conflicting findings occurred

between previous research and this systematic review, this would warrant further investigations in regards to variations in the prevalence of injury per anatomical locations between genders.

Risk Factors for Developing RRI

As outlined within the key findings, various risk factors have been identified as increasing the likelihood of developing lower extremity injuries in running. Some re-occurring risk factors which were highlighted in the results are the running distance per week, and subsequently a running distance of greater than 30 km per week being shown to increase incidence of RRI and also the presence of running related injury in the previous 12 months. (Macera, 1992) recommends that a reduction in running distance to 32 km/week and addressing previous injury will reduce the likelihood of injuries. Thus, illustrating a correlation with the findings in this systematic review. In addition to this, factors such as greater body mass index, former injury and previous sports partaking without axial loading, have all been shown to increase the likelihood of developing running related injuries in males, however it was established that more research is required to discover risk factors for injury in female runners (Buist, Bredeweg, Lemmink, van Mechelen, & Diercks, 2010). This hints at more independent gender studies being required to establish predictors for running related injury in males and females independently, as oppose to generic risk factors for all runners. Furthermore, athletes who present with excessive foot pronation have been identified as being at a greater risk of developing non-contact anterior cruciate ligament injuries (ACL), thus presenting an additional possible risk factor to be accounted for when working with runners (Christopher, Drouin, & Houglum, 2006). Despite excessive foot pronation being identified as a risk factor in previous research, this factor was not highlighted within this current systematic review, perhaps due to the sample of studies that were used. To elaborate further on the previous point, female athletes are often found to endure a greater incidence of injury by non-contact mechanism to the knee due to factors such as increased ligament laxity and decreased neuromuscular strength, particularly so for female runners during lateral pivot type actions (Hewett, 2000). Again, this highlights the need for studies to be conducted independently for male and female runners to ensure that specific risk factors for genders can be established to then allow for tailored advice to be provided to athletes in specific population groups.

Limitations

Within this systematic review, there are some limitations which can be identified for future research studies. Firstly, due to the nature of this study being a systematic review, various literature was utilized meaning there was a very wide range of age groups and running abilities included within the figures. Perhaps in future, age groups and running level could be narrowed down and made specific, in order to generate specific results for specific population groups. In addition to this, due to the nature of this study and it being a systematic review approach, it should be noted that each article used within this review would have conducted their research in a variety of ways, and as a result of this it is often difficult to draw similarities between study designs. It should be noted that the original research papers used within this review would have presented their own study limitations which therefore influences this systematic reviews results.

However, the most notable drawback for this research is in relation to the formulation of the data presented in **Figure 3** and the supporting data on the mean incidence of RRI in both females and males. It should be highlighted that the outputs presented in relation to the mean incidence of RRI in both females and males were not directly extracted from the data in **Figure 3**. Instead, these values were calculated independently of each other. This is mainly due to the issue highlighted above that various studies present an array of different data, and there was more data across the studies which discussed overall prevalence of injury per anatomical location, than there was for males and females independently. Throughout the research it was clear to see that many articles discussed prevalence of injury at specific anatomical locations in a generic fashion and did not distinguish injury incidence per anatomical site between genders independently, hence why there was more data available for **Figure 3**. This therefore explains why the incidence of injury per anatomical location in female and males independently does not align with the findings for generic incidence of injury per anatomical locations (**Figure 3**).

Future Recommendations

Future recommendations for research in this area should acknowledge gaps within current literature, as identified throughout. There have been research studies carried out in regards to injuries in running (Wen, Puffer, & Schmalzried, 1998), however it would be relevant for future research to be conducted to establish the impact of such injuries upon runners, similar to a study conducted by (Hreljac, 2004). In addition to this, it would be useful to establish if risk factors for injury are associated more with specific population groups, similar to the study conducted by (Napier, MacLean, Maurer, Taunton, & Hunt, 2018). There are a variety

of research papers discussing running related injuries in adults (aged 18 years+) however there have been less studies conducted that have investigated the incidence of injuries within children and adolescents in running (Mehl et al., 2011).

Conclusion

In conclusion, there is a reasonably high (37%) incidence of lower extremity injuries among runners. Across previous and current research, female runners have been shown to display a slightly higher incidence of running related injuries, compared to that of males. Generally, within running, injuries to the lower extremity occur most commonly at the knee area. However, the results within this study have highlighted that this is not the case when male and females are investigated individually. Female runners are mostly prone to injuring the calf/lower leg region and present lowest incidence of injury at the ankle/foot region. However, male runners were shown to injure the hip/pelvis/upper leg areas the most and the calf/lower leg presented the lowest incidence of injury; according to the findings of this study. Common risk factors for developing running related injuries were; a running distance of over 30 km per week, running more than three times a week, having suffered an injury in the previous twelve months, and having less than five years running experience. In future, research should focus on the investigation of what sort of impact the development of RRI have on runners individually, i.e., their athletic career, training regimes, ability to work etc. In addition to this, future research would benefit from the input of studies which investigated the risk factors for developing RRI for specific population groups, i.e. male runners, female runners, children, adolescent, and mature runners.

Competing Interests

The authors have no competing interests to declare.

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
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