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Screening tools as predictors of lower back and lower extremity injuries in ballet dancers: a scoping review

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UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

SCHOOL OF THERAPEUTIC SCIENCES

DIVISION OF PHYSIOTHERAPY

RESEARCH REPORT: MSc PHYSIOTHERAPY

Screening Tools as Predictors of Lower Back and Lower Extremity Injuries in Ballet Dancers: A Scoping Review

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in fulfilment of the requirement for Master of Science in Physiotherapy.

June 2023
Ethics number: M200946

DECLARATION

I, Samantha Kirby-Smith hereby declare that the information provided in this scoping review is my own. To the best of my ability, all sources utilised in the compilation of this research have been references fully using the Harvard referencing style.

This research report is being submitted to the University of the Witwatersrand, Johannesburg in partial fulfilment of a Master of Science in Physiotherapy (Sports and Exercise) coursework and research report degree. This research report has not been submitted for examination for any other degree at any university.



Signature of candidate: Date: 14-06-2023

Student number: 718638

Ethics number: M200946

DEDICATION

This study is dedicated to my parents, Jeff Kirby-Smith, and Les Kirby-Smith, for their unwavering support and devotion to my dreams.

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This study would not be complete without acknowledging the individuals who assisted me in this achievement. Firstly, I thank my parents for their support and love throughout this process and through all ventures in my life, both professional and personal. I acknowledge my friends Ciara Quinn and Victor Hugo Perez, for their support and encouragement when first applying for this degree, as well as for their undivided attention when I required support throughout the past two years. To my second reviewer Caroline Folgore, thank you for your patience and dedication to this research. It was such a support knowing that you were as committed as I was to this research contribution. Finally, and most importantly, I acknowledge and thank my supervisor, Dr Siyabonga Kunene, without whom this research would not have been possible. Thank you for your continued support, guidance, and time given to this research. I have learnt so much from you and admire all you represent in the field of sports and exercise physiotherapy.

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LIST OF ABBREVIATIONS

ACL	- Anterior Cruciate Ligament
BMI	- Body Mass Index
CINAHL	- Cumulative Index to Nursing and Allied Health Literature
DAFT	- Dance Aerobic Fitness Test
FMS	- Functional Movement Screen
IADMS	- International Association for Dance Medicine and Science
IdFAI	- Identification of Functional Ankle Instability
JBI	- Joanna Briggs Institute
JBIES	- Joanna Briggs Institute Evidence Synthesis
MCS	- Movement Competency Screen
PCC	- Population, Concept, Context
PEDro	- Physiotherapy Evidence Database
PFP	- Patellofemoral Pain
PFPS	- Patellofemoral Pain Syndrome
PICO	- Population, Intervention, Comparator, Outcome
PRISMA	- Preferred Reporting Items for Systematic Reviews and Meta-Analysis
PRISMA-ScR	- Preferred Reporting Items for Systematic Reviews and Meta-Analysis Extension for Scoping Reviews
PROSPERO	- International Prospective Register of Systematic Reviews
ROM:	-Range of Motion
SEBT	- Star Excursion Balance Test
SMCI	- Standard Measures Consensus Initiative

OPERATIONAL DEFINITIONS

1. Functional turnout: “The angle of turnout assumed by a dancer in any of the five basic ballet positions” (Armstrong and Relph, 2018), “the angle that is formed by the longitudinal bisection of the feet with the dancer in first position” (Filipa et al., 2013)
2. Forced/ Compensated turnout: “the difference between the first position turnout angle (functional turnout) and the total ROM of passive hip external rotation for both hips” (Armstrong and Relph, 2018)
3. En-pointe: “a dance position where the dancer weight bears fully, in complete plantarflexion on the tips of the toes, in specially designed pointe shoes” (Shnitser and Attanasio, 2001)
4. Demi-pointe: “a ballet position in which the subject stands on the toes, that is, with the weight of the body resting on the metatarsals” (Hiller et al., 2004)
5. En dehors: “Movement outwards”, “reference to the dancer’s ‘turnout’—her physical ability to ‘open’ the body and rotate the legs in the hip sockets” (Jackson, 2005)
6. Releve: A dancer rises onto the toes, “starts from straight leg into demi-plié finishing with straight legs on tip toes also known as demi-pointe” (Hinton-Lewis et al., 2016)
7. Fondu: A ballet movement consisting of ”single knee bend in external rotation” (Bowerman et al., 2014)
8. Temps leve: A ballet movement consisting of “single leg vertical jump in turnout” (Bowerman et al., 2014)
9. Plie: A ballet movement consisting of “simultaneous flexion of the hips, knees, and ankle joints” (Gontijo et al., 2015)
10. Developpe: A ballet movement performed in standing “in which the foot of the working limb is drawn up to the knee of the supporting limb, then the working limb abducted” (Feipel et al., 2004), can be performed in various positions.
11. Developpe a la seconde: “Developpe in second position, which best demonstrates the movement in the coronal plane” (LaViers et al., 2011)

ABSTRACT

Background:

Ballet dancers, as athletes, subject their joints to excessive ranges of motion under high load due to the specific choreography of this dance genre. Consensus within the literature is that ballet dancers experience high injury rates, specifically those which are chronic and over-use in nature. The locations most frequently affected by injury are the lower extremity and lumbar spine. There is a lack of consensus regarding valid and reliable screening tools or tests which have injury predictive capabilities.

Objectives:

To review the scope of literature on screening tools and their reliability in predicting lower back and lower extremity injuries in ballet dancers.

Method:

The methodology of this scoping review followed the recommendations of the PRISMA guidelines and the JBI reviewer's manual. This review utilised the PCC (population, concept, and context) framework. A systematic search of literature was conducted on CINAHL, PubMed and the Cochrane Database of Systematic reviews. The search strategy, study selection, and data extraction processes were carried out by two reviewers. The PRISMA-ScR was used to ensure all advised requirements of the methodology were met.

Results:

Seven studies were found to meet the inclusion criteria and their selection process is illustrated in a PRISMA flow chart. The analysis of each study's results is presented in both tabular and narrative formats. Additionally, a table format was used to present the assessment of the methodological quality of each study. Screening tools identified which were predictive of lower extremity injury include: change in right foot length, ankle plantar flexion ROM, passive ankle inversion ROM, lower extremity muscle strength, right foot pronation, BMI, balance on demi-pointe, right modified knee valgus angle during fondu and temps leve, pelvic angle during right leg fondu, patellar grind test, patellar inhibition test, MCS and DAFT. There were no screening tools identified which were investigated in terms of their lower back injury predictive ability. Three screening tools were investigated for their reliability which include: Beighton's hypermobility score (excellent), right foot length change (moderate) and the MCS (excellent).

Conclusion:

There are few studies which are prospective in design which investigate lower extremity injury prediction and no studies were identified in this scoping review which investigate lower back injury prediction. Future researchers should ensure that a clear definition of injury and diagnosis of injury by an experienced healthcare profession is provided in prospective research on this topic. A change in right foot length of 0.5cm and right foot pronation demonstrated the greatest ability to predict lower extremity injury. Insufficient right ankle plantar flexion ROM, reduced lower extremity strength, modified right knee valgus angle during fondu, pelvic angle during temps leve, grind test, patellar inhibition test, MCS and DAFT show promise in injury prediction. Of these tests, right foot length change demonstrated moderate reliability and the MCS demonstrated excellent reliability.

Keywords:

Ballet, injury, prediction, lower extremity, lower back, screening tool, screening test

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Chapter 1: Introduction

1.1 Background

Dancers, as athletes, undergo immense physical strain when executing various movements and positions required in dance choreography. Ballet specifically involves techniques that require dancers to subject their joints to end-range positions under high load. A survey which took into account the opinion of a panel of international dance experts (teachers, directors and relevant healthcare professionals) concluded that overall flexibility and strength were the two most sought after attributes in elite ballet dancers (McCormack et al., 2019). The flexibility of the hip, foot and ankle was emphasised, as well as the strength of the core, foot, and ankle. It was hypothesised that this was due to both the extent of functional turnout required in ballet, and the frequency of skilled jumps and landing positions required from dancers (McCormack et al., 2019). Landing from jumps has been estimated to be the mechanism of injury in 18.9% of injury cases among professional ballet dancers (Costa et al., 2016).

Not only are ballet dancers required to perform with flexibility and strength, but they are also required to appear graceful and petite in their movements. Due to this, strengthening programmes, have, been viewed as undesirable in that they were believed to reduce the aesthetic appearance of ballet dancers (Koutedakis and Jamurtas, 2004). The importance of strength becomes evident when considering the increase in musculoskeletal loading required for increased movement and exercise intensity required in ballet (Brogden et al., 2018).

There is variability in the reported incidence of ballet-related injuries in the literature. For instance, Ekegren et al. (2014) reported that 76% of 266 ballet dancers experienced injuries within a one year period. The over-all injury rates have been recorded as 1.38 injuries per 1000 hours of dance (Ekegren et al., 2014) as well as between 0.8-2.9 injuries per 1000 hours of dance (Caine et al., 2015). According to the research, the lower limb and lumbar spine are consistently identified as the two areas with the highest frequency of injury (Ekegren et al., 2014, Caine et al., 2015, Smith et al., 2016). A recent systematic review found that the presence of lower back pain in ballet dancers ranges between 20.3% and 79% (Henn et al., 2020). This shows the importance of lower back injury prevention strategies in this at-risk population.

Several studies (Roussel et al., 2009, Campbell et al., 2019, Biernacki et al., 2021) have highlighted several factors that may increase the risk of lower limb injury in ballet dancers, including, poor control of the lumbo-pelvic complex, weakness in core and lower extremity musculature, misalignment of the lower extremity, and reduced aerobic fitness. There is little

consensus in the literature to support the idea that hypermobility is an injury risk factor in the ballet population. A recent systematic review concluded that both forced and compensated turnout in dancers have correlations to lower back and lower extremity injury due to the complexity of biomechanical factors (Kaufmann et al., 2021). There is evidence which consistently supports the notion that ballet dancers sustain a high percentage of chronic over-use injuries (Bowerman et al., 2014, Ekegren et al., 2014, Sobrino and Guillén, 2017, Campbell et al., 2019). Important considerations are the implications for ballet dancers who have sustained injury. Time lost from dance has been reported as being as long as 28 days per injury, indicating the severity of injuries sustained by this population of dancers (Ekegren et al., 2014). With this in mind, it is clear that repetitive, frequent, or chronic injury can have career-defining implications for ballet dancers. Given the incidence and complex multifactorial nature of injury in the ballet dancing population, the importance of injury prevention strategies, such as screening of athletes, is evident. Given this perspective, it is unexpected that the literature lacks substantial evidence supporting the validity and reliability of injury prevention protocols and screening procedures designed to prevent injury in this vulnerable population (Caine et al., 2015, Altmann et al., 2019, Armstrong, 2019).

Relatively few studies have assessed various injury screening tools in the ballet population. A literature review conducted in 2019 concluded that there is a lack of consensus regarding screening strategies among the ballet population (Altmann et al., 2019). Flexibility test outcomes in ballet dancers have been linked to muscle imbalance and flexibility of the lumbar spine (Wójcik and Siatkowski, 2014). Reduced length of the rectus femoris muscle has been associated with both an increased lumbar lordosis and increased hamstring flexibility in this population (Wójcik and Siatkowski, 2014), however the association between these tests and injury was not investigated. Several studies have attempted to evaluate the effectiveness of various screening tools in preventing injury among the broader population of dancers and ballet performers. The Knee Lift Abdominal Test and the Standing Bow Test have demonstrated high reliability as screening tools and have demonstrated lower limb injury predictive ability in dancers (Roussel et al., 2009), while the functional movement screen (FMS) has recently been found to be ineffective in the prediction of general and lower extremity injury in dancers (Coogan et al., 2020). Physical examination assisted by ultrasound of the hip successfully diagnosed a high number of cam lesions in ballet dancers (Rodriguez et al., 2019). Cam lesions have been identified as a predictor of future labral tears in this population (Rodriguez et al., 2019). This suggests that ultrasound-assisted physical examination of the hip may be utilised as a screening tool to predict hip pathology in ballet dancers. In 2018, Armstrong and Relph conducted a systematic review and meta-analysis that provided evidence to support the use of ballet-specific positions as predictors

of injury. To this author's knowledge, this is currently the only systematic review and meta-analysis to evaluate the effectiveness of screening tools in the prediction of injury in dancers. In 2019, a systematic review aimed to identify intrinsic modifiable risk factors for injury in the ballet population (Campbell et al., 2019). As a secondary aim, the study attempted to identify which screening tools had the potential to detect the identified risk factors (Campbell et al., 2019). Although this was yet another step forward in the mission of identifying screening tools applicable to the ballet population, there was no conclusion on the ability of these screening tools to predict injury. Armstrong and Relph (2018) did not limit their systematic review to a specific location of injury or a specific genre of dance. This proposed scoping review, however, intends to limit the location of injury to the lower back and lower extremity and to limit the genre of dance to ballet as these are the two most frequently injured locations in ballet dancers. The primary reason for undertaking this review is the absence of any comprehensive scoping review in existing literature, which highlights the need to enhance the limited research currently available on this subject. Another justification for this review is to provide insights into the reliability of screening tools utilized for predicting lower limb and lower back injuries in ballet dancers. The current literature lacks consensus regarding the reliability of these screening tools. Reviewing the scope of literature on this topic will assist in guiding future research in a direction which will be most beneficial to injury prediction and thus prevention.

A preliminary search of the Joanna Briggs Institute Evidence Synthesis (JBIES), PubMed, PROSPERO, Cochrane Library, PEDro, CINAHL Plus and Open Science Framework revealed that there are no scoping reviews, similar to this proposed review, that have been published in the past three years. Furthermore, there are no similar scoping reviews currently underway which have been registered with JBI. This preliminary search was conducted on the 4th of May 2021.

1.2 Problem Statement

There is limited evidence to determine the ability of screening tools and protocols to predict lower limb and lower back injuries in dancers. Ballet, as a form of dance, has demonstrated a high injury rate across the literature (Ekegren et al., 2014, Caine et al., 2015, Henn et al., 2020). This high injury rate is suspected to be caused by the excessive joint ranges of motion required in the choreography typical in ballet, in combination with high load positions that require advanced levels of strength. Upon reviewing the literature, it was found that the most common injuries experienced by ballet dancers are chronic in nature and typically affect the lower extremities and lower back. This emphasises the importance of prevention strategies targeted at these locations. Considering the significant amount of time lost from dance, following injury in the ballet population, and the

career implications thereof, the general lack of consensus regarding injury prevention strategies, such as screening tools, across the literature is disconcerting. It leaves one concluding that there is little clarity on how to prevent injury in this, evidently at-risk population. There is a need to further investigate and consolidate the body of literature that deals with which screening tools can be utilised effectively by professionals to accurately predict lower back and lower limb injuries in the ballet population.

To date only one systematic review has been conducted on screening tools to predict injury in dancers. This review was conducted by Armstrong and Relph in 2018 and included a total of 42 studies. Of the 42 studies, 21 studies provided predictive statistical analysis and 13 studies reported on the reliability of screening tools and tests (Armstrong and Relph, 2018). The review concluded that the evidence supports the use of functional and compensated turnout to predict injury in ballet dancers. In addition, the authors commented on the lack of investigation of movement screening tools to predict injury in the dance population (Armstrong and Relph, 2018). It is important to note that multiple studies investigate the relationship between the results of specific screening tools and previous injury. However, it is difficult to conclude from these studies that these screening tools can then be utilised to predict future injury.

In general, there is little evidence to guide healthcare professionals, such as physiotherapists in the use of accurate screening tools to predict lower limb and lower back injuries in the ballet dancing population. Addressing this problem may contribute to the reduction in injury occurrence among this at-risk group of dancers. Upon identifying screening tools that effectively forecast injuries within this population, targeted interventions can be implemented for dancers who are identified as being at risk of injury. These interventions would aim to reduce the occurrence of injuries among the identified individuals. Since the first systematic review to investigate the effectiveness of screening tools in the prevention of dance injuries in 2018, there have been several studies that have contributed to this topic. An updated scoping review is therefore justified. This updated scoping review will, in addition, refine the subject of the review and focus on the type and accuracy of screening tools used to predict lower extremity and lower back injury in the ballet population.

1.3 Review Question

Which screening tools are used to predict lower back and lower limb injuries in ballet dancers and how reliable are these screening tools?

1.4 Review Aim

To review the scope of literature on screening tools and their reliability in predicting lower back and lower extremity injuries in ballet dancers.

1.5 Review Objectives

1.5.1 To identify the screening tools used to predict lower back injury in ballet dancers.

1.5.2 To identify the screening tools used to predict lower limb injury in ballet dancers.

1.5.3 To analyse the reliability of the screening tools in predicting lower back injury in ballet dancers.

1.5.4 To analyse the reliability of the screening tools in predicting lower limb injuries in ballet dancers.

1.6 Significance

This study is focused primarily on which screening tools are used to predict lower back and lower limb injuries in ballet dancers and to further comment on the reliability of these tools. The utilisation of accurate screening tools will guide healthcare professionals, such as Physiotherapists, to identify, more accurately, ballet dancers at risk of specific injuries. Such an approach would enable targeted intervention to prevent these injuries and thereby reduce the amount of time lost to injury among ballet dancers. The findings of this review will be of particular relevance to ballet, as a genre of dance, because it is within this sport that there is a high incidence of lower back and lower limb injuries. The proposed study will contribute towards a limited literature base on screening tools utilized in the ballet population and provide a condensed review of updated literature on this topic for relevant professionals to apply in practice. Furthermore, it will guide researchers in terms of where future studies should focus, in relation to this topic. This specific review lends itself to a scoping review approach since there is no comparator identified in the research question. A scoping review is appropriate given that the population, concept, and context of the research question is clear.

Chapter 2: Literature Review

2.1 Introduction

Dance is unique to other disciplines of sport in multiple ways. Ballet is a genre of dance which requires athletes to perform at end ranges of motion under high load. The complex biomechanics of ballet contribute to the location and nature of injuries sustained by dancers, and understanding these particular biomechanics is necessary to fully appreciate how injury occurs. Investigating the injury incidence, location, nature, and consequence of injury, in the ballet population, may help guide injury prevention screening protocols, and focus testing on relevant anatomical areas. Considering the severe consequence of ballet related injury, reducing injury incidence, would benefit these athletes significantly. Before identifying successful injury prevention screening protocols, injury risk factors in the ballet population must be examined in depth. Identifying injury risk factors guides protocols to focus on specific biomechanical, as well as other individualised factors, which have been shown to increase injury risk. Injury risk factors, in the ballet population, are extensively discussed in depth in the current literature. In addition, literature published in the past ten years has increasingly focussed on which injury prevention screening tests are better suited to prevention protocols specific to ballet dancers. Identifying what is well understood in terms of screening protocols in the literature, and what is missing from this body of work, guides researchers to develop a focused and meaningful research topic. Ballet dancers are a population at risk of injury, and thus, the development of effective injury prevention screening protocols targeted at this population, is necessary.

2.2 Method

Databases of PubMed, Cochrane, CINAHL and Google Scholar were searched between November 2021 and May 2022. Combinations of the following key words were used in the search strategy: ballet, dance, genre, technique, injury, pain, incidence, prevalence, type, risk factors, prevention, screening tool and screening test. All articles selected for inclusion in this literature review are journal articles. For the most part, articles included in this literature review have publication dates within the last ten years. On the rare occasion that an older article was included, it was either due to its unique content or to provide a comparison with more recent literature.

2.3 Ballet as a Genre of Dance

Dance, like all sport, challenges its athletes, both mentally and physically, placing unique demands on the individual. Dance, however, is distinct from other sport in that there are no winners or losers; the goal for each dancer is to produce a performance as close to perfection as possible (Yau et al., 2017). As with most sport, musculoskeletal injury in dancers is a vital area of

focus (Jacobs et al., 2012) and has received much attention in the dance world. Given that the mental and physical demands of dance are extreme, it is surprising that dancers have shown a generally poor perception and understanding of musculoskeletal injury and its consequences (Rivera et al., 2012). This contributes to the frequency of dancers dancing through, and ignoring pain, a phenomenon which plagues the dance world (Rivera et al., 2012). Oftentimes, this paradigm results in an insufficient time being taken off for rest and rehabilitation from injury (Rivera et al., 2012). There are other reasons to this too. One being that dancers typically fear the consequences of taking time off from dance, one of which includes being replaced (Simon et al., 2014). This lends support to the notion that dance is an extremely high-pressure sport. Another contributor is that dancers view time off and medical attention as necessary, only when an injury is deemed severe (Swain et al., 2018).

Regardless of these various contributory factors behind pushing through or ignoring pain, it is clear that this practice places dancers at an increased risk of injury, as well as increased risk of repetitive, chronic type injury. This represents the importance of adequate education of dancers, regarding the detrimental effects of not preventing or addressing injury early on in their career. Dancers also demonstrate progressive levels of devotion, commitment and motivation, which, although beneficial for their performance as athletes, pose significant challenges to clinicians related to the management of injuries (Russell, 2013). Ballet dancers, display exceptional, all-encompassing passion for their genre, which for the athlete, makes the decision to take time off to recover from an injury challenging (Russell, 2013). In support of this notion, it is documented that a significant number of dance students who sustain ankle injury (Simon et al., 2014) and experience lower back pain (Swain et al., 2018), do not seek medical attention. Furthermore, preprofessional ballet dancers and contemporary dancers can take up to 1.14 weeks to present to physiotherapy following the onset of injury (Fuller et al., 2020). Due to the small sample size (n=17) of dancers included in the study by Fuller et al. (2020), caution should be exercised in interpreting this value. A study investigating the time for dancers to present to physiotherapy, following injury, which includes a larger sample size may add a more realistic perspective.

For the purpose of this review, it is important to understand how ballet differs from other genres of dance such as hip-hop, contemporary, and various others. It has been proposed that technical requirements, specific to each genre, may place dancers at risk of injury (Russell, 2013). It is therefore clear that, understanding the requirements of a genre is paramount to understanding injury risk. Ballet dancers are required to maintain pleasing aesthetics whilst performing variations of repetitive jumps (Bowerman et al., 2015). The main shoe types specific to ballet include the

soft flat shoe and the more rigid pointe shoe (McPherson et al., 2019), the latter of which is only worn by female dancers. In some cases, a dancer may also dance in a demi-pointe shoe which is considered an intermediate to the two main types (Pearson and Whitaker, 2012) and occasionally, a dancer may perform barefoot during contemporary ballet (McPherson et al., 2019). The demi-pointe shoe is not used during performance and is typically worn by dancers at a young age as a means of strengthening the foot to transition into the pointe phase of their dancing. The different shoe types play a vital role in assessing dance specific movements and injury risk factors. This is due to the fact that variations in foot pressure have been observed in the different shoe types. Pearson and Whitaker (2012) found statistically significant variations in foot pressure between barefoot and pointe shoe conditions, as well as between soft and pointe shoe conditions. Pointe shoes imposed the highest plantar pressures on the foot, while soft shoes imposed the least pressure. This signifies that the foot and its associated structures are subjected to much greater demands in a pointe shoe condition. Ballet requires an inordinate amount of an athlete's time. Professional ballet dancers, have reported as many as 35.5 hours of dance per week, during performance periods (Allen et al., 2012). Given this demand, it is not surprising that a study reported that professional ballet dancers dance at this rate for as many as 46 weeks per year (Allen et al., 2012), leaving only 6 weeks per year for rest.

The desired traits of a ballet dancer should be understood to fully appreciate the dancer as an athlete. Overall flexibility and strength have been identified by ballet experts as the two most desirable traits in a ballet dancer, and specifically the flexibility and strength of the lower extremity are deemed a priority (McCormack et al., 2019). In support of this, it has been found that professional ballet dancers demonstrate higher than normal ranges of hip extension, abduction and external rotation (Rodriguez et al., 2019) in an attempt to achieve desirability and requirements of the choreography. Turnout is a combination of maximal external rotation of the lower extremity, from the hip to the foot, and is required in ballet choreography (McCormack et al., 2019). It has been determined that the hip contributes 36% while the knee contributes 32% to total turnout (Quanbeck et al., 2017) and thus flexibility in these joints is both required and desirable. Shoes play a vital role in physical requirements, and in the 'en-pointe' position in pointe shoes, maximal plantarflexion is required from a highly flexible ankle and foot (McCormack et al., 2019). Given the frequency of repetitive jumps required in ballet, it is not surprising that overall strength of the lower extremity is desired (McCormack et al., 2019). Stamina was also reported as a desirable trait (McCormack et al., 2019), suggesting that ballet requires at least some level of endurance. The final desired trait necessary of mention is that of body proportions, probably

due to the elegant aesthetics which ballet, as both an art form and a sport requires (McCormack et al., 2019).

2.4 Injury Incidence and Prevalence

In any sport discipline, it is important to determine injury incidence as this assists in determining the need for injury prevention screening protocols. In other words, the higher the injury incidence, the higher the need for successful injury prevention strategies to be developed. A paper published by Liederbach et al. (2012) proposed recommendations from the International Association for Dance Medicine and Science (IADMS) Standard Measures Consensus Initiative (SMCI). These recommendations were proposed in an effort to assist the community of dance medicine and science members in implementing standardised methods of research relating to dance related injury (Liederbach et al., 2012). One of the significant findings of this paper, was that responders of a survey demonstrated significantly different definitions and measures of injury (Liederbach et al., 2012). When it comes to the documentation of injury in the dance population, the IADMS recommends that this be done only by a licenced healthcare practitioner who has experience in the diagnosis of injury (Liederbach et al., 2012).

In preprofessional ballet dancers, injury risk has been reported as high as 76% in one year (Ekegren et al., 2014). Although this study followed the injury reporting guidelines of the IADMS, the authors acknowledge that the interpretation of the definition of injury may be subjective to the individual assessing injury. Furthermore, the study included dancers across three different elite pre-professional ballet schools, and there was no inter-rater reliability study conducted across these three schools (Ekegren et al., 2014). Having said this, the findings of this study are strengthened by the fact that injury diagnosis was made by two highly qualified and experienced physiotherapists. Injury rate in ballet is generally recorded as number of injuries per thousand hours of dance and varies across the literature. Amongst professional ballet dancers injury rates have been recorded as between 1.4 injuries per 1000 hours of dance (Novosel et al., 2019) and 4.44 injuries per 1000 hours of dance (Allen et al., 2012). Importantly, the lower statistic of the two was found in a study which used a self-reporting method of recording injury, while the study by Allen et al. (2012) noted that injuries were reported by a qualified physiotherapist. This is significant as it may indicate that when dancers are required to report injuries, rate of injuries will be lower than when an injury is diagnosed and recorded by a qualified healthcare professional.

As noted previously, ballet dancers often dance through or ignore pain, and thus the significant differences in injury rate found in these two studies is understandable, given the method of injury recording for each. In preprofessional ballet dancers, injury rate has been recorded as 1.38

injuries per 1000 hours of dance (Ekegren et al., 2014), which is slightly lower than injury rates recorded in professional ballet dancers. These findings are confirmed by those of Smith et al. (2015) in a systematic review which found that injury incidence was 0.97 injuries per 1000 hours of dance in amateur ballet and 1.24 injuries per 1000 hours of dance in professional ballet. Injury incidence is generally recorded as number of injuries per dancer. Allen et al. (2012) found that professional ballet dancers sustained 6.8 injuries per dancer over the period of one year, while Ekegren et al. (2014) found that pre professional ballet dancers sustained 1.42 injuries per dancer over the same time period. In both studies, the diagnosis of an injury was made by a physiotherapist. It should be emphasized that dancers in the study by Allen et al. (2012) were dancing 34 hours per week, while those in the study by Ekegren et al. (2014) were dancing 30.3 hours per week. This suggests that perhaps dance hours per week as well as level of dance will affect injury rate, given the significant differences found between these studies. It is also important to note that the incidence of injury in the professional ballet population, is higher during dance class compared to rehearsal and performance (Allen et al., 2012). This may be due to the greater amount of time spent in class compared to that spent rehearsing and performing.

2.5 Injury Type and Location

Understanding the pattern of injury location in athletes is important when determining which anatomical location, injury prevention screening tools should target. Injuries among ballet dancers seem to persistently occur in the lower extremity and lower back regions (Allen et al., 2012, Ekegren et al., 2014, Caine et al., 2015, Smith et al., 2016, Yau et al., 2017). This is understandable given the choreography, specific to ballet, as well as the repetitive load placed on the lower extremity and lumbar region in this genre of dance. Lower extremity injury has been found to account for 66%-91% of all injuries (Smith et al., 2015). This statistic is strengthened by the fact that the study is a systematic review, which used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). However, the study included studies from level 1 to 4 evidence, and it should be noted that the review did not report on how many studies fell under each level of evidence. Furthermore, it was not stated how many reviewers took part in each stage of the methodology.

Of injuries sustained in the lower extremity, Allen et al. (2012) found that the lower leg, ankle and foot were among the most common locations. This aligns with a number of studies which have found the ankle and foot to be amongst the most commonly injured areas (Gamboa et al., 2008, Ekegren et al., 2014, Costa et al., 2016, Smith et al., 2016, Novosel et al., 2019, Fuller et al., 2020), with the calf and knee also featuring as frequent locations (Novosel et al., 2019). Of

particular concern, with regards to the ankle, is a finding that among a population of modern and ballet dance students, 70.1% had sustained an ankle sprain, of which 53% were considered to have chronic ankle instability (Simon et al., 2014). Furthermore, the majority of ballet dancers presented with bilateral chronic ankle instability (Simon et al., 2014). This location of injury can be explained by the overload sustained by the ankle during pointe, demi-pointe and en dehors (Costa et al., 2016), while the nature of chronicity may be explained by high load repetitive movements, as well as the characteristic of dancers to persist through injury, as previously mentioned. Although the findings of Simon et al. (2014) were the result of questionnaires completed by dancers, it should be mentioned that the study utilised the Identification of Functional Ankle Instability (IdFAI) to diagnose bilateral chronic ankle instability. The study reported that the IdFAI had an 89.9% accuracy in distinguishing individuals with and without chronic ankle instability (Simon et al., 2014), thus strengthening the significance of their findings. Smith et al. (2016) noted a high period prevalence of stress fractures of the metatarsals and tibia, amongst professional ballet dancers, in a systematic review and meta-analysis. This is concerning as these injuries require a significant amount of time off from dance (Ekegren et al., 2014), which as previously mentioned, is not readily accepted by dancers.

Lower back pain is a prevalent occurrence among ballet dancers. A recent systematic review reported lower back pain in 57% of this population (Henn et al., 2020). This systematic review included 33 articles, of which 25 were designed using self-reported data collection methods (Henn et al., 2020). As discussed above, the results of research reporting on any dance related injury is strengthened when injury diagnosis is made by a qualified healthcare professional (Liederbach et al., 2012). Another study found that of 52 ballet dancers, 60% reported moderate lower back pain using the numeric pain rating scale (Wójcik and Siatkowski, 2014). This is concerning, given that the average age of dancers in this specific population was 11.64 ± 0.53 years (Wójcik and Siatkowski, 2014). This indicates that injury prevention screening protocols are required from a young age.

2.6 Injury Nature

The nature of injury sustained by this at-risk population is important to understand because it enables a more focussed approach to the development and use of injury prevention screening protocols. Consensus across the literature is that over-use injury is the most frequent pattern seen among ballet dancers (Allen et al., 2012, Sobrino and Guillén, 2017, Yau et al., 2017) and accounts for the most amount of time lost from dance (Allen et al., 2012). Ekegren et al. (2014) reported that 72% of injuries were caused by over-use in a group of pre-professional ballet

dancers over the course of one year. The findings of two slightly more recent systematic reviews support the notion that of the injuries sustained by ballet dancers, a high percentage of these are over-use in nature (Caine et al., 2015, Smith et al., 2015). Caine et al. (2015) reported that a range of 53.6% to 85% of injuries, among young ballet dancers, were classified as over-use injuries. Smith et al. (2015) reported that of the musculoskeletal injuries, 75% were over-use in nature among amateur ballet dancers, whereas 57% were over-use in nature among professional ballet dancers. Although not speculated by the authors of the latter statistics, this author poses the possibility that over-use injuries are more common in amateur ballet dancers due to a reduced skill acquisition and possibly more faulty biomechanics, when compared to the professional group. Furthermore, more degenerative conditions have been noted in older ballet dancers with more experience in the professional environment (Sobrino and Guillén, 2017) possibly indicating the effect of wear and tear over time.

2.7 Consequences of Injury

Considering the consequences of injury in this population is vital when considering the possible benefits, obtained by dancers, from successfully implemented injury prevention screening protocols. Time loss from injury varies across the literature and is reported as between 7 (Allen et al., 2012) and 28 days (Ekegren et al., 2014). As mentioned previously, tibial stress fractures are a concern in this population and can cause dancers to miss an average of 177 days of dance in a preprofessional ballet population (Ekegren et al., 2014). Time lost from dance due to injury can have catastrophic effects on a potential professional career in ballet and preventing this time loss should be of primary concern for this population. In addition to this time loss, pain itself has been related to an increased risk of burnout and depression in individuals who are physically active in a recent systematic review (Skwiot et al., 2021). The relationship between time off from dance due to injury and psychological effects of pain secondary to injury, among ballet dancers is a growing concern.

2.8 Risk Factors for Injury

It is clear from the literature that ballet dancers are a population at risk for injury. Understanding injury risk factors, both intrinsic and extrinsic, enables injury prevention screening protocols to be both purposeful and focused.

Extrinsic risk factors in ballet are important to be aware of as they provide insight into how external physical factors affect injury occurrence. Having said this, these factors are often difficult to manipulate. Professional ballet dancers are required to train and perform on a variety of floors at various venues (Hopper et al., 2014). Dance floor mechanics is an extrinsic factor which has

received little attention in the dance world. One study found that ballet dancers sustained significantly more injuries when dancing on floors with increased intra-floor reduction variability (Hopper et al., 2014). This may influence landing biomechanics amongst dancers, leading to greater chance of injury (Hopper et al., 2014). Ballet dancers are also required to dance in a variety of shoes. Dancers typically start their training on soft shoes, and as their skill advances, the dancer transitions into a pointe shoe (Pearson and Whitaker, 2012). This transition requires a significant amount of adjustment biomechanically. The soft shoe places the least amount of pressure on the plantar aspect of the foot, while the pointe shoe places the foot under the greatest amount of pressure. The demi-pointe shoe is the intermediate of the two in terms of plantar pressures. Ballet dancers who do not transition from soft to demi-pointe shoes before moving into pointe shoes have demonstrated an increased likelihood of ballet related injury, specifically in the lower leg, foot and ankle region (Pearson and Whitaker, 2012). As these injury locations have been identified as common, addressing the lack of transition into a demi-pointe shoe is important. The process of transitioning may allow the relevant biomechanical and strength changes to occur over time (Pearson and Whitaker, 2012).

The majority of injuries sustained in ballet are due to intrinsic factors (Allen et al., 2012). Intrinsic injury risk factors in ballet are extensively discussed in the literature. There is however little agreement on this topic. Hypermobility is one intrinsic factor which has received much attention and is more common in females (Foley and Bird, 2013). Although it is widely understood that ballet dancers require overall flexibility to meet the requirements of choreography, the literature on hypermobility discusses the potential detrimental effects excessive flexibility has on injury incidence. For ballet dancers, what is biomechanically safe, and what is aesthetically pleasing is in constant tension (Foley and Bird, 2013). A recent systematic review has linked hypermobility with a higher risk of chronic ankle instability, anterior cruciate ligament (ACL) injuries, labral tears, tendinopathies, degenerative conditions, and hip instability among ballet dancers (Campbell et al., 2019). The results of a study indicated that recreational ballet dancers exhibiting hypermobility in hip external rotation were at a greater risk of sustaining ankle and foot injuries (Biernacki et al., 2021). This relationship was not present in elite ballet dancers (Biernacki et al., 2021). Hypermobility, as measured by the Beighton's hypermobility scale, has been considered unrelated to injury risk in the ballet population (Biernacki et al., 2021). However, it has been hypothesised that this scoring system is not tailored to the physical requirements of ballet (Foley and Bird, 2013). One interesting argument, is that given the shock absorptive qualities to hypermobility, it may in fact act as a defence against certain injuries (Foley and Bird, 2013).

Compensated turnout refers to the difference between bilateral hip external rotation range and the degree of achieved turnout (Kaufmann et al., 2021). A recent systematic review, of sound methodological quality, found that compensated turnout was associated with increased musculoskeletal injury (Kaufmann et al., 2021). It is important to exercise caution in interpreting this finding, since the review comprised only seven articles of medium to low methodological quality. Having said this, various aspects of turnout, such as insufficient turnout (Caine et al., 2015) and degree of turnout (Campbell et al., 2019) have been suggested as injury risk factors in other studies. Advanced degrees of turnout are favourable in ballet choreography, however encouraging dancers to exceed natural ranges of turnout may lead to compensation and injury (Quanbeck et al., 2017). Given that turnout is required frequently within ballet choreography, compensated turnout being considered an intrinsic risk factor may provide a promising area of research when it comes to prevention of injury in ballet dancers.

Two systematic reviews have identified neuromuscular dysfunction and weakness in the core and lower extremity as intrinsic risk factors for injury among ballet dancers (Biernacki et al., 2021, Campbell et al., 2019). The one study highlighted that strength imbalances in the hip area can cause compensatory mechanisms, such as adopting a more flexed posture with internal rotation of the femur, potentially leading to lower extremity pathology (Campbell et al., 2019). These results are consistent with those of Biernacki et al. (2021), who reported that weak pelvic stabilisers and compensatory movements in the hip increase the risk of lower extremity injury in elite ballet dancers. Both systematic reviews were of a good methodological quality, however both studies noted that better conclusions will be obtained if future studies provide a consistent definition of injury (Biernacki et al., 2021, Campbell et al., 2019). There is a need for a better understanding of the relationship between core strength and injury, as noted in the literature (Rickman et al., 2012).

In ballet dancers, lower extremity range of motion (ROM), particularly discrepancies at the hip and ankle joint, have been recognised as risk factors for injury (Campbell et al., 2019). Isolated to the hip joint, differences between left and right hip abduction and external rotation as well as increased hip external rotation have been related to injury risk (Campbell et al., 2019). Given the fact that most injuries sustained by ballet dancers occur in the lower extremity and lumbar region, it is unsurprising that the risk factors of injury in terms of strength and ROM seem isolated to the lower limbs and core. A recent systematic review found that both female recreational and elite ballet dancers are at a higher risk of lower extremity injury if they have misalignments in their pelvic and spine (Biernacki et al., 2021). These misalignments were identified as significant risk

factors (Biernacki et al., 2021). This was a high-quality systematic review of sound methodology, however due to the heterogeneity of the included studies, a meta-analysis was not possible.

Given that professional ballet dancers can dance between 25 to 30 hours per week excluding performance time (Novosel et al., 2019) and 35.5 hours per week during performance periods (Allen et al., 2012), fatigue is a factor to consider when discussing risk of injury. Preprofessional ballet dancers have been found to be subjected to slightly higher training hours than what is recommended for their age (Ekegren et al., 2014). Given this, it is surprising that a study conducted on pre-professional and professional classical ballet and contemporary dancers found that there was no significant correlation between hours danced per week and incidence of lower back pain (Swain et al., 2018). It must be noted, however, that this finding cannot be applied to injuries of all locations and nature. Advanced levels of physical load and performance demands have been correlated to increased risk of injury and back pain in athletes of individual and team sport (Zemková et al., 2020). There is a suggestion that specifically acute increases in training load may increase risk of injury as oppose to chronically high levels of training (Zemková et al., 2020). Despite this, fatigue is still considered a risk factor for over-use injuries in ballet dancers (Campbell et al., 2019). The reason for this is that fatigue may influence landing biomechanics which is specifically relevant in the context of ballet (Campbell et al., 2019), given the presence of repetitive jumps observed in the choreography.

Finally, a relatively recent systematic review of sound methodological quality, found that for recreational ballet dancers, hours of training per week was a significant risk factor for lower limb injury, while for elite ballet dancers, training intensity was linked to lower limb injury (Biernacki et al., 2021). This speaks to the idea that elite ballet dancers may be physically accustomed to a high amount of training hours due to their level of dance but are less accustomed to shifts in intensity of training. The same study found that having low levels of aerobic fitness is a risk factor for lower extremity injury in this population (Biernacki et al., 2021). These findings are supported by the conclusions made in another systematic review which identified fatigue as an intrinsic risk factor for injury (Campbell et al., 2019).

It is important to briefly mention that history of injury (Yau et al., 2017, Campbell et al., 2019, Biernacki et al., 2021) and current disability score (Biernacki et al., 2021) are consistently identified as risk factors for future injury and future lower extremity injury. In pre-professional and professional dancers, having a history of lower back pain has been linked with a higher likelihood of experiencing lower back pain in the future (Swain et al., 2018). These findings were made in a prospective cohort study, where lower back pain was recorded by use of self-reported

questionnaire and it should be considered that of 119 participants, only 22 completed all the required questionnaires (Swain et al., 2018).

In terms of psychological risk factors, a history of depression (Yau et al., 2017), quality and quantity of sleep, stress, psychological distress and disordered eating habits have been associated with dance related injury and outcome (Mainwaring and Finney, 2017).

The final risk factor for discussion is that of age. There is mixed evidence regarding whether age influences injury incidence, with one systematic review finding conflicting evidence that age is related to lower extremity injury (Biernacki et al., 2021). What should be considered is the growth changes that occur in relation to age during periods of growth spurts. A systematic review found that young adolescent dancers had an increased risk of injury due to growth related changes in biomechanics such as ROM (Storm et al., 2018). This speaks to the fact that age, in relation to growth changes, should be considered when evaluating dancers for risk of injury. However, a significant limitation in this study was that of the 7 included articles, only one article compared dancers with non-dancers, and therefore the conclusions of the study should be interpreted with caution.

2.9 The Role of Physiotherapy: specific to the ballet population

Physiotherapists form part of the medical team which aids in the general management of ballet dancers (Allen et al., 2012). It has been found that physiotherapists and dance teachers are the two most prevalent professions to be involved in dance screening practices and that the main motivation behind such screening practices was to prevent injury and promote self-management (Armstrong, 2019). Other roles of the physiotherapist, within the ballet community, include diagnosis, treatment and rehabilitation of injury, playing a vital role in the decision on returning to sport (Allen et al., 2012). Given the various roles of the physiotherapist, specific to a ballet setting, and the fact that injury prevention is a current focus within the ballet community, it is understandable that dancers and physiotherapists are frequently engaging. In fact, physical therapy treatment sought out by dancers has been recorded as high at 90% for females and 91.3% for males (Costa et al., 2016), and physiotherapists have been found to be the most frequently contacted health care professionals by dancers who experience lower back pain (Swain et al., 2018).

As of 2012, there was a lack of research into the benefit of healthcare providers in the treatment of musculoskeletal pathology within the dance world, as reported by a systematic review (Jacobs et al., 2012). Given this, it is promising to see progress in the literature, as a more recent

systematic review found that physiotherapy interventions had a positive effect on pain, ROM and function in the treatment of musculoskeletal injury in ballet dancers (Skwiot et al., 2021). Notably, this review only included ten articles of low methodological quality, possibly reflecting the limited literature base on this topic. Of particular concern, is that none of the included articles investigated the intervention of screening for the purpose of injury prevention. In support of the role of physiotherapists in the diagnosis and treatment of dancer's injuries, Kinney et al. (2018) report a reduced time loss effect when involving a physiotherapist in the management of injury. It is argued that this may be due to the ability of the physiotherapist to make a prompt diagnosis and implement an appropriate treatment plan (Kinney et al., 2018). A study specific to professional modern dancers, found that having an inhouse physical therapist leading an injury management program resulted in reduced time loss secondary to injury, reduced injury related costs, and a 66% reduction in workers compensation injury incidence (Ojofeitimi and Bronner, 2011). Although evidence supports the fact that physiotherapists form a vital role in injury management and rehabilitation in the dance world, there is a call for better therapeutic intervention, relating to injury prevention, in the ballet population (Costa et al., 2016). The identification of successful predictive screening tools would be of vital importance in terms of making such progress.

2.10 Screening Protocols: What has been investigated thus far?

Injury prevention within the dance population is certainly warranted (Russell, 2013). Screening is one injury prevention strategy, and is essential in the promotion and preservation of health amongst dancers in the ballet population (Campbell et al., 2019). It is conclusive, across the literature, that there is a need for ballet specific injury prevention strategies. This is primarily due to the high injury rate and the large amount of time lost secondary to injury (Allen et al., 2012). Given the fact that the majority of injuries in ballet occur due to intrinsic risk factors, there has been a suggestion that injury prevention screening be focused on these identified risk factors (Allen et al., 2012). Furthermore, the focus of screening protocols to prevent injury should address physical areas of high risk such as the ankle, foot and spine (Smith et al., 2016) as well as other locations in the lower extremity. It is understood that given the many risk factors for injury amongst ballet dancers, no single screening test is sufficient in screening for injury (Campbell et al., 2019).

A few studies have investigated which screening tests have been shown to be effective in predicting injury. One study found some statistically significant relationships between disability score based on flexibility and strength tests, history of lower back pain, right foot pronation, reduced right ankle plantarflexion and reduced lower limb strength in dancers that remained uninjured and dancers that sustained injury (Gamboa et al., 2008). The strongest association to

injury was right foot pronation (Gamboa et al., 2008). Notwithstanding the above, the authors of this study commented that the screening tests used do not have sufficient reliability and validity (Gamboa et al., 2008). The findings regarding right foot pronation were supported in a systematic review by Campbell et al. (2019). Ultrasound has been successful in identifying CAM lesions in ballet dancers (Rodriguez et al., 2019). This is significant as the presence of a CAM lesion has been correlated to a positive dial test, which is an indication of hip micro-instability (Rodriguez et al., 2019). Therefore, the use of ultrasound may, indirectly, be a potential screening tool for hip micro-instability in ballet dancers. However, this method of screening requires significant resources and is therefore limited to environments which can provide such tools.

The star excursion balance test (SEBT) is the most frequently used movement screening test amongst ballet dancers (Armstrong, 2019, Ani et al., 2021). Campbell et al. (2019) found that the SEBT successfully identified compensatory movements. However, disagreement in the literature exists. Ani et al. (2021) noted that the SEBT is not specific enough to assess balance in the dance population and there was no relationship between this test and injury. Clarke et al. (2021) found that there is inconclusive evidence to confirm that the SEBT can be used to assess postural stability in dancers. The movement competency screen (MCS), another screening test, has in a recent systematic review, been recommended in the injury screening process of ballet dancers (Campbell et al., 2019). This tool includes a combination of five movements, including the single leg squat which has shown efficacy in screening for patella-femoral pain syndrome in ballet dancers (Campbell et al., 2019).

Given that a previous systematic review highlighted the need for movement screening tools within the ballet population (Armstrong and Relph, 2018), this is a promising development within the literature. The heel rise test has been suggested in the assessment of functional calf capacity in classical ballet dancers, however, correlation to injury has not been determined and further investigation regarding the use of this test as a screening tool is still required (Zellers et al., 2017). Nonetheless, it seems that the heel rise test is the most frequently administered strength test amongst dance companies (Armstrong, 2019). The FMS has been found to be ineffective in the prediction of lower limb and overall injury in collegiate dancers (Coogan et al., 2020). However, the findings of this study, which was conducted in a single institution, may not be generalisable to the entire ballet population (Coogan et al., 2020). Armstrong et al. (2018a), has instead suggested that elements of the FMS, such as the deep squat, have a greater predictive ability in assessing mechanical loading in dancers.

Differences in support of the use of hypermobility scores exist in the literature, with one systematic review supporting the use of the Beighton's hypermobility score (Campbell et al., 2019), while a level 2b study found no statistical difference between injured and non-injured dancers when it came to hypermobility (Gamboa et al., 2008). Interestingly, 75% of respondents in a questionnaire study reported that they screen for hypermobility in dance companies and that 83.3% of them use the Beighton's hypermobility scale (Armstrong, 2019). As mentioned previously, hypermobility is common among ballet dancers, due to the requirements of the genre. The Beighton's hypermobility sore does not include any ballet specific measurements, putting into question its applicability to the ballet population.

There seems to be greater consistency in the literature in relation to various aspects of turnout. Passive external rotation of the hip, functional turnout (Campbell et al., 2019) and compensated turnout (Armstrong and Relph, 2018) have been suggested as ballet specific injury screening tests, and increased compensated turnout has been identified in injured ballet dancers (Armstrong and Relph, 2018). In support of this finding, most dance schools include passive turnout and demi-plie in their screening of dance specific movements (Armstrong, 2019). Converse to these findings, Kenny et al. (2018) concluded in a reliability study, that passive hip external rotation as well as passive supine turnout and the foot posture index are not recommended in the screening of pre-professional ballet dancers. Instead, it is recommended that turnout be assessed dynamically, and in a position considered functional in ballet (Quanbeck et al., 2017).

The Fast Short-Term Fatigue protocol has been suggested as a tool for screening for injury risk in dance, but application to the genre of ballet was not discussed (Campbell et al., 2019). It does however seem that the majority of dance schools ask questions regarding overtraining and fatigue as part of their screening process (Armstrong, 2019). Furthermore, Armstrong (2019) found that the dance aerobic fitness test (DAFT) was the most commonly used test when screening for aerobic fitness.

The evidence on injury screening tools in the ballet population is inconsistent for the most part. Currently, to the author's knowledge, there is no scoping review which has investigated screening tools as a predictor of specifically, lower back and lower extremity injury in ballet dancers. Given the inconsistency in the literature, such a review may aid in determining some agreement on specific tools and tests mentioned above which warrant further investigation. This may, in turn, guide researchers in terms of which screening tools show promise in their predictive ability, as well as propose which study designs are warranted to strengthen the evidence.

2.11 Screening Protocols: What is Missing?

There is little understanding of how specific injuries may be related to ballet specific movements (Smith et al., 2016). Investigating this may further assist in the development of injury prevention screening protocols which are steered towards specific movement patterns that have been identified as causes of common injuries in ballet dancers. Generally, evidence regarding injury prevention strategies is scarce (Biernacki et al., 2021), and therefore further investigation and analysis of existing evidence is warranted. Given that injuries among ballet dancers seem to be cumulative in nature there is a need for more primary injury prevention strategies, such as screening tools (Ekegren et al., 2014). There are multiple benefits of injury prevention strategies in the ballet population, one of which is the prolonging of a dancer's professional career as a result of early injury prevention strategies implemented at a preprofessional level (Ekegren et al., 2014).

One area where focused research is warranted, is in identifying predisposing risk factors to stress fractures (Ekegren et al., 2014). Given the frequency and high amount of time lost from dance, due to this injury, in ballet dancers (Ekegren et al., 2014) further research may shed light on how injury prevention screening protocols can focus on these identified risk factors. Given the evidence on how forced or compensated turnout can result in injury, research should focus on a standardised method of assessing turnout (Kaufmann et al., 2021). There is no conclusive method of assessing turnout and no normal value of turnout that has been determined (Quanbeck et al., 2017). The use of three-dimensional motion analysis may be a possible method of accurately assessing turnout (Quanbeck et al., 2017), however, this method is potentially not practical in all ballet settings. Although most of the literature agrees that assessing turnout is an important screening test, without a reliable dynamic method of assessment, it makes this test difficult to implement effectively in a screening protocol.

The general picture of this review is that ballet dancers are at risk of injury and screening protocols to prevent injury are in great need. What is concerning, is the lack of evidence-based practice in terms of this screening process. This is evident in the mismatch between screening tools that are currently being used in the ballet setting, and the evidence that supports these screening tools.

2.12 Conclusion

Ballet is unique to other sports in both its physical and mental demands. From a physical perspective, choreography requires extreme ranges of joint motion to be maintained under high load. From a mental perspective, ballet dancers train long hours each week which can be psychologically and mentally demanding. In addition, the sport itself is dominated by a pressure to perform at a high individual level which results in dancers being compelled to dance through

pain with some injuries going untreated. Given this, it is understandable that the injury incidence, although varying in the literature, requires attention in terms of injury prevention strategies such as screening. Injuries amongst ballet dancers occur primarily in the lower extremity and lower back region and are generally over-use in nature. In terms of risk factor for injury, most agreement lies in ROM differences in the lower extremity, strength deficits in the core lower back and lower limb, compensated turnout, fatigue, and a history of injury. In addition, the literature consistently agrees that intrinsic factors pose the largest threat to injury occurrence. Well described injury prevention screening protocols, specific to the ballet population, are warranted. Some research has been conducted to address this, with various aspects of turnout being the most commonly assessed to identify dancers at risk of injury. Although this research is providing promising steps forward with regards to injury prevention, the lack of a standardised measure of turnout and compensated turnout poses difficulties when it comes to implementing such a screening approach. To the authors knowledge, there is no current scoping review which focuses on screening tools to predict injury to the lower back and lower limb in the ballet population. Given the fact that injuries seem to commonly occur in the lower extremity and lower back region among this population of athletes, a scoping review specific to screening protocols that address these areas would add to a scarce research base. Furthermore, the results of such a scoping review may guide future systematic reviews and primary research studies to investigate specific screening tests which show the most promise in terms of successful prediction of injury in the ballet population. Future research into screening tests, which show promise in identifying dancers at risk of injury, would aid in reducing injury occurrence and the consequences that ballet related injuries have for these athletes. The primary focus of any body of healthcare professionals within the sporting community is to preserve the health, wellbeing, and general success of athletes. Therefore, as a body, there is a responsibility to implement evidence-based prevention strategies such as screening tools to successfully prevent injury.

Chapter 3: Methodology

3.1 Introduction

This chapter describes the methodology used to achieve the following objectives:

- To identify the screening tools used to predict lower back injury in ballet dancers.
- To identify the screening tools used to predict lower limb injury in ballet dancers.
- To analyse the reliability of the screening tools in predicting lower back injury in ballet dancers.
- To analyse the reliability of the screening tools in predicting lower limb injuries in ballet dancers.

Prior to the commencement of this scoping review, the title and proposal were registered on Open Science Framework on the 13th of February 2022 (https://doi.org/10.17605/OSF.IO/VAQMK). This was in an effort to ensure that there was no duplication of research by other researchers interested in this topic, prior to the completion of this scoping review. The registration of scoping review titles on Open Science Framework is a recommendation from the Joanna Briggs Institute (JBI) Manual for Evidence Synthesis (Aromataris and Munn, 2020). The methodological structure for this scoping review followed the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) GROUP guidelines and the JBI reviewers manual (Moher et al., 2009, Aromataris and Munn, 2020). As indicated in these guidelines, it is advised that a second reviewer be included throughout the methodology.

The second reviewer for this scoping review was a qualified physiotherapist, with experience in the sports physiotherapy field of interest, and was trained by the primary reviewer on each stage of the methodology. A third reviewer was consulted when consensus between the primary and secondary reviewer was not reached. The PRISMA flowchart provided a method for a narrative description of the process by which studies are identified and selected for inclusion in a scoping review. The use of the PRISMA flowchart was to ensure that the method of selection is reported systematically (Aromataris and Munn, 2020, Khalil et al., 2016). The Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist (Appendix 1) was used to ensure a rigorous methodology was followed, as is recommended for scoping reviews (Tricco et al., 2018). To manage references throughout the process of this review, the Endnote software was used.

3.2 Study Design

This study was a scoping review by design and follows the JBI guidelines, as mentioned above. The reason why a scoping review design was chosen for this study is due to the research question. The review's research question is structured around a Population, Concept, Context (PCC) framework, which made a scoping review the most suitable choice. A systematic review design was, in contrast, not appropriate as systematic reviews are structured according to a PICO (Population, Intervention, Comparator, Outcome) framework. The research question for this review lacks a comparator. Furthermore, as outlined by Munn et al. (2018), a scoping review serves various objectives, including the identification and analysis of knowledge gaps, exploration of key characteristics or factors associated with a specific concept, and examination of research methodologies employed within a particular topic or field. The reviewers manual of methodology for JBI scoping reviews suggests the design of a scoping review to map the scope of literature on a relatively broad topic in the absence of an outcome measure within the research question (Peters et al., 2015). The aim of this scoping review was to review the scope of literature on screening tools and their reliability in predicting lower back and lower extremity injuries in ballet dancers.

3.3 Inclusion Criteria

The PCC framework was utilised to structure inclusion criteria. This is the advised method of developing inclusion criteria for scoping reviews (Peters et al., 2015).

3.3.1 Population

This scoping review included studies done specifically among ballet dancing participants. If the study investigated multiple genres of dance, provided there was specification of at least some participants being ballet dancers, it was included. Participants may be of any age, gender, ethnicity and participated at any level and style of ballet. Where the population of dancers was unclear, a study was considered for inclusion provided the content clearly included ballet specific positions/ movements.

3.3.2 Concept

The scope of this review encompassed studies that examined the effectiveness of screening tools or tests in predicting future lower back and/or lower extremity injuries among the ballet dancing population. When mentioned in the included study, this scoping review commented on the reliability of screening tools and/or tests to predict injury to the lower back and lower extremity in ballet dancers.

3.3.3 Context

This scoping review considered for inclusion any context in which screening tools and/or tests to predict lower back and lower extremity injury were investigated.

3.4 Exclusion Criteria

Articles were excluded if:

- The article was not published within the last 20 years.
- The article was not published in a peer reviewed journal.
- The article did not include a ballet population of dancers.
- The article investigated the relationship between a screening tool or test and previous injury, as opposed to predicting future injury.

3.5 Types of sources

This scoping review included all articles published within the last 20 years which were published in peer reviewed journals and met the inclusion criteria.

3.6 Search strategy

The search strategy for this scoping review involved a three step process as suggested by the JBI Reviewer's Manual, Methodology for Scoping Reviews (Peters et al., 2015). Step one involved a preliminary search of the literature which was conducted in March 2022 by the primary reviewer. Articles which explored the potential of screening tools to predict lower back and lower limb injury in ballet dancers were extracted. The keywords used for this search included combinations of the following: ballet, dance, injury, pain, screening tool, screening test, screening protocol, prevention, lower limb, lower extremity, lower back and lumbar. The preliminary search was conducted on the MEDLINE (PubMed) and CINAHL databases as these databases were deemed appropriate for this topic. The JBI Reviewers Manual, Methodology for Scoping Reviews recommends that the preliminary search be conducted on at least two databases (Peters et al., 2015). The title, abstract and keywords were screened by the primary reviewer to identify appropriate keywords to develop the Boolean phrase for step two of the search strategy. Relevant Medical Subject Headings terms were established by the primary reviewer. Table 3.1 represents the process of developing the final search term for this scoping review.

Table 3.1: Keywords identified for Boolean phrase

Terms connected by OR	**AND**	**Terms connected by OR**	**AND**	**Terms connected by OR**	**AND**	**Terms connected by OR**
Text Terms: Screening tool* Screening test* Screening protocol* Injury prediction Injury risk Functional screening Injury screening tool* **MeSH Terms: -**		**Text Terms:** Injur* Pain Injur* in dance **MeSH Terms:** Wounds and injury Pain		**Text Terms:** Lower back Lumbar Lower extremit* Lower limb* **MeSH Terms:** Lumbosacral region Lower extremity Low back pain Lumbar vertebrae		**Text Terms:** Ballet Danc* **MeSH Terms:** dancing

Step two commenced from inception until the end of April 2022 and involved the primary and second reviewer conducting a structured search of CINAHL, MEDLINE (via PubMed) and the Cochrane Database of Systematic Reviews using the keywords identified for the Boolean phrase represented in Table 3.1. An example of the final search term is represented in table 3.2. Once the searches of CINAHL, MEDLINE (via PubMed) and the Cochrane Database of Systematic Reviews yielded the same results for the primary and second reviewer, the Endnote software was used to import the searches and eliminate any duplicates. Where possible, the filter of “humans” was applied and the date restriction of January 2002 up until current date of search was applied. The method of this step being performed independently by two reviewers was in an effort to minimise bias. The rationale for the use of these three databases was that the search layout of each allowed for a structured and reproducible search strategy utilising Boolean terms as is recommended for scoping reviews.

Table 3.2: Boolean phrase final search term formulated on PubMed

Boolean Phrase	
("ballet"[Text Word] OR "danc*"[Text Word] OR "dancing"[MeSH Terms]) AND ("lower back"[Text Word] OR "lumbar"[Text Word] OR "lower extremit*"[Text Word] OR "lower limb*"[Text Word] OR "lumbosacral region"[MeSH Terms] OR "lower extremity"[MeSH Terms] OR "low back pain"[MeSH Terms] OR "lumbar vertebrae"[MeSH Terms]) AND ("injur*"[Text Word] OR "pain"[Text Word] OR ("injur*"[All Fields] AND "in dance"[Text Word]) OR "wounds and injuries"[MeSH Terms] OR "pain"[MeSH Terms]) AND ("screening tool*"[Text Word] OR "screening test*"[Text Word] OR "screening protocol*"[Text Word] OR "injury prediction"[Text Word] OR "injury risk"[Text Word] OR "functional screening"[Text Word] OR "injury screening tool*"[Text Word]) AND "humans"[MeSH Terms]	
Translations	
dancing[MeSH Terms]:	"dancing"[MeSH Terms]
lumbosacral region[MeSH Terms]:	"lumbosacral region"[MeSH Terms]
lower extremity[MeSH Terms]:	"lower extremity"[MeSH Terms]

Step three of the search strategy involved the primary reviewer screening all reference lists of articles yielded in the searches to identify additional relevant articles which were not yielded in the second step of this process. Step three commenced at the beginning of May 2022. This detailed search strategy is represented according to the PRISMA statement in a four-phase flow diagram (Moher et al., 2009) as suggested by the JBI Reviewers Manual, Methodology for Scoping Reviews (Peters et al., 2015). The PRISMA four-phase flow diagram is presented in figure 4.1 under chapter 4 of this review. The final search strategy was then repeated, by the primary reviewer, in August 2022. This was to ensure that no further studies, relevant for inclusion, had been published after the initial search conducted in April 2022, prior to the write up of this scoping review.

3.7 Study Selection

It has been recommended that a two-phase approach be utilised when conducting study selection for systematic reviews (Porritt et al., 2014). The initial step involved choosing studies that met the pre-established criteria for inclusion and exclusion as specified in section 3.3 and 3.4 of this chapter. The second step involves studies being selected based on a quality appraisal. Given that this is a scoping review, critical appraisal of studies selected in the first phase of this process is optional (Aromataris and Munn, 2020). Instead, it was decided that only articles published in peer reviewed journals would be included. This restriction for inclusion was in an effort to limit the inclusion of articles which are of a poor methodological quality due to the lack of critical appraisal

required in scoping reviews. Reasons for the exclusion of studies and the results of the selection process are described, in full, within chapter 4 of this scoping review in table 3. The study selection process is represented using a PRISMA flowchart in figure 4.1.

The study selection process was conducted and completed in May 2022. Study selection was completed by both the primary and second reviewer using the inclusion and exclusion criteria described in section 3.3 and 3.4 of this chapter. Firstly, the title and abstract of studies yielded by the three-step search described above were screening by both reviewers independently, and studies deemed worthy of inclusion were selected for full text review. In order for a full text review to be deemed appropriate, both reviewers needed to agree of the relevance of the title and abstract. Where agreement was not met, a third reviewer had final say. The primary and second reviewer then conducted a full text review independently, of included articles. Articles that were deemed ineligible after a thorough examination of their full text were removed from the analysis based on the inclusion criteria. Where there was disagreement between the primary and second reviewer following the full text review, reviewers met online to discuss each article to reach consensus. When consensus was not reached, a third reviewer was consulted before making a final decision. The inclusion of three reviewers in this thorough study selection process was in an effort to reduce bias.

Where there was confusion regarding a study population, the authors of the article were contacted to gain clarity on the matter. This was to ensure that no relevant article was excluded based on ambiguity.

3.8 Data Extraction

Following the comprehensive search strategy and study selection process, data extraction commenced in June 2022. The use of a data extraction table is a recommendation from the JBI Reviewers Manual, Methodology for Scoping Reviews (Peters et al., 2015). The following data from included studies was extracted: author/s, publication date, study design and level of evidence, aim/s, population size and description, screening tool/s used to predict injury, the reliability and validity of the screening tool/s, definition of injury, diagnosis of injury and results. This data is represented in table 4.2 and the headings used for data extraction are an adaptation from the data extraction table used in a systematic review by Armstrong and Relph (2018) as this review was on a similar topic. The data extraction process was piloted by the primary reviewer on three of the included articles. This pilot process was then sent for evaluation by the second reviewer, and it was deemed that no changes needed to be made. The primary reviewer extracted data from all the selected articles and then submitted it to the second reviewer for assessment.

The second reviewer made relevant suggestions where necessary, and these changes were agreed on by both reviewers.

3.9 Presentation of results

Results from the search strategy are presented in a PRISMA flowchart represented by figure 1 in chapter 4 of this review along with a narrative description. The results of the data extraction are represented in table 4. An introduction to the results is provided in a narrative format prior to the presentation of the PRISMA flowchart and data extraction table. A narrative summary is provided following the presentation of the results to provide an understanding of the cumulative results and how they relate to the aim and objectives of this scoping review. Where appropriate, tables are utilised to consolidate relevant results. Armstrong and Relph (2018) conducted a systematic review titled “Screening Tools as a Predictor of Injury in Dance: Systematic Literature Review and Meta-analysis”. In this review the authors utilised a methodological quality scoring tool which they modified from previous research. The methodological quality scoring tool contains 14 items which are scored to achieve a maximum score of 20. This approach was taken in an effort to better comprehend the relevance of the results with regard to the studies’ methodological soundness. Given the similarity in area and topic of research between this scoping review and the systematic review conducted by Armstrong and Relph (2018), the same methodological quality scoring tool was utilised in the results chapter.

3.10 Conclusion

Chapter 3 provides a comprehensive explanation of the thorough methodology followed for this scoping review and is a representation of the guidelines stipulated by the JBI Reviewers Manual, Methodology for Scoping Reviews (Peters et al., 2015). The PRISMA-ScR (Appendix 1) was used to ensure all requirements for the methodology were met .and the pages for each item on the checklist have been recorded.

Chapter 4: Results

4.1 Introduction

The aim of this scoping review was to review the scope of literature on screening tools and their reliability in predicting lower back and lower extremity injuries in ballet dancers. The two primary objectives were to determine which screening tools have been investigated in the literature for their injury predictive ability in ballet dancers, both for lower extremity injury and lower back injury. The secondary two objectives were to comment on the reliability of identified screening tools for lower extremity and lower back injury prediction. The present chapter presents the outcomes of the methodology employed, including the study selection process, the characteristics of the selected studies, the primary findings concerning the objectives of this scoping review, and the methodological rigor of the studies identified.

4.2 Study Selection

The initial search for studies yielded 382 titles and abstracts from three databases, PubMed, CINAHL and Cochrane. PubMed yielded 41, CINAHL yielded 268 and Cochrane yielded 73 study titles and abstracts. Endnote software was used to identify 48 duplicates which were subsequently removed from the selection process, leaving 334 titles and abstracts for screening. A review of the reference lists of these studies was undertaken to discover an additional 14 titles and abstracts that merited screening. A total of 348 titles and abstracts were then screened independently by two reviewers according to the inclusion (3.3) and exclusion (3.4) criteria outlined in chapter 3. Subsequently, 42 articles' complete texts were assessed separately by two reviewers for their suitability based on the inclusion and exclusion criteria. Table 3 below outlines the various reasons for study exclusion. Where the study population was unclear, authors of the article were contacted to provide clarity on whether the population included ballet dancers. In total, three separate studies' authors were contacted. Unfortunately, none of the authors who were contacted replied and these articles were subsequently excluded. A total of seven studies met the inclusion criteria in this final stage. Throughout the process of study selection, where agreement could not be reached through discussion between the primary and secondary reviewer, a third reviewer was consulted. Figure 1 illustrates the process of selecting studies using a PRISMA flow diagram.

Table 4.1: Reasons for exclusion during full text review

No.	*Reason:*	*No. excluded:*
1.	Study did not include a ballet dancing population	5
2.	Study investigated aspects of performance (example: balance) and not injury	4
3.	Study did not utilise a screening tool	4
4.	Study did not investigate the predictive ability of a screening tool/ found a relationship between a screening tool outcome and previous injury	17
5.	Other	5
Total studies excluded in full text review:		35

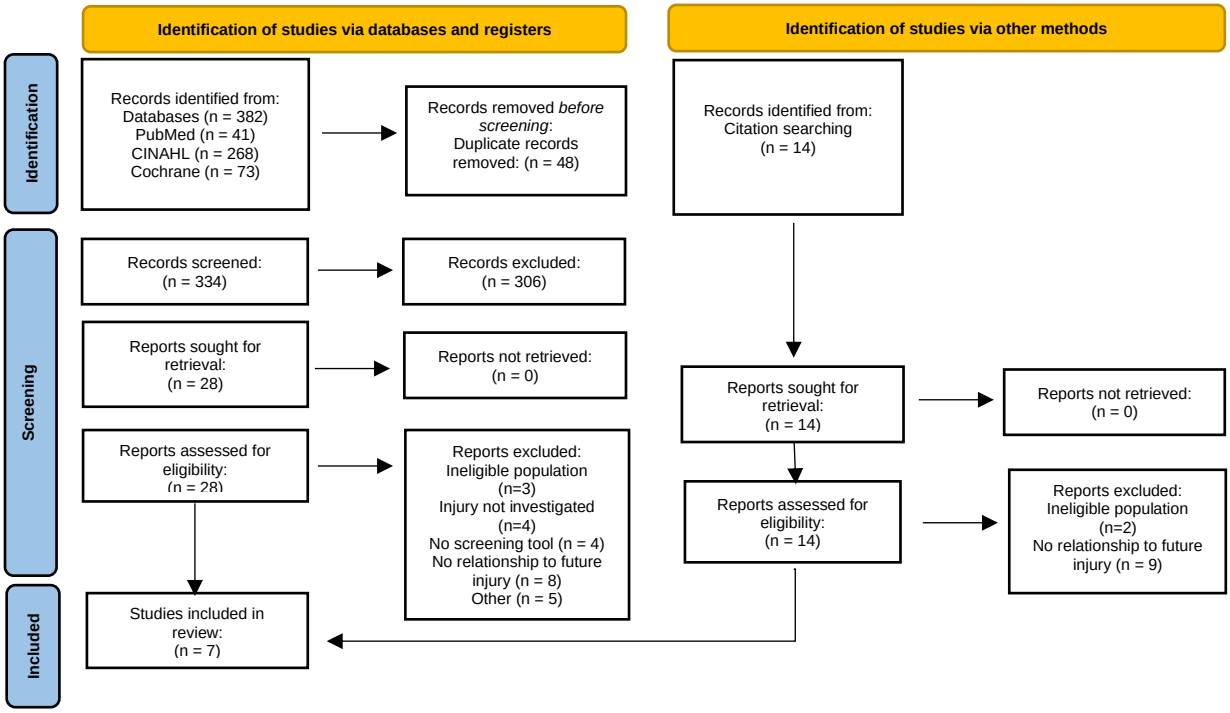


Figure 4.1: Study selection process (using PRISMA Flow Diagram, Page et al. (2021))

4.3 Summary of Included Studies

Table 4.2 offers an overview of the studies incorporated in this scoping review. This table was adapted from Armstrong and Relph (2018) with the addition of aims and reliability and validity columns. The table provides a concise summary of each included study, highlighting in italic what findings were specific to the objectives of this scoping review.

Table 4.2: Summary of included studies and main findings:

Authors:	Year:	Design and Level of Evidence:	Aims:	Population size and description:	Screening Tool/s or test/s:	Reliability and validity	Definition of Injury:	Diagnosis of Injury:	Results:
Armstrong	2020	Prospective Cohort, Level 2b	• *To determine if the total Beighton score is predictive of injury in dancers over the period of 1 year.* • *To determine the relationship between the Beighton score and injury in dancers.* • To describe the demographics of injury in dancers.	N= 82 university dancers: age 20.33 ± 0.68 years 62 females, 20 males contemporary, ballet and jazz genres	• Height, weight, and lower limb dominance. • *The Beighton score.* Joint ROM was measured using a goniometer, except for lumbar flexion. Performed by an experienced Physiotherapist.	*Intra-rater reliability of the total Beighton score was investigated: intraclass correlation coefficient of 0.98 (excellent reliability).*	• Time-loss definition: absence from dance participation for 1 or more days. • Medical-attention injury: injury did not result in time loss but required the attention of the researcher.	Injury diagnosed by a Physiotherapist.	• *No statistically significant injury predictive ability of the Beighton score both with and without lumbar flexion.* • *Total Beighton score was found to be a weak predictor of the total days a dancer was injured.* • 47 injuries were recorded in 34 dancers. • Majority of injuries occurred during stretching. • *The lower limb was the most common location of injury.*
Bowerman et al	2014	Not specified	• *To determine risk factors specific to growth, maturation, and biomechanics, for lumbar and lower extremity over-use injuries in elite adolescent ballet dancers over a 6-month period*.	N= 46 adolescent dancers, age 16 ± 1.58 years. 30 female, 16 male Ballet	• Height • Body mass • *Maturation: The Tanner Scale* • The age at which menarche commenced (female dancers) • *Growth: changes in foot length using Kinovea video analysis software (v 8.15)* • *Lower extremity alignment:* Modified knee valgus angle and lateral tilt of pelvis – during temps leve and fondu	*Photographing and foot length measuring - moderately reliable in author's own pilot study (ICC: 0.54; typical error 0.09cm).* *No reliability for Tanner Scale* *No reliability for knee and pelvic angles*	• "Any physical harm resulting in pain or discomfort that required a dancer to modify their dance activity during one or more classes, or which required a dancer to cease all dance related activity." • Only dance-related injuries that arose from overuse and affected the lower back and lower extremities were considered eligible	Diagnosis and recording of injury made by a Physiotherapist.	• 59 injuries reported for 29 dancers, 16 of which suffered multiple injuries. • *A 0.5cm growth in right foot length was associated with moderate increase in injury risk.* • *A 10° greater right knee angle was associated with a moderate decrease in injury risk for the fondu, and a small decrease in injury risk for the temps leve.* • *Pelvic angles during temps leve on left and fondu on right associated with small to moderate changes in injury risk.* • Age, height, body mass, *maturation level* and menstruation were associated with *insignificant changes in injury risk.*
Gamboa et al	2008	Retrospective descriptive cohort, Level 2b	• To describe the rate and location of injuries in elite adolescent ballet dancers throughout a span of 5 years. • *To examine the effectiveness of screening information in differentiating between injured and non-injured dancers over a 5-year period.*	N= 204 adolescent elite ballet dancers, age: 14.7 ± 1.9 years, male and female	• World Health Organisation Disability Scale (modified for dancers) • *Postural analysis.* • *Strength – upper extremity, lower extremity, core: trunk and scapular* • *Flexibility tests for the upper and lower extremity.* • *Orthopaedic testing: Lachman's, varus/valgus test for the knee at 0° and 30°, forefoot to rearfoot*	Not investigated or reported. The selection of test procedures for dance screenings was based on established "best practices". Testers were trained in test procedures to maximize reliability.	If a dancer had a musculoskeletal issue and visited a physical therapist for at least one treatment session, it was classified as an injury.	In-house Physical Therapist	• Distribution of injuries: most occurred in the foot and ankle (53%) followed by the hip (21.6%), knee (16.1%) and back (9.4%) • The injury rate was 1.09 per 1000 athletic exposures and 0.77 per 1000 hours of dance. Significant differences between injured and non-injured dancers for: • Higher score on the World Health Organisation Disability Scale modified for dancers. • History of lower back pain • *Increased prevalence of right foot pronation* • *Decreased lower extremity muscle strength.*

					counter rotation mechanics, Craig's test, ROM using a goniometer: hip internal and external rotation, ankle D/F and P/F. • *Function: standing leg turnout, gesture leg turnout, Releve balance, plie turnout alignment, pelvic alignment during developpe* • Testers were trained in test procedures, but there was no report on the qualification of testers.				• *Insufficient right ankle plantar flexion* All injuries occurred in the lower extremity and lower back region.
Hiller et al	2008	Prospective cohort, Level 2b	• *To identify internal factors that could predict lateral ankle sprains in teenage dancers throughout a period of 13 months.*	N= 115 dancers (ballet dancers mentioned but specific number in this genre was not specified), 21 male and 94 female, age: 14.2 ± 1.8 years.	• Age • Dance history • Previous ankle sprain • *Modified Beighton score.* • *Cumberland Ankle Instability Tool.* • *Modified ankle anterior drawer test.* • *ROM: Active hip external rotation, passive ankle inversion and eversion, DF (lunge test) and 1st MTP extension* • *Single leg standing with eyes closed (no. of foot lifts in 30 seconds)* • *Balance on demi-pointe (5 seconds).* • *Laboratory Tests: flat foot stability, demi-pointe stability, recovery from inversion perturbation.* • No mention of qualification or experience of testers.	Reliability and validity not investigated. Reliability and/or validity was mentioned for the following: *Cumberland ankle instability tool: valid and reliable (values not provided), Modified ankle instability test: excellent intra-rater reliability, passive ankle inversion and eversion using goniometer: reliability acceptable, active hip external rotation measured with a plurimeter: very good intra-rater reliability (ICC 0.92, 95% CI 0.82-0.97), D/F ROM measured with a weightbearing lunge test: excellent reliability, single leg standing with eyes closed: good intra-rater reliability (ICC 0.73, 95% CI 0.4-0.89).*	An Ankle sprain defined as "an inversion injury that had resulted in either swelling or bruising in the area and limping for more than 1 day"	No diagnosis by a healthcare professional. Dancers were contacted and asked to report on incidence of lateral ankle sprain.	• Previous lateral ankle sprain was associated with an increased risk of future lateral ankle sprain on the contralateral side - sensitivity of 70% and specificity of 66.3% • *Younger age, greater passive inversion range and inability to balance on demi-pointe predicted increased risk in the test group, but this was no longer significant when tested on the validation group.* • *None of the functional measured screening tools were predictive of future lateral ankle sprain in this population.*
Lee et al	2017	Prospective cohort, Level 2b	• Determine the injury incidence amongst pre-professional dancers attending full-time training over the period of 1 full academic year.	N= 66 elite pre-professional full-time dancers (40 female, 26 male),	• Initial questionnaire included: age, height, weight, *BMI*, gender current and previous injury history, year of pre-professional dance training, dance major,	*Prior to this study, the MCS intra-rater reliability was investigated, for the primary researcher, in a pilot study: Excellent*	Injury defined as:" any physical complaint sustained by a dancer resulting from performance, rehearsal, or class, and resulting in a	Self-reported	• Injury incidence: 2.27 injuries per 1000 hours of dance exposure and 3.35 injuries per 1000 dance exposures. • The most common site of lower limb injury was the ankle, followed by the knee, foot and hip/thigh. The most

			• *Investigate the correlation between being dance exposure and the likelihood of getting injured, as well as the association between risk factors and the probability of sustaining an injury throughout an entire academic year.*	age 18.15 ± 1.45 years, 32 ballet dancers and 34 modern dancers.	and age of commencing dance. • *Movement Competency Screen (MCS).* Casio EX-ZR100 digital cameras were used to film subjects and video analysis was performed by the primary researcher.	*(ICC 0.99, CI 0.98-0.99).*	dancer injury report or triage, irrespective of the need for medical attention or time-loss from dance activity.		common side of trunk injury was the thoracic spine followed by the lumbar spine, most common site of upper limb injury was the shoulder. • Significant association between total number of dance exposures (p=0.016) per month and average number of dance exposures (p=0.027) and total number of reported injuries per month. • No significant injury predictive value (p=0.964) for total hours of dance exposure. • *An MCS score of less than 23 was significantly (p=0.035) associated with increased risk of future injury.*
Steinberg et al	2019	Not specified.	• *To evaluate changes in young female dancers related to body morphology, anatomical alignment, and prevalence of patellofemoral pain (PFP) across one year of pubertal growth.* • *To identify risk factors to developing PFP in young female dancers across one year of pubertal growth.*	N= 60 female dancers – no specification regarding genre, age 12.5±0.5 years	• *BMI* • *Lateral and medial laxity of the patella at 30° of knee flexion* • *Lachman test* • *Drawer test* • *Patellofemoral grinding test* • *Patella Inhibition test* • *Beighton Hypermobility Test* • *Trunk and lower extremity alignment* • *Hip, knee, ankle, and foot ROM (measured using a goniometer)* • *Evaluation of dance technique: releve and plie* • Ultrasonography assessment – sonographer was blinded to the results of the musculoskeletal assessment.	Not investigated or reported.	Patellofemoral pain: A dancer was considered to have PFP if both of the following criteria were met: • Knee pain reported as ≥3 VAS, around and/or in the retro patellar region. • Movements loading the patellofemoral joint aggravated pain – weightbearing in a knee flexed position adversely affecting dancing or daily activities.	Diagnosis of PFP made by two orthopaedic surgeons.	• *The presence of PFP at follow-up was found to be associated with a positive grinding test during baseline.* • *Positive patellar inhibition test at baseline was associated with the presence of PFP at follow up.* • *Dancers who developed PFP had significantly lower BMI than dancers who did not develop PFP over the course of the year.*
Twitchett et al	2010	Not specified	• *To determine the relationship between ballet injury and the following: body fat percentage, active and passive flexibility, lower limb power, upper body and core endurance and aerobic capacity over a 15-week period.*	13 elite female ballet dancers aged 19 ±0.7 years	• *Body fat percentage* • *Two variations of developpe a la seconde* • *Standing vertical jump height measured using a jump meter.* • *Press-up test in a modified position.* • *Plank.* • *Dance Specific Aerobic Fitness Test*	Not investigated or mentioned from previous research.	No definition of injury.	Number, severity, and nature of injury was recorded by a healthcare Professional (specific qualification not specified)	• *Significant negative correlation between lower % body fat and increased length of time that activity was modified due to injury.* • *Significant positive correlation observed between the number of injuries and the heart rate measured at the end of the DAFT.A higher heart rate correlated to an increased number of injuries sustained.*

Key: *italic text indicates information specifically relevant to the aim and objectives of this scoping review*

4.3.1 Study Design

From the study selection process described above, seven studies were included in this scoping review. The study designs of the included studies are shown in table 4.3 below.

Table 4.3: Study design

Design:	***Included studies:***
Prospective cohort	3
Retrospective descriptive cohort	1
Not specified	3

Of the seven studies selected for this scoping review, three were prospective cohort studies (Hiller et al., 2008, Lee et al., 2017, Armstrong, 2020), one was a retrospective descriptive cohort study (Gamboa et al., 2008) and three studies did not indicate the study design (Twitchett et al., 2010, Bowerman et al., 2014, Steinberg et al., 2019).

4.3.2 Study Population

Of the seven included studies, three included only a ballet population of dancers (Gamboa et al., 2008, Twitchett et al., 2010, Bowerman et al., 2014), one study included ballet, contemporary and jazz dancers (Armstrong, 2020), one study included ballet and modern dancers (Lee et al., 2017), one study included dancers in the dance and ballet streams of two schools (Hiller et al., 2008) and one study did not specify the genre of the population (Steinberg et al., 2019). The study by Steinberg et al. (2019) which did not specify a population dance genre, was included because the evaluation of dancer technique utilised ballet specific movements. These ballet specific movements include releve and plie movements.

Of the seven included studies, five included both male and female participants (Gamboa et al., 2008, Hiller et al., 2008, Bowerman et al., 2014, Lee et al., 2017, Armstrong, 2020) and two included only female participants (Steinberg et al., 2019, Twitchett et al., 2010). All studies either reported on age criteria or reported age of participants in their results. Table 4.4 below reports the age of participants for each study. The mean age of participants ranged from 12.5 ± 0.5 years to 20.33 ± 0.68 years.

Table 4.4: Age of participants

Study:	***Age (years):***
Armstrong, 2020	20.33 ± 0.68
Bowerman et al, 2014	16 ± 1.58
Gamboa et al, 2008	14.7 ± 1.9
Hiller et al, 2008	14.2 ± 1.8
Lee et al, 2017	18.15 ± 1.45
Steinberg et al, 2019	12.5 ± 0.5
Twitchett et al, 2010	19 ± 0.7

4.3.3. Definition and Diagnosis of Injury

Of the seven included studies, six provided a definition of injury (Gamboa et al., 2008, Hiller et al., 2008, Bowerman et al., 2014, Lee et al., 2017, Steinberg et al., 2019, Armstrong, 2020) and one study did not provide a definition of injury (Twitchett et al., 2010). There were some similarities between the definitions of injury provided. Four studies referred to time-loss and or activity modification due to injury (Hiller et al., 2008, Bowerman et al., 2014, Steinberg et al., 2019, Armstrong, 2020). Two studies specified that an injury was recorded if the dancer sought medical attention (Gamboa et al., 2008, Armstrong, 2020) and one study specified that an injury was considered to have occurred if the dancer completed an injury report or triage (Lee et al., 2017).Two studies specified the type of injury, being lateral ankle sprain (Hiller et al., 2008) and PFP (Steinberg et al., 2019) in the definition as this was specific to the aims of these studies. Five studies made reference to specific symptoms, however these all varied and included: pain or discomfort (Bowerman et al., 2014), musculoskeletal issue (Gamboa et al., 2008), swelling or bruising (Hiller et al., 2008), physical complaint (Lee et al., 2017), and pain intensity ≥3/10 VAS (Steinberg et al., 2019).

In three studies injury was diagnosed by a Physiotherapist (Gamboa et al., 2008, Bowerman et al., 2014, Armstrong, 2020). In two studies injury was self-reported (Hiller et al., 2008, Lee et al., 2017). In one study injury was diagnosed by orthopaedic surgeons (Steinberg et al., 2019) and in one study injury diagnosis was made by a healthcare professional with no specification as to the qualification of this professional (Twitchett et al., 2010). In four studies no specific type of injury was investigated (Gamboa et al., 2008, Twitchett et al., 2010, Lee et al., 2017, Armstrong, 2020). These studies all reported that the most common site of recorded injury over the course of the study was the lower extremity (Gamboa et al., 2008, Twitchett et al., 2010, Lee et al., 2017,

Armstrong, 2020). Two studies investigated a specific type of injury: lateral ankle sprain (Hiller et al., 2008) and PFP (Steinberg et al., 2019). One study investigated only lumbar and lower extremity over-use injuries (Bowerman et al., 2014).

4.3.4. Methodological Quality

Armstrong and Relph (2018), in their systematic review and meta-analysis on screening tools as a predictor of injury in dance utilised a 20-point scoring system to evaluate the methodology of included studies. The same scoring system was used in this scoping review and is represented in table 4.5. The 14-item scoring system provides a maximum possible score of 20. Where articles did not score for level of evidence, it was because the exact design of the study was not stated by the authors, making it difficult to assume a level of evidence. A summary of the methodological quality findings is provided following the table.

Table 4.5: Methodological quality score (taken from Armstrong and Relph (2018))

Domain:	Armstrong (2020)	Bowerman et al. (2014)	Gamboa et al. (2008)	Hiller et al. (2008)	Lee et al. (2017)	Steinberg et al. (2019)	Twitchett et al. (2010)
Design [a] (1)	1	1	1	1	1	1	1
Level of evidence [b] (5)	4	-	4	4	4	-	-
Selection criteria [c] (1)	0	0	0	0	0	0	0
Setting [d] (1)	1	1	1	1	1	1	0
Demographic information [e] (1)	1	1	1	1	1	1	1
Description of screening tool [f] (2)	2	2	2	2	2	2	2
Injury definition [g] (1)	1	1	1	1	1	1	0
Injury diagnosis [h] (1)	1	1	1	0	0	1	-
Statistical analysis [i] (1)	1	1	1	1	1	1	1
Predictive statistical analysis [j] (1)	1	1	1	1	1	1	1
Reliability of index test [k] (2)	2	0	0	1	2	0	0
Percentage missing [l] (1)	1	1	0	1	1	1	0
Outcome [m] (1)	1	1	1	1	1	1	1
Confounders [n] (1)	0	0	0	0	0	0	1
Total score (20)	17	11	14	15	16	11	8

[a]Study design (1 point = prospective/ prospective AND retrospective, 0 point = retrospective)
[b]Level of evidence (Oxford Centre for Evidence-Based Medicine Levels of Evidence: level 1 = 5 points; level 2 = 4 points; level 3 = 3 points; level 4 = 2 points; level 5 = 1 point)
[c]Selection criteria (inclusion AND exclusion criteria were clearly described = 1 point)
[d]Setting (enough information, including venue name, was provided to identify the setting = 1 point)
[e]Demographic information (age (mean or median and SD or range) and gender were reported = 1 point)
[f]Description of the screening tool (test device or instruments = 1 point, protocol of screening tool(s) reported = 1 point, insufficient data to permit replication of the test)
[g]Injury definition (clear and appropriate definition is provided = 1 point)
[h]Injury diagnosis (made by physical therapist/physiotherapist or doctor = 1 point, self-assessed = 0 point)
[i]Statistical analysis (detail given on mean or median, SD, P value or CI = 1 point)
[j]Predictive statistical analysis (multivariate regression analysis or RR/OR used as predictive value = 1 point)
[k]Reliability of index test (reliability reported from previous research = 1 point, reliability reported from actual study data = 2 points)
[l]Percentage missing (all included subjects measured and if appropriate missing data or withdrawals from a study reported or explained = 1 point)
[m]Outcome (outcome clearly defined and method of examination of outcome adequate = 1 point)
[n]Confounder (most important confounders and prognostic factors identified and adequately taken into account in design study = 1 point)

All seven studies utilised some level of prospective design. Four studies were a level 2 evidence (Gamboa et al., 2008, Hiller et al., 2008, Lee et al., 2017, Armstrong, 2020) while three studies were not scored based on insufficient available information concerning the type of study (Twitchett et al., 2010, Bowerman et al., 2014, Steinberg et al., 2019). None of the studies clearly stated both an inclusion and exclusion criteria pertaining to the selection of participants. All studies provided sufficient information regarding the study setting and all studies clearly explained the demographics of the participants. All studies sufficiently reported on the screening tool used which permits for replication of the test. Although injury definitions differed across all seven studies, only one study (Twitchett et al., 2010) did not provide a definition of injury. Four studies utilized the expertise of either a physiotherapist/physical therapist or a doctor to diagnose the injury (Gamboa et al., 2008, Bowerman et al., 2014, Steinberg et al., 2019, Armstrong, 2020) and in one study (Twitchett et al., 2010) although the authors mention injury diagnosis being made by a healthcare professional, the exact qualification of the professional was not stipulated. Therefore, no score was provided for this domain of the study. All studies provided detail regarding statistical analysis and applied predictive analysis. Two studies investigated and reported on reliability of screening tools which showed a relationship to future injury (Lee et al., 2017, Armstrong, 2020) while one study (Hiller et al., 2008) reported on reliability of the screening tool from previous research. Five studies reported on missing data or reasons for participant withdrawal (Hiller et al., 2008, Bowerman et al., 2014, Lee et al., 2017, Steinberg et al., 2019, Armstrong, 2020). All studies reported adequately on the outcome within the study. Only one study reported sufficiently on the important confounders identified (Twitchett et al., 2010). The methodological quality score ranged from 8 to 17 points with a mean score of 13.14 points.

4.3.5. Screening Tools Investigated to Predict Lower Extremity and Lower Back Injury

This subsection of chapter four classifies screening tools identified in included studies into ten categories namely, hypermobility, growth and maturation measures, ROM, muscle strength, anthropometrics and posture, flexibility, balance, alignment and function, special orthopaedic tests, and standardised screening tools. These categories were, in part, adapted from Armstrong and Relph (2018). Where appropriate, categories were added and adjusted as required by the screening tools identified in this scoping review. Within each category the screening tools identified are discussed in terms of their ability to predict injury, the genre of dance included in the studies, presence of an injury definition provided and method of injury diagnosis.

4.3.5.1 Hypermobility

The relationship between hypermobility and injury was investigated in three studies and all studies used the Beighton scale as a measurement tool (Hiller et al., 2008, Steinberg et al., 2019, Armstrong, 2020). In two studies a score of ≥4 classified a dancer as hypermobile (Hiller et al., 2008, Armstrong, 2020). Steinberg et al. (2019) classified a dancer as hypermobile if she obtained a Beighton score of ≥5. Armstrong (2020) included a combination of contemporary, ballet and jazz genres, Hiller et al. (2008) included dancers in the dance and ballet streams of two schools and Steinberg et al. (2019) did not specify the genre of dance. Two studies concluded that there was no statistically significant predictive relationship between the Beighton score and injury (Hiller et al., 2008, Armstrong, 2020) and Armstrong (2020) found that with lumbar flexion included (P=0.02, 95% CI = -8.70 to 0.35)) and excluded (P=0.03, 95% CI = -7.98 to 0.43) the Beighton score was a weak predictor of total days injured. In addition, Armstrong (2020) found no significant differences in the Beighton score of dancers who sustained multiple, single or no injuries. Steinberg et al. (2019) found that there was a significant ($p < 0.001$) increase in the prevalence of hypermobility from baseline to follow-up but did not mention a relationship between the Beighton score and injury in their findings. All three studies provided a definition of injury (Armstrong, 2020, Hiller et al., 2008, Steinberg et al., 2019). In two studies injury diagnosis was made by a Physiotherapist (Armstrong, 2020) and two orthopaedic surgeons (Steinberg et al., 2019) and was self-reported in one study (Steinberg et al., 2019).

4.3.5.2 Growth and Maturation measures

One study reported on growth and maturation measures where growth was measured using changes in foot length and maturation was measured using the Tanner scale (Bowerman et al., 2014). This study included only ballet dancers. A 0.5cm growth in right foot length was associated with a moderate increase in injury risk (RR = 1.41, CI = 0.93-2.12), while the Tanner scale was linked to insignificant changes in injury risk (RR = 1.06, CI = 0.59-1.90) where the effects were unknown (Bowerman et al., 2014). A definition of injury was provided, and the diagnosis of injury was made by a Physiotherapist.

4.3.5.3 Range of Motion

Three studies reported on ROM of various joints using various methods of measurement (Gamboa et al., 2008, Hiller et al., 2008, Steinberg et al., 2019). Measurements included those for hip external rotation (Gamboa et al., 2008, Hiller et al., 2008, Steinberg et al., 2019), hip internal rotation (Gamboa et al., 2008, Steinberg et al., 2019), hip abduction (Steinberg et al., 2019), ankle dorsiflexion (Gamboa et al., 2008, Hiller et al., 2008, Steinberg et al., 2019), ankle

plantar flexion (Gamboa et al., 2008), ankle inversion and eversion (Hiller et al., 2008), ankle-foot en-pointe (Steinberg et al., 2019) and first metatarsophalangeal joint extension (Hiller et al., 2008). Gamboa et al. (2008) and Steinberg et al. (2019) used a goniometer to measure ROM. Hiller et al. (2008) used a goniometer to measure passive ankle inversion, ankle eversion and first metatarsophalangeal joint extension, a weight bearing lunge test to measure ankle dorsiflexion and a plurimeter to measure hip internal rotation. One study included only ballet dancers (Gamboa et al., 2008), one study included dancers in the dance and ballet streams of two schools (Hiller et al., 2008) and one study did not mention the genre of dance (Steinberg et al., 2019). From these studies, only two measures were found to be related to future injury, that of right ankle plantarflexion (Gamboa et al., 2008) and passive ankle inversion (Hiller et al., 2008). Gamboa et al. (2008) found a significant difference between dancers who sustained and injury and those that did not (P = 0.037, RR = 1.50, 95% CI = 1.05-2.15) related to insufficient right ankle plantarflexion where the likelihood of an insufficient ROM in the right ankle for plantar flexion was 50% higher among injured dancers. Hiller et al. (2008) found that in the test group there was an increased risk of lateral ankle sprain (HR = 1.06, 95% CI = 1.00-1.12) predicted by increased passive ankle inversion ROM. These results were no longer significant when tested on the validation group. All three of these studies included a definition of injury. Diagnosis of injury was made in one study by a Physiotherapist (Gamboa et al., 2008), in one study by two orthopaedic surgeons (Steinberg et al., 2019) and in one study by dancer self-report (Hiller et al., 2008).

4.3.5.4 Muscle Strength

Various muscle strength tests were investigated in two studies (Gamboa et al., 2008, Twitchett et al., 2010). Gamboa et al. (2008) compared upper extremity, lower extremity, core (trunk) and core (scapular control) between injured and non-injured dancers and Twitchett et al. (2010) investigated muscle power using standing vertical jump height and muscle endurance using the press up test and plank. Both studies included only ballet dancers. Lower extremity muscle strength, as measured by an average score from 16 muscle tests, was significantly (P = 0.045) lower in the injured group of dancers (Gamboa et al., 2008). Standing vertical jump height, press-up test and plank test did not correlate to injury occurrence or length of time that activity was modified for due to injury (Twitchett et al., 2010). Gamboa et al. (2008) provided a definition for injury while Twitchett et al. (2010) provided no definition for injury. Injury diagnosis was made by a Physiotherapist in the study by Gamboa et al. (2008) and by self-report in the study by Twitchett et al. (2010).

4.3.5.5 Anthropometrics and Posture

Of the seven included studies, two investigated the relationship between injury and posture (Gamboa et al., 2008, Steinberg et al., 2019) and four investigated the relationship between injury and anthropometric values (Twitchett et al., 2010, Bowerman et al., 2014, Lee et al., 2017, Steinberg et al., 2019). Three studies included only ballet dancers (Gamboa et al., 2008, Twitchett et al., 2010, Bowerman et al., 2014), one study included both ballet and modern dancers (Lee et al., 2017) and one study did not specify the genre of dance (Steinberg et al., 2019). Gamboa et al. (2008) found a significant (P = 0.005, 95% CI = 1.19-2.54, RR 1.74) difference between injured and non-injured dancers regarding right foot pronation, where the injured dancer was 74% more likely to have a pronated right foot. Steinberg et al. (2019) found no significant relationship between genu-recurvatum, knee varum, hind-foot valgus, hallux valgus and scoliosis and subsequent PFP. Bowerman et al. (2014) investigated height and body mass, Lee et al. (2017) and Steinberg et al. (2019) investigated body mass index (BMI) and Twitchett et al. (2010) investigated body fat percentage. Height (RR= 1.03, 90% CI= 0.85-1.25) and body mass (RR= 1.08, 90% CI= 0.85-1.37) were found to have an insignificant relationship to injury risk (Bowerman et al., 2014) while lower body fat percentage was found to significantly (r= -0.614, P= 0.026) correlate to an increased length of activity modification due to injury (Twitchett et al., 2010). Lee et al. (2017) found that BMI had no statistically significant (P= 0.667, 95% CI= -0.141-0.220) relationship to number of injuries, while Steinberg et al. (2019) found that dancers who developed PFP had a significantly lower BMI than dancers who did not develop PFP. Of these five studies, four included a definition of injury (Gamboa et al., 2008, Bowerman et al., 2014, Lee et al., 2017, Steinberg et al., 2019) and one study provided no definition of injury (Twitchett et al., 2010). Injury diagnosis was made by a Physiotherapist in two studies (Gamboa et al., 2008, Bowerman et al., 2014), two orthopaedic surgeons in one study (Steinberg et al., 2019), a non-specified healthcare practitioner in one study (Twitchett et al., 2010) and by self-report in one study (Lee et al., 2017).

4.3.5.6 Flexibility

Of the seven included studies, one study investigated the relationship between upper and lower extremity flexibility and injury (Gamboa et al., 2008). For the upper extremity, pectoralis minor and latissimus dorsi length were measured and for the lower extremity hamstring (measured in turnout and parallel), hip flexor, quadricep, hip internal and external rotators as well as the Ober's test were measured. The population was comprised only of ballet dancers. The study reported no significant differences between dancers who were injured and those who did not sustain injury related to both upper extremity (P= 0.232) and lower extremity (P= 0.348) flexibility. The study

provided an injury definition and diagnosis of injury was made by a physiotherapist (Gamboa et al., 2008)

4.3.5.7 Balance

Of the seven included studies, two studies investigated the relationship between balance and injury (Gamboa et al., 2008, Hiller et al., 2008). Single leg standing balance with eyes closed, balance on demi pointe (Hiller et al., 2008) and releve balance (Gamboa et al., 2008) were assessed. Hiller et al. (2008) did not specify a genre of dance for included participants, however certain tests were ballet specific while Gamboa et al. (2008) included only ballet dancers. One study reported that an inability to balance for five seconds on demi pointe significantly (HR= 3.75, 95% CI= 1.02-13.73, P= 0.05) predicted an increased risk for a lateral ankle sprain in the test group, however this finding was no longer significant (HR= 1.25, 95% CI= 0.29-5.46, P=0.77) when tested on the validation group (Hiller et al., 2008). One study found that there was no significant difference (right P= 0.345, left P= 0.299) in releve balance time between injured and non-injured dancers (Gamboa et al., 2008). A clear definition of injury was provided in both studies (Gamboa et al., 2008, Hiller et al., 2008). In one study injury diagnosis was made by self-report (Hiller et al., 2008) and in one study injury diagnosis was made by a physiotherapist (Gamboa et al., 2008).

4.3.5.8 Alignment and Function

Five of the seven included studies assessed the relationship between function and alignment and subsequent injury (Gamboa et al., 2008, Hiller et al., 2008, Twitchett et al., 2010, Bowerman et al., 2014, Steinberg et al., 2019). Tests included a modified knee valgus angle and lateral pelvic tilt measured in both fondu and temps leve movements (Bowerman et al., 2014), standing leg turnout, gesture leg turnout, plie turnout alignment, pelvic alignment during developpe, forefoot-to-rearfoot counter-rotation mechanics (Gamboa et al., 2008), mediolateral ankle movement with the foot flat and in demi point, recovery time following an inversion perturbation (Hiller et al., 2008), evaluation of releve and plie in first position technique (Steinberg et al., 2019) and flexibility in two variations of developpe a la seconde (Twitchett et al., 2010). Three studies included only ballet dancers (Gamboa et al., 2008, Twitchett et al., 2010, Bowerman et al., 2014), one study included dancers from two dance and ballet schools (Hiller et al., 2008) and one study did not specify the dance genre of participants (Steinberg et al., 2019). For the fondu, a moderate reduction in injury risk was associated with a 10° increase in the right modified knee valgus angle (improved alignment) (RR= 0.68, 90% CI= 0.45-1.03). Similarly, for the temps leve, a small reduction in injury risk was observed with a 10° increase in the right modified knee valgus angle (RR= 0.72, 90%

CI= 0.53-0.98)(Bowerman et al., 2014). A moderate reduction in injury risk (RR= 0.52, 90% CI= 0.30-0.90) was observed with a 2° increase in pelvic angle (indicating poor alignment) during left leg temps leve. However, a small increase in injury risk (RR= 1.28, 90% CI= 0.91-1.80) was associated with a 2° increase in pelvic angle during right leg fondu (Bowerman et al., 2014). Gamboa et al. (2008), Hiller et al. (2008), Twitchett et al. (2010), and Steinberg et al. (2019) found no significant injury predictive ability of their measures of alignment and function. Four studies provided a definition of injury (Bowerman et al., 2014, Gamboa et al., 2008, Hiller et al., 2008, Steinberg et al., 2019) and one study provided no definition of injury (Twitchett et al., 2010). In two studies injury diagnosis was made by a physiotherapist (Gamboa et al., 2008, Bowerman et al., 2014), by two orthopaedic surgeons in one study (Steinberg et al., 2019), by a non-specified healthcare practitioner in one study (Twitchett et al., 2010) and by self-report in one study (Lee et al., 2017).

4.3.5.9 Special Orthopaedic Tests

Of the seven included studies, three investigated the relationship between special orthopaedic tests and subsequent injury (Gamboa et al., 2008, Hiller et al., 2008, Steinberg et al., 2019). Special tests investigated in these studies include Lachman's test (Gamboa et al., 2008, Steinberg et al., 2019), knee varus and valgus test (at 0° and 30° of knee flexion), Craig's test (Gamboa et al., 2008), modified ankle anterior drawer test (Hiller et al., 2008), lateral and medial patella laxity test (at 30° knee flexion), Drawer test (knee), Patellofemoral grinding test, and Patellar Inhibition test (Hiller et al., 2008). One study included only ballet dancers (Gamboa et al., 2008), one study included dancers from two dance and ballet schools (Hiller et al., 2008) and one study did not specify the dance genre of participants (Steinberg et al., 2019). Of the special orthopaedic tests investigated, only a positive grinding test and a positive patellar inhibition test was found to be significantly associated with subsequent injury (Steinberg et al., 2019). Steinberg et al. (2019) found that dancers had a 2.78 greater chance of developing PFP at follow-up with a positive grinding test at baseline and a 2.40 greater chance of developing PFP at baseline and at follow-up with a positive patellar inhibition test at baseline compared to dancers who had negative tests at baseline. All three studies provided a definition for injury (Gamboa et al., 2008, Hiller et al., 2008, Steinberg et al., 2019). Injury diagnosis was made by a physiotherapist in one study (Gamboa et al., 2008), by self-report in one study (Hiller et al., 2008) and by two orthopaedic surgeons in one study (Steinberg et al., 2019).

4.3.5.10 Standardised Screening Tools

Three of the seven included studies investigated the relationship between standardised screening tools and subsequent injury (Hiller et al., 2008, Twitchett et al., 2010, Lee et al., 2017). Investigated screening tools included the Cumberland Ankle Instability Tool (Hiller et al., 2008), MCS (Lee et al., 2017) and Dance Specific Aerobic Fitness Test (DAFT) (Twitchett et al., 2010). One study included only ballet dancers (Twitchett et al., 2010), one study included dancers from two dance and ballet schools (Hiller et al., 2008) and one study included ballet and modern dancers (Lee et al., 2017). The Cumberland Ankle Instability Tool was found not to be predictive of lateral ankle sprain by Hiller et al. (2008). Lee et al. (2017) reported that a MCS mean score of <23 was significantly (P= 0.035, 95% CI= -0.186-0.023) associated with subsequent injury. Twitchett et al. (2010) found a significant (r= 0.590, P= 0.034) positive correlation between increased number of injuries sustained and an increased heart rate at the end of the DAFT. Two studies provided a definition of injury (Hiller et al., 2008, Lee et al., 2017) and one study provided no definition of injury (Twitchett et al., 2010). Two studies relied on self-report for diagnosis of injury (Hiller et al., 2008, Lee et al., 2017) and in one study injury diagnosis was made by a non-specified healthcare practitioner (Twitchett et al., 2010).

4.3.6 Reliability of Screening Tools

The secondary objectives of this scoping review were to comment on the reliability of identified screening tools for lower extremity and lower back injury prediction. In this subsection of chapter four the reliability of screening tools which were statistically predictive of injury are reported. Of the screening tools and tests reported on above, 14 were found to be associated with future injury. Table 4.6 represents the identified screening tools as well as the reliability of these, reported in the investigating study. Of the identified screening tools associated with future injury, only three were investigated for reliability. These are the Beighton score (Armstrong, 2020), right foot length (Bowerman et al., 2014) and the MCS (Lee et al., 2017).

Table 4.6: Reliability of screening tools predictive of injury

Category:	Tool/ Test:	Reliability:	Authors:
Hypermobility	Beighton Score	Investigated: Intrarater reliability intraclass correlation coefficient (ICC) of 0.98 (excellent)	Armstrong (2020)
Growth and Maturation:	Right foot length	Investigated: ICC of 0.54 (moderate)	Bowerman et al. (2014)
Range of Motion:	Right ankle plantar flexion	Not investigated or reported.	Gamboa et al. (2008)
	Passive ankle inversion	Not investigated. Reported in the study:" acceptable reliability"	Hiller et al. (2008)
Muscle strength:	Lower limb strength (Average score of 16 muscle tests)	Not reported or investigated.	Gamboa et al. (2008)
Anthropometrics and Posture:	Right foot pronation	Not investigated or reported.	Gamboa et al. (2008)
	BMI	Not investigated or reported	Steinberg et al. (2019)
Balance:	Balance on demi-pointe	Not investigated or reported.	Hiller et al. (2008)
Alignment and Function:	Modified knee valgus angle	Not investigated or reported.	Bowerman et al. (2014)
	Pelvic angle	Not investigated or reported.	Bowerman et al. (2014)
Special Orthopaedic Tests:	Grinding test	Not investigated or reported.	Steinberg et al. (2019)
	Patellar inhibition test	Not investigated or reported.	Steinberg et al. (2019)
Standardised screening tools:	MCS	Investigated (pilot study): ICC of 0.99 (Excellent)	Lee et al. (2017)
	Dance Specific Aerobic Fitness Test (DAFT)	Not investigated or reported.	Twitchett et al. (2010)

4.4 Conclusion

The search strategy utilised in this scoping review yielded seven studies which spoke to the objectives. The study design of the articles included in this analysis varied, with three studies employing a prospective design, one study utilizing a retrospective design, and three studies not specifying their specific study design. Three studies included only ballet dancers, two studies included a combination of dance genres, and one study did not specify the dance genre of their population. Six studies included a clear definition of injury while one study provided no definition of injury. Five studies reported that injury was diagnosed by a healthcare professional while in two studies injury was self-reported. Screening tools and tests were categorised into ten categories namely, hypermobility, growth and maturation, ROM, muscle strength, anthropometrics and posture, flexibility, balance, alignment and function, special orthopaedic tests, and standardised screening tools. There were no screening tools and tests predictive of injury which were identified for hypermobility and flexibility. Screening tools and tests identified as predictive of injury include, change in right foot length, ankle plantar flexion ROM, passive ankle inversion, lower extremity muscle strength, right foot pronation, BMI, balance on demi-pointe, right modified knee valgus angle during fondu and temps leve, pelvic angle during right leg fondu, patellar grind test, patellar inhibition test, MCS and DAFT. These identified screening tools and tests are presented in table 4.7. An association was observed between the Beighton's hypermobility score and the total number of days with injury. Additionally, body fat percentage was found to be associated with the duration of activity modification required following injury. Three of the identified screening tools were investigated for their reliability and these are the Beighton hypermobility score (excellent), right foot length change (moderate) and the MCS (excellent). All the included studies spoke to the objective of identifying screening tools as a predictor of lower extremity injury, however there were no studies which commented on the ability of screening tools to predict lower back injury in ballet dancers. The relevance of these results is discussed in chapter five of this scoping review.

Table 4.7: Screening tools/ tests found to be predictive of injury

Category:	Tool/ Test:	Author:
Growth and Maturation	Change in right foot length	Bowerman et al. (2014)
Range of Motion	Ankle plantar flexion ROM	Gamboa et al. (2008)
	Passive ankle inversion	Hiller et al. (2008)
Muscle Strength	Lower extremity muscle strength	Gamboa et al. (2008)
Anthropometrics and Posture	Right foot pronation	Gamboa et al. (2008)
	BMI	Steinberg et al. (2019)
Balance	Balance on demi-pointe	Hiller et al. (2008)
Alignment and Function	Right modified knee valgus angle during fondu and temps leve	Bowerman et al. (2014)
	Pelvic angle during right fondu	Bowerman et al. (2014)
Special Orthopaedic Tests	Patellar grind test	Steinberg et al. (2019)
	Patellar inhibition test	Steinberg et al. (2019)
Standardised Screening Tools	MCS	Lee et al. (2017)
	DAFT	Twitchett et al. (2010)

Chapter 5: Discussion

5.1 Introduction

To the researcher's knowledge this is the first scoping review to investigate which screening tools can predict musculoskeletal injury to the lower extremity and lumbar region in ballet dancers. The objectives of this study were to identify which screening tools can predict lower back and lower extremity injury in ballet dancers and analyse the reliability of identified screening tools. Chapter five discusses the relevance of the results outlined in chapter 4, pertaining to the objectives of this scoping review and comments on the direction which should be taken by future research on this topic. The methodological quality of included studies is also discussed. Given the consequences of injury in the ballet population, including time loss between seven (Allen et al., 2012) and 28 days and as long as 177 days (Ekegren et al., 2014), the identification of screening tools which may predict injury is relevant in this population.

5.2 Study Design

There is a need for prospective study designs on the topic of screening tools to predict lower back and lower limb injuries in ballet dancers. The relevance of prospective study designs on this topic is that the ability of a screening tool or test to predict future injury is investigated. Retrospective designs identified in the search strategy for this scoping review commented on the relationship between a screening tool and previous injury. The difficulty in finding associations between a current outcome and future injury in a retrospective study, is that the outcome of a specific test may not have been associated with the underlying cause of injury, but rather the result of injury. Although Gamboa et al. (2008) categorised their study as retrospective, there were elements of prospective investigation which enabled the inclusion of the study. Three studies included in this scoping review did not specify the study design (Bowerman et al., 2014, Steinberg et al., 2019, Twitchett et al., 2010). These studies were included because during full text review there was sufficient prospective evidence which lent itself to the objectives of this scoping review. It is important for researchers to clearly define the design of their study to allow transparency for professionals who are seeking to apply research to practice. There are obstacles to prospective study designs, one of which is time and resources. As prospective research investigates a present outcome with a future outcome, sufficient time and follow up is required to investigate the relationship between the two outcomes. Availability of resources to allow for sufficient follow up is oftentimes a challenge. Finally, there are ethical considerations when it comes to prospective research in relation to injury prevention. When a screening tool's predictive ability is chosen for investigation in a prospective study, it is because there is knowledge available which suggests

that the outcome of this tool may predict injury. Therefore, whether it is ethical to observe a dancer who has tested positive on a specific screening tool and not intervene is questionable. Intervening, would however, interfere with the concluded predictive ability of the test. These obstacles may contribute in part to the scarcity of prospective study designs on this topic. To this author's knowledge, this is the first scoping review on the predictive ability of screening tools for lower limb and lower back injury in ballet dancers. The scarcity of systematic reviews and scoping reviews on this topic may be due to the fact that there is limited primary prospective evidence available.

5.3 Population

As mentioned previously, dance is a sport which encompasses many different genres, each with unique requirements in terms of skill and technique. Given that injury is related to the requirements of a specific sport, it is important to clearly define the sport of the included population in research. Of the studies included in this scoping review, one did not specify the genre of dancers included (Steinberg et al., 2019). This makes it difficult for professionals to apply the results of the research to a specific genre of dance. The study was included because some of the screening tests included were specific to the ballet population and therefore the assumption was made that at least some of the participants were ballet dancers. Furthermore, three studies included a mixed genre of participants (Armstrong, 2020, Hiller et al., 2008, Lee et al., 2017) which creates confusion for the reader in the specificity of the results to the ballet population. Armstrong (2020) and Hiller et al. (2008) did not indicate the number of dancers which fell into each genre of dance while Lee et al. (2017) clearly stated the number of dancers which fell into the ballet and modern dance genres. When research in this field utilises a mixed genre group, clearly stating the number of dancers in each genre and how the results relate to each genre is beneficial when applying the results to practice. During the search strategy for this scoping review, several studies met all inclusion criteria except for clarifying whether the population included ballet dancers.

5.4 Definition and Diagnosis of Injury

Although it was not an objective of this scoping review to investigate the injury definition and diagnosis practices within the literature, this is pertinent to acknowledge in relation to injury prevention screening research. Six the seven studies included in this scoping review provided a clear definition of injury (Gamboa et al., 2008, Hiller et al., 2008, Bowerman et al., 2014, Lee et al., 2017, Steinberg et al., 2019, Armstrong, 2020). Five of these studies indicated that injury diagnosis was made by a healthcare professional (Gamboa et al., 2008, Twitchett et al., 2010, Bowerman et al., 2014, Steinberg et al., 2019, Armstrong, 2020) and in two studies injury diagnosis was made by a means of self-report (Hiller et al., 2008, Lee et al., 2017). Armstrong

and Relph (2018), in their systematic review and meta-analysis on screening tools as predictors of injury in dancers recommended that four factors should be met in studies on this topic to be considered good practice. These four factors are prospective design, a definition of injury, a diagnosis of injury made by a physical therapist/ physiotherapist or doctor and the use of regression models or risk measurement (Armstrong and Relph, 2018). Although six of the included studies presented some similarities in their definitions of injury, it is challenging to compare the results due to variations in the investigated screening tools and the types of injuries examined across these studies. The IADMS provides insight into how a definition of injury as well as a clear diagnosis result in better injury surveillance (Liederbach et al., 2012). It is suggested by the IADMS that a clear and complete image of injury incidence is not possible when injury is self-reported (Liederbach et al., 2012). This is relevant to the studies included in this scoping review because where injury diagnosis was made by self-report, the picture of injury incidence in the study population is not necessarily clear and reliable. This means that, the predictive ability results of the investigated screening tool may be unreliable. It has been suggested in literature that dancers are known to dance through pain and injury either for fear of taking time off and being replaced (Rivera et al., 2012) or because the dancer views medical attention as necessary only when injury is deemed severe (Swain et al., 2018). This further supports the need for professional injury diagnosis in this population as the dancer may not be a reliable enough reporter to allow for accurate results when it comes to research. The IADMS further recommend that injury diagnosis should be made by a healthcare practitioner with training in the terminology and identification of injury (Liederbach et al., 2012). For a qualified healthcare practitioner to accurately make an injury diagnosis, a clear definition of injury is required, and this should be reported in literature investigating injury occurrence. The IADMS recognises that many definitions for injury exist (Liederbach et al., 2012). Although each of the studies included in this scoping review provided different definitions of injury, the mere stating of the clear definition aids the reader in understanding exactly what constituted an injury in that particular study. Again, this aids in the utilisation of the study results in practice.

5.5 Methodological Quality

The methodological quality of included studies ranged from 8 to 17 points with a mean score of 13.14 points based on the scoring system utilised by Armstrong and Relph (2018). It is important to note that Armstrong and Relph (2018) did not provide an interpretation of this scoring tool. Therefore, it is difficult to comment on the general methodological quality of the included articles, rather, comments are made on individual categories within this tool. Armstrong and Relph (2018) recommend that as a minimum, a definition of injury should be provided, and the diagnosis of

injury should ideally be made by a physiotherapist/ physical therapist or a doctor in studies pertaining to this topic. Four studies (Gamboa et al., 2008, Bowerman et al., 2014, Steinberg et al., 2019, Armstrong, 2020) met both recommendations , one study (Twitchett et al., 2010) did not meet either recommendation and two studies (Hiller et al., 2008, Lee et al., 2017) provided a definition for injury, but injury diagnosis was made by self-report. As mentioned previously, injury definition and an accurate diagnosis are important factors when considering the reliability of a study's results. In other words, when the outcome of a study is the occurrence of injury, if a clear definition of injury is not defined and if a professional trained in the diagnosis of that injury does not make the diagnosis, the outcome of injury is difficult to conclude. None of the studies provided both an inclusion and exclusion criteria. This is problematic for a reader when applying the results of the study in practice as it is not fully understood whether the results apply to the target population. Reporting on the reliability of a screening tool which is being investigated is important. This provides perspective as to how consistent a specific tool can be in terms of its predictive ability. Only three studies (Hiller et al., 2008, Lee et al., 2017, Armstrong, 2020) reported on reliability of screening tools which had a relationship to future injury, two of which investigated reliability within the study itself (Lee et al., 2017, Armstrong, 2020). It is important for a reader to understand the reliability of a test to make an informed decision on whether to utilise the tool in practice. Only one study (Twitchett et al., 2010) reported adequately on confounders within the research. It should be mentioned that this study obtained a low methodological quality score of 8. However, as stated before, it is difficult to interpret this value as Armstrong and Relph (2018) did not provide an interpretation of the overall score. It is necessary for researchers to report on confounders to ensure the internal validity of a study. This scoping review has revealed that there is a need for predictive studies on this topic to ensure the following: a diagnosis of injury should be made by a specified healthcare practitioner, preferably a physiotherapist/ physical therapist or doctor, inclusion and exclusion criteria should be clearly defined, the reliability of the screening tool should be investigated within the study or at the very least be reported on from previous research and researches should clearly state identified confounders.

5.6 Hypermobility

The relationship between the Beighton's score and future injury was investigated in three studies (Hiller et al., 2008, Steinberg et al., 2019, Armstrong, 2020). While the research indicates that there is no injury predictive ability of this score, it is important to note that Armstrong (2020) found that the total Beighton score was a weak predictor of total days injured. This study scored high (17 points) in terms of methodological quality and the intrarater reliability was reported as excellent (ICC: 0.98) from the authors' own reliability study. While predicting the total number of

days injured may provide insight as to which dancers will require more time off from injury, this relationship was weak, and it does not assist in injury prevention. In discussing the relevance of these findings, it is important to relate the results to the physical requirements of ballet. Overall flexibility is one of the most sought after attributes in elite ballet dancers (McCormack et al., 2019). As such, stretching to attain flexibility is a prominent feature in training. The lack of injury predictive ability of this scale relating to ballet dancers, may be because overall flexibility is an innate requirement of the genre's choreography. Furthermore, this author argues that given the specific choreography of ballet, through their training dancers are likely to achieve strength within excessive ranges of motion. This may provide an explanation as to why this score is not predictive of injury within the ballet genre. In addition, the sport itself may attract individuals who are hypermobile as the requirement of overall flexibility is more easily obtained by such individuals. Schmidt et al. (2017) found that ballet dancers demonstrate a higher prevalence of Beighton scores 4, 5 and 6 when compared to gymnasts and team handball players.

Research has found that a relationship, in ballet dancers between hypermobility and risk of chronic ankle instability, ACL injuries, labral tears, tendinopathies, degenerative conditions and instability of the hip (Campbell et al., 2019). Having said this, the literature agrees that the Beighton score is not associated with increased injury risk and this is true not just for ballet dancers, but other athletic populations too. Ruemper and Watkins (2012) found no correlation between general joint hypermobility, as measured by the Beighton score, and injury in contemporary dancers. Instead the results indicated a statistically significant relationship between joint hypermobility syndrome, as measured by the Brighton criteria, and number of injuries as well as time-loss injuries (Ruemper and Watkins, 2012). This study was retrospective in its design. Schmidt et al. (2017) demonstrated similar results in their cross-sectional study on a population of ballet dancers, gymnasts, and team handball players. No significant relationship was found between the Beighton score and injury prevalence in any of these athletic populations (Schmidt et al., 2017). Finally, Blokland et al. (2017) found that irrespective of Beighton score cut-off points, there is no association between general joint hypermobility and injury among elite female soccer players. This was a prospective cohort study. Foley and Bird (2013) hypothesise that perhaps the reason it has poor ability to predict injury in ballet dancers is because the Beighton scale is not tailored to the physical requirements of ballet dancers. Comparing the results from this scoping review with other literature investigating the Beighton score in athletic populations, it seems that this this score is not useful in terms of injury prediction. Surprisingly though, 75% of respondents to a questionnaire report screening for hypermobility in dance companies, 83.3% of which use

the Beighton scale (Armstrong, 2019). This is an example of screening practices being used where there is little evidence to support their implementation in a dance setting.

5.7 Growth and Maturation

Bowerman et al. (2014) found that a 0.5cm increase in right foot length over a period of six months was statistically linked to a moderate increase in injury risk among ballet dancers. The authors clearly defined injury and the diagnosis of injury was made by a physiotherapist adding strength to these findings. Kinovea video analysis software (v 8.15) was used to measure foot length. Kinovea is a method which is widely used to assess and analyse human movement in sports and clinical settings (Puig-Diví et al., 2019). The reliability of this method was investigated in the author's own pilot study where the results indicated moderate (ICC: 0.54; typical error 0.09cm) reliability (Bowerman et al., 2014). This assessment of reliability is lower that other reliability studies. While no literature was found on the use of Kinovea in measuring foot length, comparison with literature on the use of Kinovea in the measurement of other human movement is made. Puig-Diví et al. (2019) investigated the reliability and validity of Kinovea to obtain angles and distances using coordinates in four perspectives. Their findings revealed that Kinovea has excellent reliability with a ICC value of between 0.99 and 1 (Puig-Diví et al., 2019). Pueo et al. (2020) in a slightly more recent study, found that smartphone-kinovea showed excellent reliability in measuring vertical jump height in 112 participants. Kinovea software is free (Puig-Diví et al., 2019) and is therefore a convenient tool to utilise in a screening setting. Important to mention is that the average age of the ballet dancers in the study by Bowerman et al. (2014) was 16 ± 1.58 years. This therefore limits the utilisation of changes in foot length as an injury predictive screening tool to individuals within this age range. In addition, while this is a promising finding in the prevention of injury amongst ballet dancers, it is an outcome which is impossible to change. In other words, once a foot length change has been observed, intervention to change this outcome is not possible. Therefore, intervention to prevent injury in the identified individual would need to focus on the relevant effects of rapid growth change on participation. In other words, the identification of a 0.5cm increase in right foot length, over a six-month period, may identify a dancer going through significant growth change, however the intervention to prevent injury needs to be focused on the effects of change in growth in this population. Changes in biomechanics such as ROM have been observed during periods of growth spurts in dancers and have been identified as increasing risk of injury according to Storm et al. (2018). If a change of 0.5cm in right foot length is observed, it may be advised to perform a biomechanical screening for any further imbalances which can be addressed through intervention.

5.8 Range of Motion

Gamboa et al. (2008) found that ballet dancers who sustained injury were 50% more likely to have insufficient ankle plantar flexion on the right. While this study is strengthened by its clear definition of injury and the fact that injury diagnosis was made by a physical therapist, it is unclear what was considered normal ROM. Without a clear indication of what ROM was considered normal for ankle plantar flexion, it is difficult for practitioners to conclude what was considered insufficient ROM. The findings of Gamboa et al. (2008) contradict other research in this field. Steinberg et al. (2012) investigated the relationship between PFP and joint ROM in dancers. It was concluded that dancers who demonstrated reduced passive plantarflexion ROM were significantly less likely to develop PFP (Steinberg et al., 2012). Significant to note is that Steinberg et al. (2012) included a population of mixed genre dancers and it is unclear how many of the participants were ballet dancers, while Gamboa et al. (2008) included only ballet dancers in their study. This may allude to the fact that that predisposing factors to future injury vary across dance genres.

Hiller et al. (2008) found that greater passive ankle inversion ROM was predictive of lateral ankle sprain in dancers, however these results were no longer statistically significant when tested on the validation group. While the use of a validation group adds strength to this study, there was little insight into possible reasons for the discrepancies in the results between the test group and the validation group. Therefore, the use of passive ankle inversion ROM as a screening tool to predict injury in ballet dancers cannot be recommended. The prediction of lateral ankle sprains in this population is particularly important when considering the prevalence of this injury among dancers. Simon et al. (2014) found than within a population of ballet and modern dancers, 70.1% had sustained an ankle sprain, 53% of which were considered to have chronic instability. This statistic certainly justifies further research into the prediction of this injury.

Gamboa et al. (2008) measured ROM using a goniometer and the reliability of this tool was not investigated or mentioned. There is scarce recent evidence investigating the reliability of a goniometer to measure ankle plantar flexion. Dickson et al. (2012) found that an inclinometer (ICC: 0.94) had a higher intra-rater reliability than a goniometer (ICC: 0.84) when measuring plantarflexion in 26 modern dancers. It was further concluded that clinician experience influenced the outcome of goniometric measurements (Dickson et al., 2012). While the goniometer did not reveal poor reliability, it can be argued that specific to a population of dancers, an inclinometer is more reliable when measuring plantar flexion.

5.9 Strength

In terms of strength, the only significant finding was that of Gamboa et al. (2008) where the injured group of dancers had a significantly lower score for lower extremity strength. While this study provided a definition of injury and indicated that injury was diagnosed by a physiotherapist, there was little explanation regarding the methods of testing. The authors indicate that manual muscle testing was conducted for right and left hip flexion, extension, abduction, adduction, internal rotation, external rotation; knee flexion and extension, where an average score was given. However, the manual muscle testing techniques were not described and an indication as to how strength was scored was not provided. As noted above, without a clear description of testing technique, while these results may be promising for the purpose of this scoping review, the applying the results in practice is difficult. There is some agreement in the literature regarding reduced lower extremity strength in dancers and its implications for injury. Biernacki et al. (2021) in their systematic review, identified that reduced lower extremity strength was a risk factor for lower limb injury in pre-professional and professional ballet dancers. While this systematic review was of a high methodological quality, the injury predictive ability of this strength deficit was not discussed. This was supported in another systematic review which concluded that core and lower extremity muscle weakness are intrinsic modifiable risk factors for injury in ballet dancers (Campbell et al., 2019). Again, the challenge here lies within the association made between weakness and previous injury as appose to future injury. While this literature adds support to the findings by Gamboa et al. (2008) in this review, there is still a need for future research on this topic which is prospective in design. Given that strength of the lower extremity is one of the most desirable traits sought after in ballet dancers (McCormack et al., 2019) one must question whether this is due to an injury protective effect or purely an improved capability to achieve the requirements of choreography. Gamboa et al. (2008) did not investigate or comment on the reliability of the manual muscle testing methods utilised, however it was mentioned that the method chosen was based on best practices in dance screening settings. The difficulty with manual muscle testing is that there is a reliance on the subjectivity and strength of the tester. Little literature has been found the reliability of manual muscle testing techniques. There is some literature to support the use of dynamometry. Whiteley et al. (2012) found that both a handheld dynamometry and a biodex isokinetic dynamometer showed excellent inter-rater reliability for the measurement of eccentric hamstrings, isometric hamstrings and isometric quadricep strength within a population of 216 male professional football players. Toonstra and Mattacola (2013) found that portable fixed dynamometry and isokinetic dynamometry showed high reliability for the measurement of knee flexion and extension strength while handheld dynamometry showed fair

to poor reliability for the same measures. This study only included 16 healthy participants which may account for the difference in findings compared to Whiteley et al. (2012) specific to handheld dynamometry. Without knowing the exact method utilised by Gamboa et al. (2008) to measure lower extremity strength, it is difficult to relate research regarding reliability of strength testing to these findings.

5.10 Anthropometrics and Posture

Gamboa et al. (2008) found that injured ballet dancers were 74% more likely to have a pronated right foot. A clear definition of injury and diagnosis of injury made by a physiotherapist adds some strength to this finding. The explanation behind this finding may lie in the phenomenon of compensated turnout. Turnout is a functional requirement in ballet choreography where the desired goal is to achieve 180° of functional turnout. However, this is often not anatomically possible and so the phenomenon of compensated turnout occurs where dancers employ various strategies to achieve an apparent increase in turnout range. One of these strategies is hyper-pronation of the feet (Carter et al., 2019, Kaufmann et al., 2021). Studies have demonstrated that there is increased risk of injury due to compensated turnout. Baker Jenkins et al. (2013) found that for every 1% increase in compensated turnout, there was a 9% increased chance of sustaining 2 or more injuries in a group of 47 dancers. While the population of this study was not clearly defined in terms of genre of dance, it is applicable to ballet due to the frequency of turnout required. These findings may allude to the fact that increased pronation is due to repeated compensated turnout which predisposes a dancer to injury. Cimelli and Curran (2012) in a more recent study, found that there was an association between pronation during turnout and lower extremity injury. This study was retrospective in design and included only 12 modern dancers. Gamboa et al. (2008) did not investigate or comment on the reliability of assessing foot pronation. Kirmizi et al. (2020) found that the assessment of navicular drop (pronation) using a digital calliper had an excellent (ICC average: 0.970) intra-rater reliability in the study of 60 healthy individuals. Assessment of posture is a cost and time efficient method of screening and allows for easy application in a screening practice setting.

The use of BMI as a predictive screening tool revealed mixed results within this study. Lee et al. (2017) found that there was no statistically significant relationship between BMI and injury prediction while Steinberg et al. (2019) found that dancers who developed patellofemoral pain syndrome (PFPS) had a reduced BMI compared to dancers who did not develop PFPS. Importantly, when comparing these results, Lee et al. (2017) while providing a definition of injury, diagnosed injury by self-report. Whereas Steinberg et al. (2019) provided a definition of PFPS

and diagnosis of PFPS was made by two orthopaedic surgeons. As mentioned, it is important for researchers investigating injury to avoid self-reports of injury, especially in the ballet population as its reliability is questionable. Within the culture of ballet, there is a phenomenon of disordered eating patterns to maintain a low body weight for aesthetic purposes. While an association between disordered eating and a low BMI has not been made in this study, one can assume that given the culture of ballet, there is a possibility that some dancers with a low BMI may have disordered eating patterns. Thomas et al. (2011) found supporting evidence for the findings by Steinberg et al. (2019). The presence of disordered eating was associated with an increased likelihood of injury within the culture of ballet where thinness is valued (Thomas et al., 2011). This study was, however, retrospective in design. Steinberg et al. (2019) did not mention or investigate the reliability of BMI as a tool and did not provide a value for what was considered low, normal, or high. Lebiedowska et al. (2021) investigated the reliability of the BMI to identify whether women (n: 267) were underweight, overweight, or obese. The significance in their findings related to the fact that BMI does not successfully account for various composites of the body. While the measurement of BMI is an easily implemented measurable tool, the intervention needs to be multidisciplinary, and it would be advised to involve a dietician for a full body composition assessment.

5.11 Flexibility

No studies found a statistically significant injury predictive ability of flexibility tests. Gamboa et al. (2008) found that flexibility tests, both for the upper extremity and lower extremity, had no injury predictive ability despite the specificity of the test method to ballet. Hamstring flexibility was measured in turnout as well as in parallel (Gamboa et al., 2008) demonstrating the effort of the authors in measuring flexibility in ballet specific positions. As mentioned in section 5.5 of this discussion, it is highly desirable for ballet dancers to have increased flexibility as overall flexibility is an innate requirement of the genre. Therefore, where you have a population which is generally likely to have an increased flexibility due to training, this may not be an appropriate tool to use when assessing for injury risk.

5.12 Balance

An inability to balance for five seconds on demi-pointe was significantly associated with future lateral ankle sprain in a test group, however these finding were no longer significant in the validation group (Hiller et al., 2008). Having said this, it is important to note that this study utilised a self-report method of diagnosing injury which may have influenced their results. The inability of balance to predict future injury was supported by the findings of Gamboa et al. (2008) which

indicate that there is no significant injury predictive ability of releve balance time. Other methods of evaluating balance in dancers have been investigated. Clarke et al. (2021) concluded that balance tests, including the SEBT, the modified Romberg test, the Airplane test, the BioSway Balance System, and a dance specific pirouette test require further study to confirm their functional specificity to dance. A scoping review by Ani et al. (2021) confirmed that there is a need for effective balance screening tests in dance, as the current balance screening tests are not specific enough for assessing improvements in balance or when making return to dance decisions. Currently, there is little evidence to support the use of balance screening tests both for predicting injury as well as assessing balance in ballet dancers, regardless of the specificity of the test to dance. It is surprising then, that 34.38% of respondents to a survey reported including the SEBT in their screening of dancers in companies, schools, and universities.

5.13 Alignment and Function

A 10° greater right modified knee valgus angle (better alignment) for the fondu was found to moderately reduce injury risk, and for the temps leve demonstrated a small reduction in injury risk (Bowerman et al., 2014). The same study found that a 2° greater pelvic angle (poor alignment) during a temps leve on the left was associated with a moderate reduction in injury risk, while the same observation during a right leg fondu was associated with a small increase in injury risk (Bowerman et al., 2014). The latter finding may initially seem confusing, and it is important to understand the difference between a temps leve and a fondu. During a temps leve there is impact load, while during a fondu there is no impact load. The authors of this study argued that during a temps leve, an increased pelvic angle may be injury protective in that it assists in dissipating forces of impact (Bowerman et al., 2014). While the authors sufficiently described the method of using cameras to measure these angles during each movement, there was no mention or investigation of reliability of this method. The study is strengthened by the fact that it provided a definition of injury and injury diagnosis was made by a physiotherapist. When comparing these results to other literature there seems to be disagreements on whether alignment is related to injury risk. Bowerman et al. (2015) found in their systematic review that there was little evidence to support that poor lower extremity alignment is linked to an increased risk of over-use injuries in elite female ballet dancers. Contrary to this, a systematic review found that for both elite and recreational ballet dancers, alignment was a risk factor for injury (Biernacki et al., 2021). Reasons for the disagreement in the literature may be due to the fact that alignment constitutes many biomechanical factors and as such there are many methods of measuring alignment, especially within the genre of ballet. It is difficult, to compare the findings of Bowerman et al. (2014) with other literature because the methods of assessing alignment are significantly different. Having

said this, Armstrong and Relph (2018) concluded in their systematic review and meta-analysis that there is support for the use of ballet specific positions as predictors of injury. Given the results from this scoping review, it seems that additional research is required to investigate this relationship, utilising structured and well described methods.

5.14 Special Orthopaedic Tests

The special orthopaedic tests identified in the studies within this scoping review, are predominantly specific to the knee, followed by the hip and ankle. Steinberg et al. (2019) found that a positive grind test and a positive patellar inhibition test at baseline were significantly associated with PFP at follow-up. The study provided a clear definition of injury and injury diagnosis was made by two orthopaedic surgeons which adds strength to their findings. It has been found that in a population of 1359 female dancers, of which some included classical ballet dancers, 23.6% experienced PFPS (Steinberg et al., 2012). Therefore, any test which shows predictive ability for this condition is relevant within the dance population. There is little evidence in the literature supporting the use of the grind and patellar inhibition test for the diagnosis of PFPS in the form of reliability studies, however these tests are used to diagnose PFP in other research. Steinberg et al. (2020) investigated the use of isometric exercise and somatosensory training in the treatment of PFP in young dancers where both the grind and patellar inhibition test were used to confirm a diagnosis. Cook et al. (2010) found that the strongest diagnostic test for PFPS was pain during resisted knee muscle contraction. The authors concluded that further diagnostic strength was achieved when a combination of pain felt during resisted muscle contraction of the knee, pain with squatting and pain during palpation were used (Cook et al., 2010). Further research is needed to determine the reliability of both the grind test and patella inhibition test to strengthen the usage of this test when screening to predict PFP in ballet dancers.

5.15 Standardised Screening Tools

Two standardised screening tools were found to have injury predictive ability in this scoping review. The MCS was found to be related to the occurrence of future injury as dancers (including ballet dancers) who scored less than 23 on the MCS were significantly more likely to sustain an injury (Lee et al., 2017). While this study provided a definition for injury, the diagnosis of injury was made by self-report, which as discussed previously reduces the reliability of these findings. The MCS includes a combination of five movements, one of which is the single leg squat. The single leg squat has been found to be effective in screening for PFP in ballet dancers (Campbell et al., 2019). The MCS was however was found not predictive of injury in a military population (Milbank et al., 2016). More specific to the dance population there is some evidence to support

the use of the MCS. In a population of 77 pre-professional and professional ballet and contemporary dancers, the MCS correlated with transversus abdominus activation and strength of the hip abductors adductors and external rotators (Benoît-Piau et al., 2021). While evidence in terms of the injury predictive ability of the MCS is limited, this correlation indicates a relationship between the MCS and strength in dancers. This may be where its injury predictive ability lies. In terms of reliability, Lee et al. (2017) found in a pilot study (prior to the conduction of their primary study) that the intrarater reliability of the MCS was excellent (ICC 0.99, CI: 0.98-0.99). This is supported by current literature in which the MCS composite score showed good reliability in a population of pre-elite youth athletes when administered by a single rater (Mann et al., 2022). Given the high intra-rater reliability of the MCS and the findings of Lee et al. (2017), the MCS, although not ballet specific, shows promise in its applicability to screening in the ballet population. In addition, it is an easily administered, cost effect method of screening, allowing for efficient application in a screening setting. Given the statement by Armstrong and Relph (2018) that there is a lack of investigation of movement screening tools to predict injury in the dance population, the results from Lee et al. (2017) show promise in furthering steps in this category of injury prevention.

Twitchett et al. (2010) found that there was a significant relationship between an increased number of sustained injuries and an increased heart rate at the end of the DAFT. An increased heart rate at the end of the test correlates with reduced aerobic fitness. This study only included 13 elite female ballet dancers and did not provide a definition of injury. Diagnosis of injury was, however, made by a non-specified healthcare provider. The authors discuss the relationship between fatigue and possible subsequent alignment and biomechanical changes which may place an increased strain on musculoskeletal structures, predisposing a dancer to injury (Twitchett et al., 2010). McCormack et al. (2019) stated that stamina is a desired trait in ballet dancers, representing the acknowledgement of ballet as an endurance sport. Given this, injury predictive ability of the DAFT seems an appropriate area for future research to focus on. Interestingly, Armstrong et al. (2018b) found that fatigue, following the DAFT, did not correlate to changes in performance on the SEBT in 35 university dancers. While the mechanisms behind the findings of Twitchett et al. (2010) are likely multifaceted, it does not seem that balance is affected by fatigue in dancers. Having said this, future research is required utilising a larger population size, where a definition of injury is clear, to further validate the findings of Twitchett et al. (2010). Reliability was not mentioned or investigated by the authors, however Wyon et al. (2003) found that the reliability of the DAFT was acceptable when heart rate was used as the outcome measure among dancers. Importantly professional ballet dancers can dance between 25 and 30 hours per week (Novosel

et al., 2019) and up to 35.5 hours per week during performance periods (Allen et al., 2012). Given this, fatigue seems an appropriate measure to include when screening for potential injury in this population.

5.16 Strengths

The strengths of this study lie in its methodology. The proposal was registered on Open Science Framework as is recommended by the JBI Manual for Evidence Synthesis. The structure of the methodology is in accordance with the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Group guidelines as well as the JBI reviewer's manual. Throughout the process of methodology, a second reviewer was included and where consensus was not reached a third reviewer was consulted. This was done to prevent the occurrence of bias in the selection and data extraction process. The PRISMA flowchart was utilised as the method of reporting results by means of illustration. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis extension for Scoping Reviews (PRISMA ScR) (Appendix 1) was completed to ensure rigorous methodology was followed. The exclusion criteria specified that studies which were not published in peer reviewed journals would not be included. This was done to ensure that the research being reviewed was of good methodological quality.

5.17 Limitations

A limitation of this study is that only seven studies were selected for inclusion. In addition, no study was found to investigate the prediction of lower back injury. This may be due to the fact that there is limited research which has prospective design on this topic and as such leads to limited results. To ensure a comprehensive search, the search terms were derived from previous literature on this topic, with necessary modifications made. However, the limited number of studies selected may indicate a fault in the search terms used in the search strategy.

5.18 Relevance

Research consistently reports that the lower back and the lower extremity are the two most frequently injured locations among ballet dancers (Ekegren et al., 2014, Caine et al., 2015, Smith et al., 2016). While many studies have investigated the relationship between various risk factors and injury in the ballet population, few have been prospective in study design and thus determining predictive ability is not possible. Where chronic, over-use type injury constitutes a high percentage of sustained injury (Bowerman et al., 2014, Ekegren et al., 2014, Sobrino and Guillén, 2017, Campbell et al., 2019), the consequences of injury must be avoided through injury prevention screening practices. To this author's knowledge, this is the first scoping review to investigate screening tools which predict injury to the lower extremity and lower back among ballet

dancers. Armstrong and Relph (2018) conducted a systematic review and meta-analysis on screening tools to predict injury in dancers and included 42 studies. While this scoping review included only seven studies, it identified three additional studies (Twitchett et al., 2010, Steinberg et al., 2019, Armstrong, 2020) which were not reviewed by Armstrong and Relph (2018). This scoping review therefore adds further contribution to a limited literature base on this topic. The findings of this scoping review may guide healthcare and dance professionals in their goals of identifying dancers who are at risk of injury. In addition, it sheds light on which screening tools have been found to be ineffective in the prediction of injury in the ballet population and thus, do not warrant inclusion in dance screening practices. Future research on this topic should at the very least include a clear definition of injury, ensure that the diagnosis of injury is made by a relevant healthcare professional, be prospective in design, and either investigate or provide researched evidence on the reliability of the tool being investigated.

Chapter 6: Conclusion

Ballet is a sport and genre of dance which requires excessive active ranges of joint motion to be maintained under high load conditions, with movement which is repetitive in nature. In general, there is little evidence of prospective design on the topic of injury prediction in ballet. While the ethics and obstacles relating to prospective study designs require some discussion, there is a need for prospective design in predictive studies to guide professionals in the use of specific screening tests. While it may be accepted that studies include a mixed genre of dancers, it should be specified how many dancers fall into each genre and how the results may be applied to specific genres. Providing a definition and healthcare provider diagnosis of injury strengthens the reliability of the results on this topic. This is specifically relevant in ballet related research, as dancers have been found to be unreliable when it comes to self-reporting injury. There is a clear indication that researchers need to ensure both inclusion and exclusion criteria are mentioned in the methodology. In addition, there is a similar need for researchers to report on confounders within their study, thereby ensuring internal validity. Regarding the objective of identifying screening tools to predict lower back injury, no specific screening tools were identified in this scoping review. Given the high incidence of lower back pain in ballet dancers, this is a concerning finding. Articles which were identified in the search strategy which specifically investigated screening tools for back pain, were excluded due to the lack of a prospective design, as they were unable to comment on the predictive ability of investigated tools. In terms of the objective of identifying screening tools to predict lower extremity injury in ballet dancers a few interesting findings were made in this scoping review. The Beighton’s hypermobility scale is not advised as an effective injury predictive

screening tool in ballet. While there is evidence that it may be a weak predictor of total days injured, the scale itself is not ballet specific in design and thus it seems ineffective in predicting injury. A change of 0.5cm in right foot length shows promise in its injury predictive ability and demonstrated moderate reliability. This is an easily administered test and future research should investigate how a change in foot length relates to injury, in an effort to direct where intervention in identified ballet dancers should be implemented. There is some support for insufficient right ankle plantar flexion and reduced lower extremity strength however the methods and cut off points for administering testing was not defined, making it difficult to apply these findings in practice. Future research should investigate the predictive ability of lower extremity strength and ankle ROM and provide a clear description of testing procedures and cut off values. Right foot pronation may predict lower extremity injury. While reliability of this test was not investigated in the research, current literature suggests that navicular drop (pronation) has excellent reliability. The finding that right foot pronation has been predictive of injury in the ballet population is relevant to dance schools, teachers and practitioners working in this field, as it is an effective, easily administered tool. Modified right knee valgus angle during fondu and pelvic angle during temps leve on the left demonstrate some ability in predicting injury in ballet dancers. Future research should investigate this relationship further, conduct a reliability study and ensure that the testing procedure is well described and reproducible. The grind and patellar inhibition tests show promise in prediction of PFP in ballet dancers. Future research should investigate the reliability of these tests to further validate their application in practice. Finally, the MCS test and the DAFT demonstrated injury predictive ability in two studies. Future research should investigate the injury predictive ability of the DAFT utilising a larger population size of ballet dancers. In addition, the MCS demonstrated excellent reliability, further justifying the use of this tool in screening practice. This scoping review followed a sound methodological quality, and its findings contribute to a small literature base on the topic of screening tools to predict lower limb injury in ballet dancers. There is a significant need for further research into identifying screening tools predictive of lower back injury in the ballet population.

APPENDICES

APPENDIX 1: Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	Cover Page
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	x-xi
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	20
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	19-20
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	37
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	38
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	39-41
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	39-40
Selection of sources of evidence	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	41
Data charting process	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	42
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	42

Critical appraisal of individual sources of evidence	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	42
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	42
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	44-45
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	46-50
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	50-51
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	45-48
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	52-59
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	64-74
Limitations	20	Discuss the limitations of the scoping review process.	74
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	75
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	No funding was provided.

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where sources of evidence (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

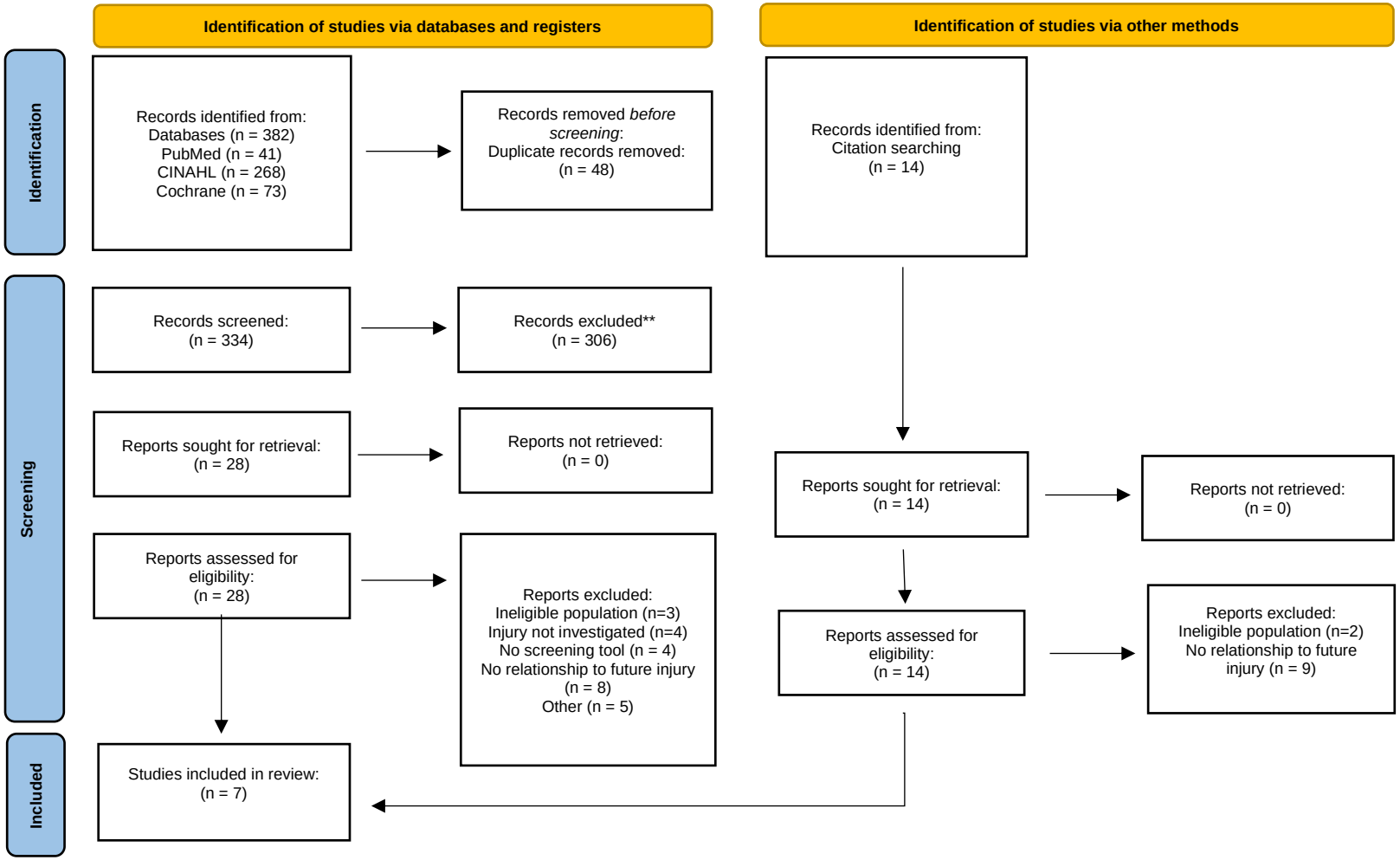
† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with information sources (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-085

Appendix 2: PRISMA 2020 Flow diagram for new systematic reviews which included searches of databases, registers, and other sources:



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).
**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/

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