Determining pointe readiness in young adolescent female dancers: A systematic review

Determining Pointe Readiness in Young Adolescent Female Dancers: A Systematic Review

Hough-Coles, K[1] and Wyon M[1,2]

[1]Sport and Physical Activity Research Centre, University of Wolverhampton

[2]National Institute of Dance Medicine and Science, UK

ABSTRACT

Dancing 'en pointe' is an integral aspect of ballet for female dancers who start pointe training in young adolescence. The primary objective of this review was to investigate the screening tests used to determine pointe readiness in young adolescent female dancers, and the secondary objective was to determine the injuries associated with pointe training. The search engines Google Scholar, PubMed, Scopus, and Web of Science were mined using Medical Subject Heading terms "pointe", "pointe readiness", "injury", "young", "adolescent", "female", "dancer" and a manual search of relevant articles was conducted. Inclusion criteria included: females; aged 8-20 years; pre-pointe, training en pointe; pointe-related injury. Search strategy followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The following data were extracted; first author, year of publication, study design, participant size, mean age, testing, outcome, and general notes of each study. Risk of bias was evaluated using the Research Triangle Institute Item Bank (RTI-IB). Eight cross-sectional studies met the inclusion criteria. Results suggested topple, airplane, sauté, and relevé tests are statistically better determinants of pointe readiness than chronological age alone. Utilising these methods alongside age, strength, body maturation, range of motion (ROM), and teacher evaluation could provide an all-round insight into a dancer's readiness for pointe. However, the included studies had

contradictory outcomes with regards to pointe-related injury and the review's conclusions are limited by methodological design.

Keywords: pointe, pointe readiness, female, young, adolescent, injury, dancers

INTRODUCTION

Dancing en pointe is synonymous with the great prima ballerinas, and is a prerequisite for all professional female ballet dancers.[1,2] For young ballet dancers, training en pointe is an exciting and important development. It exemplifies progression in their dance education[1,3,4] and dedication to the art.[3] Many young dancers perceive that their progression en pointe will be precipitous,[1] yet transition to pointe requires attaining numerous criteria to determine readiness. These criteria include; chronological age,[1-3,5-8] core, ankle, and pelvic stability,[1,2,4,6-10] core, lower limb, and ankle strength,[1,2,4,6-10] range of motion (ROM),[1,2,4,6-10] flexibility of the foot and ankle (plantarflexion),[1,2,4,6-10] balance,[1,2,10] foot, ankle, and lower limb alignment,[1,2,8,10] technique,[2,4,10] years of training,[2,3,5-10] musculoskeletal maturation,[2,6,8] and stability and control while raising and lowering (or performing relevé) onto and from pointe.[2,11]

Pointe Readiness Assessment

Currently, there is no known universal screening protocol that can accurately determine pointe readiness. There are numerous tests available for dance teachers to assess pointe readiness and help highlight dancers who can progress to pointe, need supplementary training, or should not perform en pointe.[2] Literature[6,11] suggests that the most significant functional test for pointe readiness is the airplane test (which helps determine a dancer's level of core stability); relevé and pirouette tests are also relevant indicators.[2,6,11]

Anatomically, dancers should encompass an array of physical attributes to perform en pointe correctly and safely.[1,2] Dancers are required to demonstrate adequate and stable ankle ROM[1,6,7] (plantar flexing the foot in parallel with the tibia), strong tendu (extending the foot of the working leg across the floor to pointe while the other foot supports weight), adequate strength and alignment in the core and lower extremities,[12,13] and 90° to 100° of plantarflexion at the ankle during relevé.[1,2,4,14] Subsequently, it has been suggested that dancers require at least two years of ballet experience prior to going en pointe [12,13] and pointe training should be discouraged for dancers who are only doing one ballet class a week or have reduced ROM of the ankles and feet.[8] Dancers with the required and stable ROM, who engage in numerous ballet lessons, may have a greater proprioceptive ability to handle pointe training.[15] However, despite numerous physical attributes needed to successfully and safely train en pointe, chronological age is still the most common guideline used by many dance teachers to determine pointe readiness.[1]

Age, Growth, and Injury

Generally, dancers begin pointe training around 12 years of age,[1,2,6,8,12,15-17] with pubertal growth spurts occurring around the same timeframe.[1,8,18] However, chronological age does not always equate bone age[8]. There are significant physiological differences in female development that are dependent on the onset and rate at which puberty occurs.[18] During puberty, girls aged approximately 10 to 12 years have a major increase in growth velocity from 5.5cm/year to a peak of around 10.5cm/year, and body mass gain velocity of 8.5kg/year. Such substantial growth changes occur in each child at an individual rate;[18] ballet dancers, in particular, mature later than the average rate.[19,2021] Therefore, starting pointe training simultaneously with the pubertal phase could present a number of issues. Firstly, growth plates become vulnerable due to constant 'remodelling' throughout puberty and are more receptive to tensile forces than the surrounding bone.[2,22] Secondly, rapid bone growth compared with that of the connective tissues, initiates a decrease in motor ability and dynamic balance[23] and learned motor patterns become unreliable.[24,25] Thirdly, load and strain on muscles and ligaments increase, due to vulnerability of a young dancer's musculoskeletal system,[4,13,26] which has been shown to cause a higher prevalence of injury.[27] Finally, dancing prematurely en pointe could prevent the closure of ossification centers of the foot,[4,10,28] as complete ossification in the feet does not occur until around 18 years of age.[2,4,8] However, there is no medical evidence to date of damage to a growing foot corresponding with the onset of pointe during growth spurts.[2,8]

Pointe-Related Injury

When en pointe, the ankle is exposed to 12 to 13 body weight (BW) of force,[3,4,29,30] with increased forces of approximately 150N/cm^2 on the toes en pointe compared to 41N/cm^2 barefoot.[31] Furthermore, dancing en pointe and demi-pointe can increase the load on the gastrocnemius-soleus and flexor hallucis longus muscles, which help keep the ankle and foot stabilised.[15] Therefore, increased forces and load located at the ankle and foot could increase the risk and incidence of pointe-related injury, especially in those dancers who train en pointe prematurely, or lack the physical attributes needed to dance safely en pointe.[4,10,28,30,32,33]

The most prevalent injuries occurring in young adolescent dancers are found at the ankle, knee, and foot and are often caused by poor technique (generally because of overuse and fatigue),[34] weak hip musculature associated with inversion of the subtalar joint and increased postural sway,[35-37] and an increase in training load when en pointe.[38] Posterior ankle impingement and ankle sprains are frequent in dancers en pointe and are conceivably caused by premature initiation of pointe training.[4,10,28] Additionally, reduced ankle ROM can cause stress fractures in dancers who 'over pointe' the feet whilst en pointe.[39] Consequently, dancing with poor technique while wearing ill-fitting pointe shoes can lead to retrocalcaneal bursitis (inflammation of the bursa at the attachment of the Achilles tendon), hallux rigidus (arthritis in the joint at the base of the big toe), and sesamoiditis (inflammation of the sesamoid bones at the ball of the foot beneath the big toe joint).[15]

Dancers who lack joint stability and muscle coordination may not have the required physical attributes or a mature enough musculoskeletal system to endure the increased amounts of stress and load once en pointe.[2,4,17] Therefore, a 'gradual approach' to pointe training should be adopted to prepare dancer’s for these increased demands on the body, which in-turn may decrease the risk of pointe-related injury.[4,29,31,40]

The objectives of this systematic review were to: investigate the test procedures used in dance to determine pointe readiness in young adolescent female dancers; and identify the injuries associated with pointe training.

METHODOLOGY

Search Strategy

One reviewer (KHC) compiled the search strategy using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram (**Figure 1**), the second reviewer (MW) oversaw the search strategy and PRISMA process. PRISMA guidelines were used to identify articles included and excluded in the systematic review (**Figure 1**).[41] A protocol was developed prior to this review. To identify all materials, four databases: Google Scholar, PubMed, Scopus, and Web of Science, were searched in February 2020. The search involved identifying peer-reviewed publications in the English Language, with no publish date limit. In addition to these searches, a manual hand search of the Journal of Dance Medicine & Science and relevant reference lists was also conducted. Medical Subject Heading (MeSH) terms "pointe", "pointe readiness", "injury", "young", "adolescent", "female", "dancer" were used in different combinations (**Table 1**). Full articles were reviewed (see inclusion and exclusion criteria).

Inclusion and Exclusion Criteria for Considering Studies

Inclusion criteria included: peer-reviewed English language studies; female dancers aged 8-20 years; studies specific to pointe readiness; injury incidence causal to pointe training. Exclusion criteria included: review and opinion literature, dissertations, thesis', abstracts, works in progress; persons aged 0-7 and 20+ years female dancers, males; sportspersons, ballet (non-pointe specific) and all other genres; any injury not linked to pointe training.

Study Selection

Two reviewers (KHC and MW) screened all studies identified by the search strategy. KHC imported potentially relevant studies into EndNote X9 (Clarivate, PA, USA), and duplicates were removed. There were seventeen full-text articles assessed for eligibility; nine articles were excluded (**Table 2**). Eight studies met the inclusion criteria for this review (**Table 3**).

Data Extraction

Two reviewers (KHC and MW) extracted the following information for review: First author; publication date; participant information; age; study design; method; testing; and outcomes. General notes and observations from the study were also acknowledged.

Risk of Bias Assessment

Two reviewers (KHC and MW) assessed the risk of bias of all eight included publications. The quality of reporting was not evaluated as there is evidence to suggest that such evaluations can introduce bias and misleading scores in systematic reviews.[42,43] For this review, the eight included studies were appraised using the Research Triangle Institute Item Bank (RTI-IB).[44] The revised RTI-IB is suitable for use with observational study designs and sets out appropriate guidelines and scoring.[45] The tool rates a study as having high risk of bias when one or more of the key items are negative or unclear. Questions 2, 5, 6, 9, 12, and 13 from the item bank were used to assess risk of bias of all eight included studies. Due to there being no gold standard that exists for evaluating risk of bias in observational studies, the tool can be changed to reflect the design of the included studies (for example, case study or cross-sectional); therefore, the questions chosen to evaluate the eight included studies in this review, reflect their cross-sectional design.[44,45]

RESULTS

This review is based on eight observational cross-sectional studies; published between 1985-2019 (**Table 2**). DeWolf et al,[5] Hewitt et al,[3] Nunes et al,[33] Pearson and Whitaker,[38] and Richardson et al,[6] involved young adolescent female dancers in their studies. Guggenheim[46] evaluated 11 ballet schools via a questionnaire for dance teachers/directors (total number of participants was not recorded). Meck et al[1] studied a pre-pointe evaluation questionnaire undertook by dance teachers, health professionals, and assessors (37% response rate). Finally, Solomon et al[7] included young adolescent female dancers and non-dancers of similar status.

Participant Data

This review found a vast variation in age range (8 to 20 years), and years of experience (2 to 14 years) (**Table 2**). Collectively this review consisted of 260 young adolescent female dance participants; 100 pre-pointe participants;[3,5-7,33] 76 pointe participants;[3,5,7,33,38] and 10 non-dancers as a control.[7] One study divided their pointe population into beginner (n=7) and intermediate (n=10).[3] There was a lapse in data when reporting age[1,46] and years of experience,[1,38,46] which limited analysis, interpretation of results, and outcomes.

Risk of Bias

The outcome of the Risk of Bias RTI-IB of all eight included studies was summarised as high, low, or some concerns[45]. The results from the RTI-IB were input into excel and uploaded into the ROBVIS software tool (**Figure 3**).[47] All eight included studies showed bias; detection bias was most prominent, where none of the studies [1,3,5-7,33,38,46] implemented or reported blinding of the assessors from the outcome, exposure, or intervention status of the participants. Selection bias confounding and detection bias confounding showed low risk of bias in six studies [1,3,5,6,33,38]; however, the studies were limited by methodological design and therefore detection bias was considered as high risk of bias. Five studies (5/8)[1,3,5,6,33] showed low risk of bias for selective outcome reporting; however, three studies (3/8)[7,38,46] showed some concerns by not reporting all statistical data or outcomes. Penultimately, five studies (5/8)[3,5,6,33,38] showed low risk of bias for confounding; yet, two studies (2/8)[1,7] showed some concerns, and one study (1/8)[46] showed high risk of bias, due to not reporting or taking into account potential confounders. Overall assessment found that four studies (4/8)[3,5,6,33] showed low risk of bias, three studies (3/8)[1,7,38] showed some concerns, and one study (1/8)[46] showed high risk of bias; this was mainly due to flaws in methodological design, lack of blinding, and limited or unclear reporting of statistical analysis.

Testing Procedures

The studies in this review found that pointe readiness in young adolescent female dancers is tested a multitude of ways, but showed little conformity overall, due to the diverse methods used to determine readiness. Meck et al[1], in their survey of 74 dance schools, found that out of 21 pre-pointe evaluation components assessed, eight were most common: age (95.9%), relevé alignment and stability (94.6%), years of experience (91.9%), plié alignment and stability (89.2%), present injuries (87.8%), past injuries (82.4), upper body alignment and stability (79.7%), and tendu (77%). DeWolf et al,[5] Hewitt et al,[3] Richardson et al,[6] and Solomon et al[7] stated that younger, pre-pointe dancers, with fewer years of experience, performed significantly worse in the sauté test,[3,6] airplane test,[3,5,6] topple test,[3,6] relevé endurance,[5] isometric strength,[5] isokinetic strength,[7] and star excursion balance test in three directions.[5] Additionally, teacher evaluation statistically correlated with relevé,[5] airplane[5,6], topple[6] and sauté[6] tests.

DeWolf et al,[5] Richardson et al,[6] and Hewitt et al[3] evaluated the heel-rise or relevé test (to measure strength, detect movement pattern instability, and measure plantar flexion), and plank tests[3,6] (to assess the correct placement of the pelvis and core stability); DeWolf et al[5] found a significant difference ($p<0.01$) between number of relevés completed and successful pointe students. Hewitt et al[3] found no significant difference between pre-pointe and pointe groups and Richardson et al[6] found no significant difference between age and experience groups, when testing heel rise and plank. Authors noted that heel raise and plank tests could be used for diagnostic purposes.

Pointe-Related Injury

Three out of the eight included studies evaluated pointe related injuries,[1,33,38] pre-pointe or non-pointe-related injuries,[1,33] self-reported injuries[38] and clinically reported injuries.[1,33] Pearson and Whitaker[38] found a significant difference in foot pressures between barefoot and pointe shoe ($p<0.01$) and demi-pointe shoe and pointe shoe ($p<0.01$). They indicated that wearing a demi-pointe shoe in between soft and pointe shoes would provide a suitable transition stage for dancers to gradually become accustomed with the increase in pressures at the ankle and foot. The questionnaire sent out to dancers revealed that incidence of injury was lower in dancers wearing demi-pointe shoes prior to pointe shoes than straight to pointe shoes. Additionally, dancers who wore demi-pointe shoes as a transition to pointe sustained fewer lower leg, ankle, or foot dance-related injuries.[38] Meck et al[1] found that clinicians reported 87.8% of dancers' with a current injury, and 82.4% a previous injury, associated with dancing en pointe. Nunes et al[33] showed that the number of painful sites was significantly different in non-pointe (1.3±1.9) and pointe (2.9±2.1) groups ($p<0.04$). Yet, the only risk factor out of five that predicted that the number of painful sites, was the number of years of ballet experience ($p<0.001$). The study concluded that more years of ballet experience equated to an increased number of painful sites. Yet, numerous variables and risk factors were not considered, and bias was not eliminated. Furthermore, Meck et al[1] and Pearson and Whitaker[38] did not statistically evaluate the questionnaires used in their study, leaving questions of how reliably these results involving injury can be interpreted.

DISCUSSION

This systematic review aimed to evaluate how young adolescent female dancers are assessed when considering readiness for pointe training, and injury aetiology associated with the onset of pointe training. A definitive conclusion was not achieved in this systematic review, as there was little conformity in the research methodologies and variables measured in the selected studies. However, there were numerous tests more commonly used to determine readiness, which may indicate their use when screening.

Pointe Readiness Testing

Traditionally, chronological age, years of experience, ROM, and teacher evaluation have been the criteria used when determining pointe readiness.[2,6] However, there are other methods available, which may be more accurate. Meck et al[1] stated that correct execution of movements, such as tendu, relevé, and plié, are vital requirements for technique, and dancers displaying weak tendu and reduced or excessive ROM may be predisposed to injury. Analogously, Solomon et al[7] reported that young female dancers have significantly greater ROM at the ankle than young female non-dancers, those dancers with either extreme ROM or hypermobility may need additional strength at the ankle for control and safety en pointe. Therefore, in-depth testing and teacher evaluations are needed prior to pointe training to assess each individual dancer’s needs, as not all dancers will be technically equipped to train en pointe immediately, or ever.[2]

Chronological age is still the primary evaluation used by dance teachers when assessing a dancer's pointe readiness.[46] Correspondingly, Nunes et al[33] suggested that progressing en pointe around age 11 would ensure adequate strength and dance experience. DeWolf et al[5] noted that very little difference was found between pre-pointe and pointe dancers regarding age and dance experience. Still, age alone is not a relevant factor as it does not take into account individual variation in biological maturation.[2] Therefore, these factors do not inevitably correlate with a dancer's readiness for pointe.

The included studies found the sauté test,[3,6] airplane test,[3,5,6] topple test,[3,6] relevé endurance,[5] isometric strength,[5] isokinetic strength,[7] and star excursion balance test in three directions,[5] were significantly better evaluators when assessing readiness for pointe, than merely chronological age. Additionally, Richardson et al[6] suggested that significant functional tests should be used alongside chronological age, years of dance experience, maturity status, commitment to dance, and medical history. Thus, collaboration of both traditional methods and functional test measures may be a more accurate means of assessment for dance teachers and health professionals, to determine a dancer’s readiness.[6]

Meck et al[1] and DeWolf et al[5] suggested that relevé endurance is the most frequently used musculoskeletal measure in pre-pointe screenings by dance and health professionals. Yet, there is no relevant research to indicate what number or duration of relevés delivered would quantify pointe readiness. DeWolf et al[5] determined that students performing 15 relevés were 'more likely' to be successful at pointe as they performed significantly better than pre-pointe students in the relevé endurance test. Additionally, it was concluded that 15 to 17 continuous single-leg relevés and two quality airplane manoeuvres should be used as a minimum evaluation for pointe readiness.[5] Again, no such research exists to support this evaluation. In addition to these tests, Hewitt et al[3] and Richardson et al[6] suggested that the heel-rise test and plank tests should be utilised as supplementary components when testing pointe readiness. However, it may be helpful to note that the heel-rise test in Hewitt et al[3] consisted of the dancer performing relevés (snatching onto the balls of the feet or toes en pointe from demi-plié), not heel rises (rising onto balls of feet or toes en pointe, without a snatch or demi-plié). The test termination also varied; Hewitt et al[3] counted the number of relevés at a rate of 30 per minute until fatigued, whilst Richardson et al[6] determined a pass at 20 or more heel raises. Clarity of testing measures is not apparent in these studies, so it is difficult to say if heel-rise or relevé is a better determinant of pointe readiness.

Pointe-Related Injury

Few dance institutions have onsite professional healthcare available, making the clinical reporting of injuries limited.[1] Only Meck et al[1] and Nunes et al[33] reported clinical reporting of injury, while Pearson and Whitiker[38] used dancers' self-reporting injury.

Pearson and Whitaker[38] found significant pressure differences between dancing in barefoot or flat ballet shoe and pointe shoes. In their questionnaire, they also found that the incidence of injury was lower in dancers who wore demi-pointe shoes prior to pointe shoes (than straight to pointe shoes). They acknowledged that wearing demi-pointe shoes, also known as soft blocks or pre-pointe shoes, is beneficial; these are pointe shoes minus the hard insole or shank.[48] Dancers are unable to rise onto pointe in soft blocks but can experience how pointe shoes would feel on the feet when dancing allowing the dancer to make a gradual load progression from soft shoe to pointe shoe, by strengthening the foot musculature. Progressive training allows structures in the feet to strengthen so that dancers get accustomed to the increased pressure and demands of pointe training, consequently decreasing the risk of injury.[40] However, this is the only study to suggest wearing a demi-pointe shoe as a transition to pointe shoe to limit pointe-related injury; therefore, it is difficult to determine whether it is a reliable factor or not.

Nunes et al[33] argued that the number of painful sites self-reported by dancers was significantly predicted by the years participated in ballet class prior to the onset of pointe training, not type of shoe worn. It was concluded that dancing in pointe shoes did not increase knee and ankle instability or other musculoskeletal injuries. This may be explained by pointe training stimulating bone growth through the piezoelectric effect, which increases osteoblasts and initiates higher peak bone mass,[49,50] sequentially strengthening the bone enough to cope with the demands of pointe on the body at a younger age.[46] Ultimately, without in-depth longitudinal studies, the correlation between injury and pointe training remains contradictory.

Presently, there lacks a regulation system for dance teachers and institutions to ensure mandatory pre-pointe evaluation screening measures. Unfortunately, utilising every test within the eight included studies is not plausible, in terms of time and significance. Dancers may become injured if not screened or are assessed by unqualified individuals.[1,32] This demonstrates the value of dancers' involvement with educated teachers and clinicians.[1] There is a void in research regarding a universal screening procedure and specific guidelines that could be used within institutions, which is imperative for dance teachers when assessing readiness for pointe. However, the lack of replication in methodologies and variables tested in the included studies reduces this review's ability to make a meaningful conclusion on the optimal components of a pre-pointe screen.

LIMITATIONS

This review was limited in its design as there was a discrepancy of included studies; There were only eight included studies, all cross-sectional design. No longitudinal studies were found; therefore, the progression from pre-pointe to pointe training was not examined. Throughout the included studies, the was a lack of consistency when using the pointe readiness tests. Three of the included studies involved questionnaires, physical testing of participants was not apparent, therefore readiness for pointe could have been interpreted. Finally, due to the limited amount of included studies, there was a diverse range of experience (vocational to professional).

Sparse scientific data and a lack of statistical analysis in some of the included studies caused vagueness and inconsistencies and constructed unreliable results. To make research more accurate, data, testing, and methodologies need to provide consistency and in-depth procedures to provide clarity.

CONCLUSIONS

Overall, this review did not provide any substantial outcomes to the objectives. However, relevé, airplane, sauté, and topple tests were found to be significantly better predictors of readiness; four out of eight included studies used two or more of these tests in their research. When used concurrently with chronological age, musculoskeletal maturation, strength tests, ROM measurements, and teacher assessment, these tests could provide a better evaluation for pointe readiness.

Ubiquitous and effectual screening and intervention methods for dancers advancing en pointe could give dance teachers the facility to determine pointe readiness safely and accurately, which may help limit injury occurrence.[51-53] However, although screening is recommended, this review demonstrates that there is a paucity in research, statistical evidence, and conclusive testing protocols.

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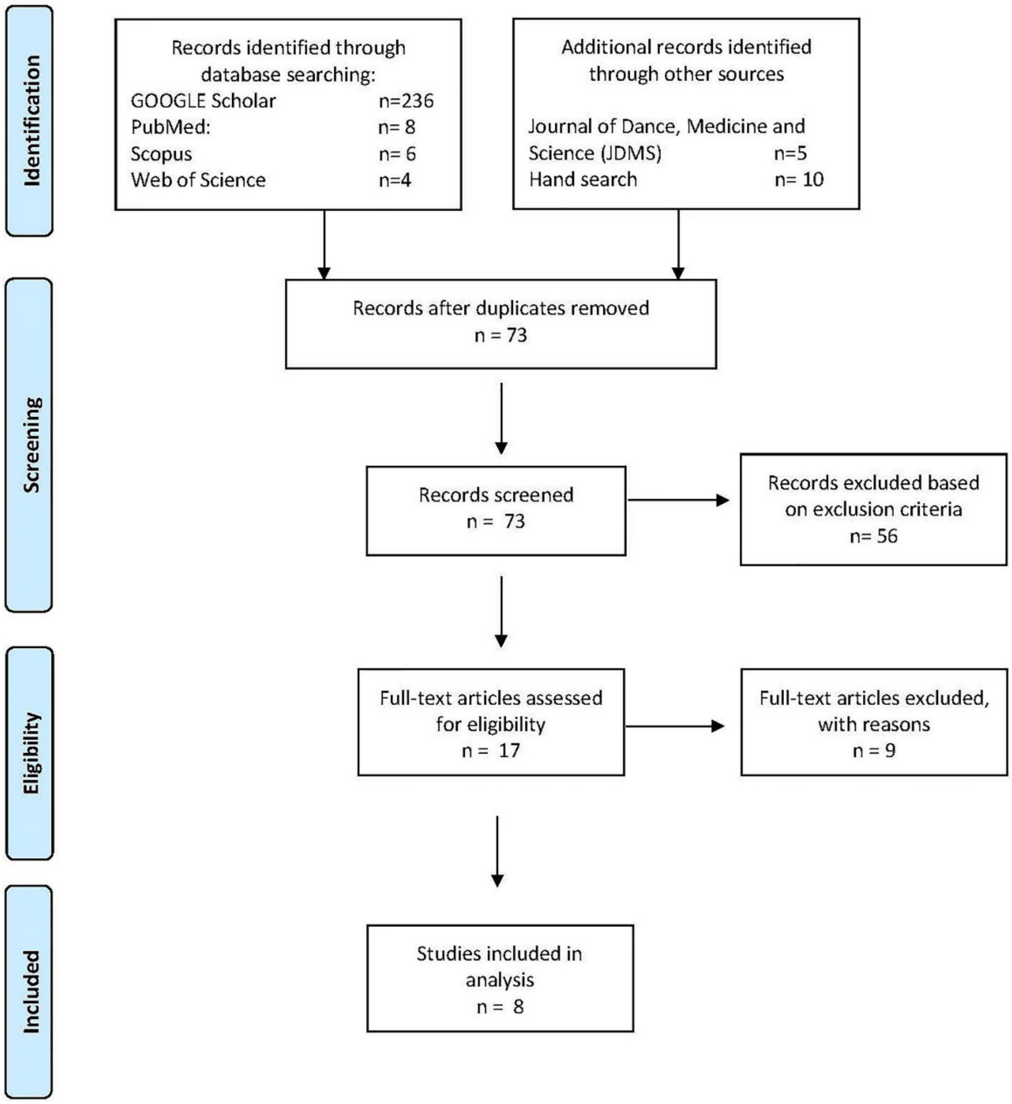

Figure 1: PRISMA Analysis of Included and Excluded Studies

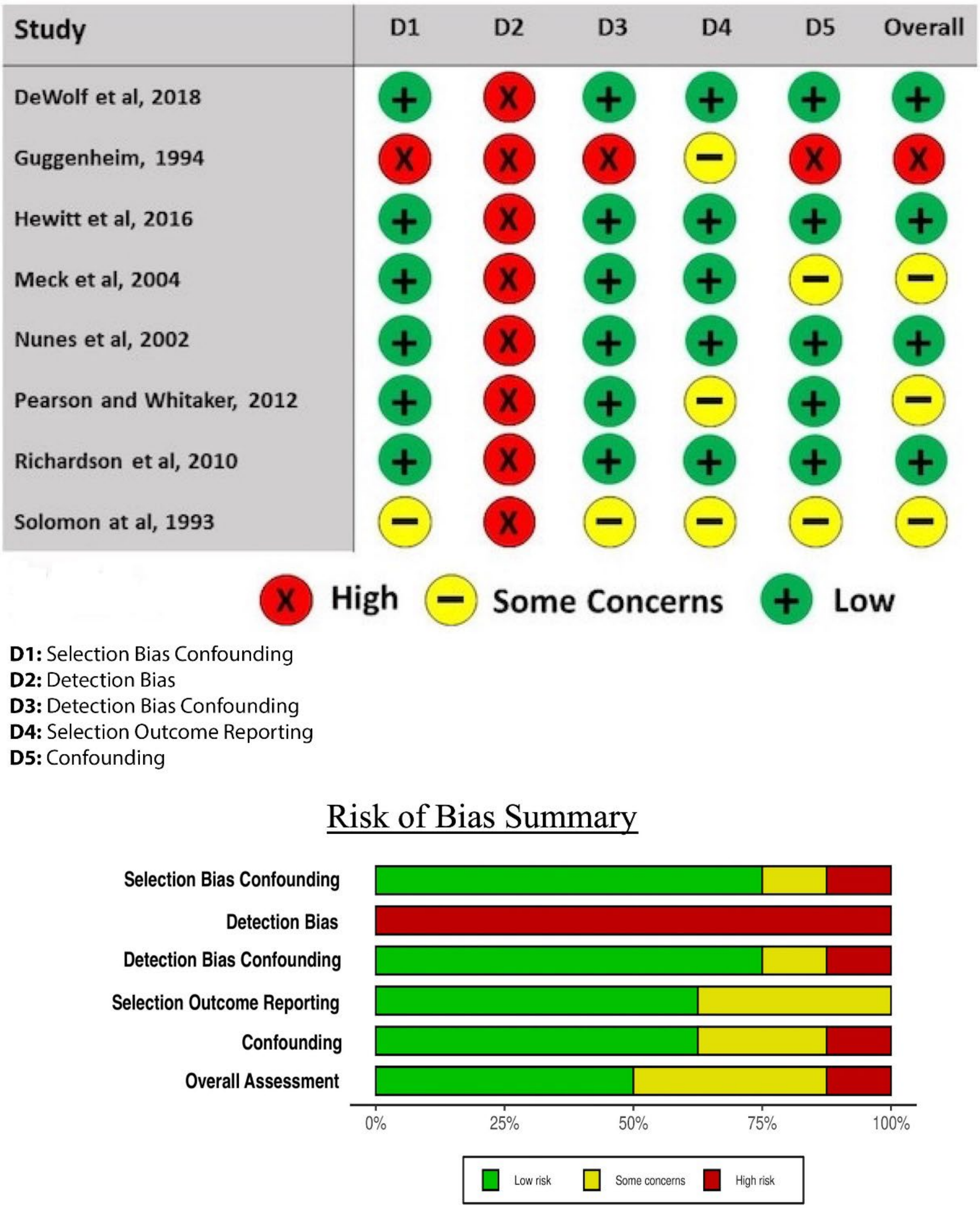

Figure 2: Risk of Bias Assessment Summary

Table 1: Google Scholar Search Combinations using MeSH Terms

"Pointe Readiness"	63
"Pointe Readiness" and "Injury"	57
"Pointe Readiness" and "Adolescent dancers"	20
"Pointe Readiness" and "Adolescent Dancers" and "Injury"	20
"Pointe Readiness" and "Young Dancers"	34
"Pointe Readiness" and "Young Dancers" and "Injury"	34
"Pointe Readiness" and "Young Adolescent Female Dancers"	2
"Pointe Readiness" and "Young Adolescent Female Dancers" and "Injury"	2

Table 2: Characteristics of Full-Text Articles Excluded, with Reasons

Authors	Title	Reasons for exclusion
Altmann, C., Roberts, J., Scharfbillig, R. and Jones, S.	Readiness for en pointe work in young ballet dancers are there proven screening tools and training protocols for a population at increased risk of injury. *J Dance Med Sci*, *2019 23*(1), pp.40-45.	Commentary – non-study
Albers, D., Hu, R., McPoil, T. and Cornwall, M.W.	Comparison of foot plantar pressures during walking and en pointe. *Kinesiol Med Dance*, *1993*(15), p.1.	Not relevant to inclusion criteria. It was about foot pressures, not pointe readiness.
Cunningham, B.W., DiStefano, A.F., Kirjanov, N.A., Levine, S.E. and Schon, L.C.,	A comparative mechanical analysis of the pointe shoe toe box. *Amer J of Sports Med 1998 26*(4), pp.555-561.	Not relevant to inclusion criteria. It was about pointe shoes, not dancers.
Lai, J.C. and Kruse, D.W.,	Assessing readiness for en pointe in young ballet dancers. *Pediatr Ann*, *2016 45*(1), pp.e21-e25.	Commentary – non-study
Moser, B.R.	Posterior ankle impingement in the dancer. *Curr Sports Med*, *2011 10*(6), pp.371-377.	Commentary – non-study
Shah, S.	Determining a young dancer's readiness for dancing on pointe. *Curr Sports Med*, *2009 8*(6), pp.295-299.	Commentary – non-study
Shah, S.	Premature growth plate closure in a ballet dancer en pointe. *Clin J Sport Med*, *2017 27*(5), pp.e69-e71.	Not relevant to inclusion criteria. It was a case study on one dancer, about foot pressures and growth plate arrest, not pointe readiness.
Walter, H.L., Docherty, C.L. and Schrader, J.	Ground reaction forces in ballet dancers landing in flat shoes versus pointe shoes. *J Dance Med Sci*, *2011 15*(2), pp.61-64.	Not relevant to inclusion criteria. It was about landing forces, not about pointe readiness.
Weiss, D.S., Rist, R.A. and Grossman, G.	When can I start pointe work? Guidelines for initiating pointe training. *J Dance Med Sci*, *2009 13*(3), pp.90-92.	Commentary – non-study

Table 3: Summary of Studies Included in the Review Analysis

STUDY	DESIGN	PARTICIPANTS	AGE (yrs.)	TESTING	OUTCOME	NOTES
DeWolf et al, 2018[5]	Cross-sectional	Total n=49 pre-pointe n=28 pointe n=21	Pre-pointe = 10.21±1.17 Pointe= 11.42±0.81	Six variables evaluated: Non-weight bearing plantar and dorsiflexion ROM; weight-bearing lunge test; relevé endurance; PF isometric strength; airplane; star excursion balance test in three directions	Pointe group performed significantly better than the pre-pointe for relevé endurance, isometric strength, airplane, and star excursion test in three directions	Calculated that 15 continuous single-leg relevés and 2 airplanes up and down manoeuvers might be the best cut of levels when using them as a test for a pre-pointe screen and to distinguish better pointe and pre-pointe dancers.
Guggenheim, 1994[46]	Cross-sectional	Ballet schools n=11; n=10 responded to all questions	Not stipulated	Questionnaire regarding initiation of pointe	Age = 9-11 years Training before pointe = 2-5 years with a majority of 2-3 years Pointe regime in the first year ranged from 5-10 minutes to two hours Pointe regime in the second year ranged from two 15-minute sessions per week to 4 pointe sessions a week varying in length from 30 minutes to an hour. 8/10 schools prohibited obese children from doing pointe	Participant number was unavailable. Answers were not controlled, so interpretation of the questions could vary. Without testing the dancers physically, readiness for pointe is hard to gage. Generalised initiation regimes may not be appropriate for all dancers.
Hewitt et al, 2016[3]	Cross-sectional	Female ballet students n=29 pre-pointe n=12 beginner pointe n=7 intermediate pointe n= 10	13±3	Heel raise test; plank; sauté; topple test; airplane test; teacher's rating	Sauté, topple, and airplane all have value and may be useful for determining pointe readiness	Participants were from different studios and were not equally matched in experience, training techniques, and dance backgrounds. The teacher's rating may not be reliable or valid as they could vary dramatically on their idea of what is needed to be pointe ready
Meck et al, 2004[1]	Cross-sectional	Pre-pointe evaluation questionnaire undertook by dancer teachers, health professionals, and assessors. Of the 200 sent, 74 participants responded	Not available	21 components determining pre-pointe evaluation; age, years of dance, menses history, present injuries, past injuries, x-ray, MRI, bone scan, spinal alignment, gait analysis, proprioception, muscle length, range of motion, manual muscle test, relevé, plie, Porte de bras, tendu, passé, develop, upper body.	8 out of 21 components were reoccurring: age, years of dance, present injuries past injuries, relevé alignment and stability, plie alignment and stability, tendu, and upper body alignment and stability. Age was selected by 95.9% of the participants. Least frequently selected was MRI and X-Ray, by 1.4% of participants.	Age of participants was not available, but it was requested to specify the minimum age for students allowed to go on pointe. Ages ranged 9-13 years, 39.2% aged at 12 years.

Nunes et al, 2002[33]	Cross-sectional	Nonprofessional female ballet dancers n=31 Non pointe n=12 Pointe n=19	Non pointe= 12.1±2.7 Pointe= 16.8±1.8	Descriptive questionnaire determining if non-pointe or pointe; years on pointe; age; height; weight; years post menarche; ligamentous laxity; involvement of physical activity (number of activities and hours per week. Scientific techniques – Lachman test (ankle); anterior drawer test (ankle); stress test (anterior talofibular ligament); and 4 criteria from the modified Beighton's score.	Dancing in pointe did not increase the likelihood of having knee and ankle stability. The number of painful sites in non-pointe (1.3±1.9) and pointe (2.9±2.1) was predicted by the number of years participating in ballet classes (p, 0.001).	Small sample size (non-pointe n=12 and pointe n = 19). Participants were from two different studios. Lower extremities were only tested. No pointe readiness tests used or information on how readiness was decided.
Pearson and Whitaker, 2012[38]	Cross-sectional	Female dancers n=8 Questionnaire group. Female vocational students n=65	19.63±1.06 13.49±1.42	Foot pressures in barefoot, soft ballet shoe, demi-pointe shoe, and pointe shoe were tested; additionally, a questionnaire was given to 65 adolescent female vocational dancers asking which type of shoe the used and injury occurrence before and after the onset of pointe work.	Dancers wearing demi-pointe shoes before beginning pointe training were less likely to sustain injury and reported their first dance-related injury later, compared to the 30% of dancers who did not wear demi-pointe shoes.	Small cohort tested (n=8) compared to large cohort completing the questionnaire (n=65). Participants were not equally matched. Those tested (n=8) were university undergraduate dance degree students, trained up to RAD intermediate ballet level. The questionnaire group (n=65) were recruited from vocational schools, with ballet as their primary discipline.
Richardson et al, 2010[6]	Cross-sectional	Pre-pointe students n=37	12.3±2.2	Nine tests evaluated; pencil test, balance tests, topple test, double leg lower (DLL) test, single-leg step down (SLSD) and airplane, single-leg sauté test, and single-leg heel raise test	Results indicated that those tests which measure dynamic core and lower extremity control (topple, single-leg sauté, airplane) were good indicators of pointe readiness; and, alongside a dancer's chronological age, medical history, and years of dance experience, would be a comprehensive evaluation for teachers and parents to determine pointe readiness.	There was a stark difference between the dancers; average training years (1-12 years). Pre-professional dancers (n=33) had 5.5-9 hours of ballet training a week. Community program students (n=4) had 1.5-3 hours of training per week.
Solomon et al, 1993[7]	Cross-sectional	Total n=32 Group 1-pointe av. 1.22 years n=11 Group 2-pre-pointe n=11 Group 3- non-dancer control n=10	Group 1-pointe 11.01±0.71 Group 2-pre-pointe 9.83±0.93 Group 3 control 10.35±0.70	Tested passive range of motion at the ankle, and isokinetic strength of the knee and ankle	Young female dancers have a greater range of motion at the ankle than young female non-dancers; non-dancers produce increased peak torque insignificant muscles of the lower extremities; pointe students marginally have greater strength and range of motion that pre-pointe dancers;	Lower extremities were only tested, core strength and balance were not evaluated to determine all-around strength for pointe.

					the study also found that isokinetic testing is not an accurate indicator, due to dancing on pointe being eccentric movements and not isokinetic; and, having an adequate range of motion to plantarflex the foot in parallel with the tibia, appears to be essential to progress to en pointe training.	