Physical Therapy in Sport 38 (2019) 106–114

Contents lists available at ScienceDirect

Physical Therapy in Sport

journal homepage: www.elsevier.com/ptsp

Literature Review

Intrinsic modifiable risk factors in ballet dancers: Applying evidence based practice principles to enhance clinical applications

Ryan S. Campbell [a, *], Michael E. Lehr [b], Andrew Livingston [b], Meghan McCurdy [b], J. Kristopher Ware [a]

[a] Orthopedic Associates of Hartford, PC, Hartford, CT, USA
[b] Lebanon Valley College, Department of Physical Therapy, 101 North College Avenue, Annville, PA, 17003-1400, USA

ARTICLE INFO

Article history:
Received 23 October 2018
Received in revised form
22 April 2019
Accepted 27 April 2019

Keywords:
Injury risk
Risk factors
Ballet dancers
Screening

ABSTRACT

Introduction: The risk of musculoskeletal injury is multifactorial (Bahr 2005). Injury risk is a composite of intrinsic and extrinsic risk factors that can be modifiable or non-modifiable. Ballet dancers have unique risk factors, due to the nature of their art and sport. The purpose of this literature review is to identify intrinsic modifiable risk factors for injury in ballet dancers. The secondary purpose is to investigate potential screening tools which can be used to identify these risk factors.
Methods: The authors performed a review of the literature in October 2017 within the databases of MEDLINE Complete, SPORTDiscus, and PubMed Central following a list of inclusion and exclusion criteria.
Results: A review of the available literature identified seven intrinsic modifiable factors specifically for ballet dancers and seven appropriate screening tools.
Discussion: The literature identified the most common intrinsic modifiable risk factors associated with ballet dancers to be: hypermobility, fatigue, overuse, neuromuscular dysfunction, degree of turnout, weakness of core and lower extremity musculature, and lower extremity range of motion (ROM) discrepancies.
Conclusion: Sports medicine professionals who manage these performing artists can use this literature review to help develop injury prevention programs and enhance return to sport decision.
© 2019 Elsevier Ltd. All rights reserved.

1. Introduction

The demands of competitive sports are associated with an elevated risk of musculoskeletal injury. Each sport has its own inherent risks and some injuries are more commonly seen in certain sports than others. Among common activities in which children and adults can participate, dance has become increasingly popular. Of the specific types of dance and similar art forms, ballet appears to be the most highly researched. Ballet is a high-performance dance requiring an advanced level of technical skills which frequently place great stress on structures and thus may cause injury (Costa, Ferreira, Orsini, Silva, & Felicio, 2016). A high level of endurance, balance, flexibility, and strength are necessary to perform ballet dancing.

As with many athletes, ballet dancers encounter multiple musculoskeletal injuries for a variety of reasons. The epidemiology of injury can be multifactorial, in that, there may be more than one event or aspects leading up to the point of injury (Bahr & Krosshaug, 2005). This is what makes determining the true cause of an injury so challenging. Risk factors for injury need to be considered. Risk factors can be categorized as intrinsic and extrinsic relative to the injured person. The risk factors that are extrinsic are external to the individual such as surface type, shoe wear, and type of athletic event (practice versus competition) which can influence the athlete's performance. Intrinsic risk factors are internal to the individual such as age, sex, body mechanics, and motor control which impacts the athlete's ability to execute sport-related activities (Lehr, Kime, Onks, Silvis, & Streisel, 2017). Other descriptors of risk factors include modifiable or non-modifiable classifications. Modifiable risk factors are able to be manipulated or changed with non-invasive interventions such as strengthening and increasing mobility. Non-modifiable risk factors are those which are unable to be changed by simple intervention; examples of non-modifiable risk factors include anatomical anomalies, previous injury, and a person's age (Lehr et al., 2017; Steinberg et al., 2012). Those risk

* Corresponding author.
E-mail address: RCampbell@oahctmd.com (R.S. Campbell).

https://doi.org/10.1016/j.ptsp.2019.04.022
1466-853X/© 2019 Elsevier Ltd. All rights reserved.

factors that are considered intrinsic modifiable risk factors are those internal to the athlete which can be altered or removed through intervention from a rehabilitation team, such as postural control, and fatigue. (Sabato, Walch, & Caine, 2016). The benefit of identifying common intrinsic modifiable risk factors, encourages a more comprehensive management of the ballet dancer. This information can be used to enhance clinical reasoning during discharge planning, as well as help develop injury prevention and performance enhancement programs. Up to this point, the literature has utilized systematic reviews to investigate risk factors for lower extremity overuse in ballet dancers (Bowerman, Whatman, Harris, & Bradshaw, 2015), and general musculoskeletal injury (Kenney, Whittaker, & Emery, 2015). At this time, no literature review exists that provides a targeted scope on intrinsic modifiable risk factors in ballet or offers an evidence informed recommendation as to what screening tools can be used by the clinician to effectively capture them.

The primary purpose of this literature review is to identify intrinsic modifiable risk factors for injury within ballet dancers. The secondary aim of this literature is to investigate potential screening tools that effectively identify these risk factors in this unique performing artist group. While the specific psychometric investigation of the screening tools is outside the scope of this article, the goal is to initiate discussion on what a battery of tests may look like to capture the identified risk factors. This will assist sports medicine professionals who manage these athletes to develop injury prevention programs and enhance return to sport decisions. The intent of this literature review is to move the science of injury prevention/management forward by not only building upon previous research in this area, but providing a focused, evidence-informed recommendation to guide advanced clinical practice to better serve this unique population.

2. Methods

The authors performed a review of the literature in October 2017 within the databases of MEDLINE Complete (2007 to October 2017), SPORTDiscus with Full Text (2007 to October 2017), and PubMed Central (2007 to October 2017) (Table 1). For the Boolean search terms used in the database searches, see Table 1. The results of the three searches were gathered; duplicates were removed; and reference lists from the results were examined to add additional literature to enhance the overall search. Full texts of articles for potential use were screened by two authors (A.L. and M.M.). After analysis and discussion of available information and relevance toward intrinsic modifiable risk factors in ballet dancers, the following inclusion criteria were established: (i) full text, (ii) published in English, (iii) peer-reviewed articles, (iv) addressed injury risk factors for musculoskeletal pathologies, (v) identified screening tools for injury risk factors within sports, (vi) clinically applicable to ballet (Fig. 1). Based on the criteria, 56 articles are included; 2066 were excluded (See Appendix 1.).

2.1. Data extraction

Two examiners reviewed and discussed the articles while considering the inclusion and exclusion criteria until 100% agreement was achieved. Levels of evidence and scope of inquiry were key components of the discussion when determining final inclusion. In the event an agreement wasn't reached, then the article was excluded and not integrated into the recommendations.

3. Results

The cumulative literature review resulted in 61 articles from Medline, 42 articles from SPORTDiscus, and 2045 articles from PubMed Central (PMC). Following the removal of duplicates and exclusion of 2066 articles based on the search criteria, 56 articles were included in the literature review.

Based on the primary purpose of this literature review of identifying intrinsic modifiable risk factors in ballet dancers, specific information from the 56 articles included was extracted and resulted in the seven intrinsic modifiable risk factors summarized in Fig. 2.

Based on the secondary purpose of this literature review, 36 screening tools were identified by the authors in the included articles as being adequate assets to coaching staff and medical professionals in order to identify the risk factors that put these dancers at risk for injury throughout their careers. In order to cover the list of intrinsic modifiable risk factors identified, a battery of the seven most useful and practical screening tools were chosen as those recommended by the authors. These screening tools are listed in Fig. 3. The risk factors are cross referenced with the identified screening tools in Fig. 4.

4. Discussion

Ballet dancers have their own unique set of tasks and movements, which need to be performed to complete their dance routines. The multifactorial nature of injuries lends a challenge to health professionals managing these performing artists. This literature review offers an opportunity for the sports medicine

Table 1
Terms searched within databases.

Source (Search Date Range)	SPORT Discuss (2007–October 2017)	MEDLINE Complete (2007–October 2017)	Pubmed Central (2007–October 2017)
Search Terms	(“injury risk” OR “injury” OR “risk of injury” OR “injury prediction” OR “injury risk factors” OR “risk factors” OR “risk factors for injury”) AND (“screening” OR “screening tools” OR “screen” OR “injury screen” OR “injury risk screen” OR “functional movement screen” OR “movement screen” OR “functional screen” OR “movement competency screen” OR “screening for injury” OR “injury risk assessment” OR “assessment tools” OR “assessment of injury risk") AND (“ballet” OR “ballet dancers” OR “ballet performers” OR “dancers” OR “dance” OR “dance company” OR “injuries in dance” OR “dance injuries")	(“injury risk” OR “injury” OR “risk of injury” OR “injury prediction” OR “injury risk factors” OR “risk factors” OR “risk factors for injury”) AND (“screening” OR “screening tools” OR “screen” OR “injury screen” OR “injury risk screen” OR “functional movement screen” OR “movement screen” OR “functional screen” OR “movement competency screen” OR “screening for injury” OR “injury risk assessment” OR “assessment tools” OR “assessment of injury risk") AND (“ballet” OR “ballet dancers” OR “ballet performers” OR “dancers” OR “dance” OR “dance company” OR “injuries in dance” OR “dance injuries")	(“injury risk” OR “injury” OR “risk of injury” OR “injury prediction” OR “injury risk factors” OR “risk factors” OR “risk factors for injury”) AND (“screening” OR “screening tools” OR “screen” OR “injury screen” OR “injury risk screen” OR “functional movement screen” OR “movement screen” OR “functional screen” OR “movement competency screen” OR “screening for injury” OR “injury risk assessment” OR “assessment tools” OR “assessment of injury risk") AND (“ballet” OR “ballet dancers” OR “ballet performers” OR “dancers” OR “dance” OR “dance company” OR “injuries in dance” OR “dance injuries")

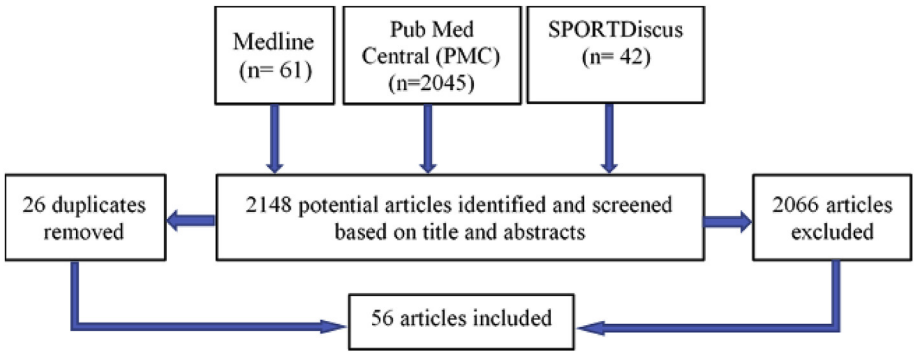

Fig. 1. Database search results.

Intrinsic Modifiable Risk Factors	
Hypermobility	Barber Foss et al., 2009; De La Motte et al., 2015; Groh and Herrera, 2009; Ivokvic et al., 2007; Kim SJ et al., 2010; Mandarakas et al., 2014; Marulli et al., 2017; Ruemper and Watkins, 2012; Scheper et al., 2014; Steinberg et al., 2013
Fatigue	Bronner et al., 2016; Jacobs, 2012; McCriskin et al., 2015; Quammen et al., 2012; Sabato et al., 2016
Overuse	Anderson et al., 2016; Costa et al., 2016; DiPasquale et al., 2015; Groh and Herrera, 2009; Guddal et al., 2017; Halabchi et al., 2013; Rehmani et al., 2015; Sabato et al., 2016; Smith PJ et al., 2015; Sobrino et al., 2015
Degree of Turnout	Jenkins et al., 2013; Rehmani et al., 2015; Sobrino et al., 2015; Steinberg et al., 2012
Neuromuscular Dysfunction	Barber Foss et al., 2009; Clark and Gupta, 2012; DiPasquale et al., 2015; Enseki et al., 2014; Harris-Hayes et al., 2009; Hoogenboom and Voight, 2015; Jacobs et al., 2012; McCriskin et al., 2015; Sabato et al., 2016; Schmidt et al., 2011; Smith PJ et al., 2015; Sobrino et al., 2015; Steinberg et al., 2011; Steinberg et al., 2012; Turner et al., 2012; Van Dillen et al., 2008; Waryasz and McDermott, 2008
Core and Lower Extremity Weakness	Kivlan et al., 2013; Rehmani et al., 2015; Steinberg et al., 2011; Steinberg et al., 2012; Steinberg et al., 2013; Van Dillen et al., 2008
Lower Extremity Range of Motion Discrepancies	Carcia et al, 2011; Fong et al., 2011; Kivlan et al., 2013; McCriskin et al., 2015; Steinberg et al., 2012

Fig. 2. Intrinsic modifiable risk factors identified for ballet dancers.

professional to target specifically the intrinsic modifiable risk factors from both a prehabilitation and rehabilitation standpoint. Based on this review, the authors suggest that no one screen can capture a majority of the risk factors identified. Therefore, it is most prudent for the sports medicine professional to use a battery of tests that most comprehensively addresses the evidence-based risk factors, which the evidence suggests (see Fig. 4)

It is worth noting that the most robust injury risk factor found from our review is previous injury. Although this is a non-modifiable risk factor, it should be kept in mind that it may influence current intrinsic modifiable risk factors in dancers. Many of the intrinsic modifiable risk factors in dancers are closely interrelated and can impact one another. For the rehabilitation team, as well as instructors who want to keep their athletes at peak performance for the duration of their dancing careers, it is vital they take the time to utilize the screening tools recommended in order to identify dancers with the greatest risk of injury.

4.1. Hypermobility

According to the research, one of the strongest risk factors for injury is hypermobility throughout the dancer's body or in one specific joint. Hypermobility can be defined as generalized joint hypermobility (GJH) or as joint hypermobility syndrome (JHS). GJH can be either hereditary or acquired, whereas JHS is strictly a hereditary condition that is inherited through an autosomal dominant

Screening Tools	
Movement Competency Screen (MCS)	Lee at al., 2017
Beighton Hypermobility Scale	Barber Foss et al., 2009; Reumper and Watkins, 2012; Waryasz and McDermott, 2008
Fast Short-Term Fatigue Protocol (FAST-FP)	Quammen et al., 2012
Star Excursion Balance Test (SEBT)	De la Motte et al., 2015
Rolling	Hoogenboom and Voight, 2015
Passive Hip External Rotation	Jenkins et al., 2013; Steinberg et al., 2013
Total Passive Turnout (TPT)	Jenkins et al., 2013; Steinberg et al., 2013

Fig. 3. Most useful screening tools as decided by authors.

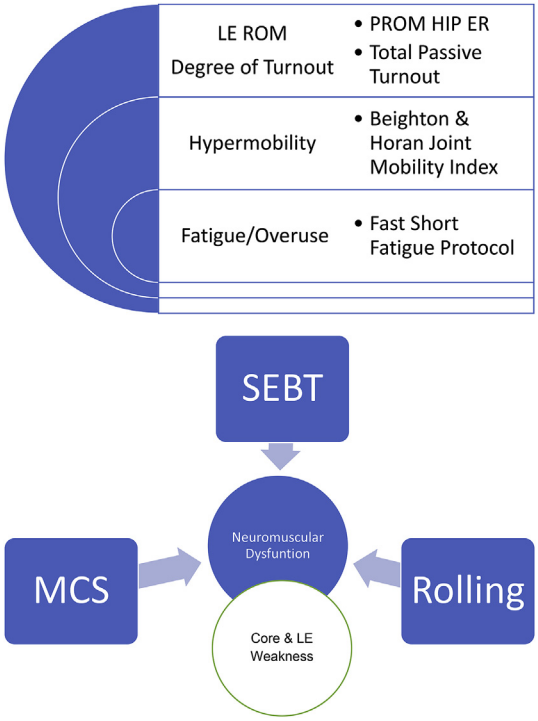

Fig. 4. Screening tools for assessing specific risk factors.

gene and appears locally or globally (Ruemper & Watkins, 2012). "The presence of GJH was significantly higher in dancers (66%) when compared to non-dancer controls (29%)" (Scheper, de Vries, Juul-Kristensen, Nollet, & Engelbert, 2014). This increased prevalence of GJH should be considered when looking at past injury and injury risk. Significant correlations have been found between those with JHS and injury. While research has not shown GJH to be directly correlated to injury, it is still considered to be an important risk factor in dancers because GJH may progress to JHS (Ruemper & Watkins, 2012).

Hypermobility often results in injuries such as chronic ankle instability (De la Motte, Arnold, & Ross, 2015; Mandarakas, Pourkazemi, Sman, Burns, & Hiller, 2014), anterior cruciate ligament (ACL) injuries (Kim, Kumar, & Kim, 2010), labral tears (Groh & Herrera, 2009), tendinopathies (Steinberg et al., 2011), degeneration (Groh & Herrera, 2009), instability of the hip (Groh & Herrera, 2009), and others. Hypermobility within the foot can allow for a collapse of the medial arch, which increases stresses on the second metatarsal area on both the dominant and nondominant limbs (Barber Foss, Ford, Myer, & Hewett, 2009). This can allow for medial tibial stress syndrome to develop because forces are not distributed properly; in turn, this can then lead to ankle instability due to the abnormal stresses placed upon the ankle. Tendinopathy has been proven to be a common result of joint hypermobility and can affect dancers differently depending on the style of dance performed (Steinberg et al., 2013). Laxity of structures within the knee joint have been associated with increased rates of anterior cruciate ligament (ACL) injuries (Kim et al., 2010). Hyperextension of the knee due to generalized joint laxity has been noted as a factor for ACL injuries especially in non-contact situations (Kim et al., 2010). Chronic ankle instability (CAI) has been identified in the ballet population. CAI is defined as perceived instability, mechanical instability, and recurrent sprains in populations studied (Mandarakas et al., 2014). Prevalence in adults ranges from 7 to 53% where in children the prevalence was found to be even higher (Mandarakas et al., 2014). "Increased incidence of instability is likely due to increased levels of generalized joint laxity in this population" (Mandarakas et al., 2014).

To assess for hypermobility and general joint laxity, the literature identified two effective screening tools. Research from Barber Foss et al. and Reumper and Watkins showed that an athlete's score on the Beighton and Horan Joint Mobility Index could be a useful tool to indicate risk for acute and/or chronic lower extremity injury (Barber Foss et al., 2009; Ruemper & Watkins, 2012). The Star Excursion Balance Test was found to be useful in identifying compensatory movements especially when assessing maximal reach. These compensatory movements were more prevalent in the group with a history of CAI versus the uninjured group. Since many dancers with hypermobility experience ankle injuries due to instability, this may be a useful screening tool to assess injury risk (De la Motte et al., 2015).

4.2. Fatigue

Throughout the research, fatigue appeared as a possible link to increased injury rates. Research has identified a strong link between fatigue and increased incidence of overtraining and overuse injuries (Sabato et al., 2016). The fatigue that "accompanies the rigor, volume, and demands of practice and performance for these

dancers significantly increases the risk for injury" (Sabato et al., 2016). During a 9 hour "workday", 90% of female ballet dancers had less than 60 consecutive minutes of rest at any one time during that period. For 33.3% of the dancers, consecutive rest time was less than 20 min during the 9-h workday. Rest was defined as performing activities below 1.5 METS (Twitchett, Angioi, Koutedakis, & Wyon, 2010).

Fatigue plays a role within the landing mechanics of athletes as technique is compromised. One author reports findings that "most ACL injuries within athletes occur late in the day and later in the season indicating fatigue from a long performance period resulted in the increased number of knee injuries" (Jacobs, Hincapié, & Cassidy, 2012). In relation to significant knee injuries, the combination of landing mechanics at the knee and hip joints during an unanticipated task under greater amounts of fatigue will increase the likelihood of injury (Quammen et al., 2012).

As the knee moves closer to 30 degrees of flexion in landing, the peak anterior translation is thought to occur putting the athlete at increased risk for ACL injury (Quammen et al., 2012). Fatigue has also been shown, in elite athletes, to alter knee abduction (or increasing knee valgus), internal rotation, and adduction moments during landing tasks which also puts the dancer at risk for sustaining a knee injury because fatigue has altered their neuromuscular control during demanding tasks (Quammen et al., 2012). Muscle fatigue exacerbates the neuromuscular control at the knee joint, and also puts athletes at risk for ankle injury and instability (McCriskin, Cameron, Orr, & Waterman, 2015). The increase of ankle instability secondary to fatigue may only accentuate the hypermobility component of the ankle, which was discussed earlier, further increasing the risk for injury of the dancer. Because ankle injuries are extremely prevalent in dancers, minimizing fatigue will greatly benefit these dancers, decreasing their risk of injury further. Males are at higher risk for endurance related injuries as research has shown that male dancers have decreased levels of cardiorespiratory endurance and slower running speeds than their female counterparts (Bronner, Codman, Hash-Campbell, & Ojofeitimi, 2016).

This literature review did not reveal extensive information regarding appropriate screening tools for fatigue. There was only mention of two different fatigue protocols that were both used in the same study. A study by Quammen et al. used both the functional agility short-term fatigue protocol (FAST-FP) and the slow linear oxidative fatigue protocol (SLO-FP) to assess the change in dancers' mechanics. Both of these protocols were able to elicit changes in knee flexion during sport, a situation that Quammen et al. theorized could put dancers at higher risk for ACL injury. The authors recommended this fatigue protocol be used in conjunction with a screening tool such as the Landing Error Scoring System to help quantify changes in lower extremity mechanics (Quammen et al., 2012).

4.3. Overuse

Of the injuries documented in dance, overuse injuries accounted for 75% of all injuries with similar findings between male and female counterparts (Smith et al., 2015). Sixty-four percent of all female dancer injuries and 50% of all male dancer injuries were a result of overuse (Smith et al., 2015). Other research showed 21.7% of injuries reported were a result of overuse and 6.5% were a result of overuse combined with alignment issues in elite athletes (DiPasquale, Becker, Green, & Sauers, 2015). The higher rate of overuse injuries was directly related to the level of fatigue a dancer experienced during trainings and performances (Sabato et al., 2016; Smith et al., 2015). The highest number of overuse injuries appeared within rehearsals prior to performance showings or competitions, where changes in choreography require constant repetitive techniques to be displayed until they have been mastered for the upcoming performance (Sobrino, de la Cuadra, & Guillén, 2015). The lack of rest between the high number of repetitions is likely a significant cause to increased prevalence of overuse injury within ballet dancers (Sobrino et al., 2015).

Overuse injuries are extremely common in the lower extremity, not only dance, but in other dynamic sports as well, "due to the repetitive submaximal loading of the musculoskeletal system without adequate rest" (Guddal et al., 2017). The constant repetitive motions experienced in ballet, as well as other well know sports such as hockey, golf, and soccer, have been linked to labral abnormalities within the hip due to the repeated and frequent external rotation (Groh & Herrera, 2009). This excessive and repetitive external rotation can eventually cause continued stress on the spine, putting dancers at risk for back injuries as a result of overuse and degraded movement functions within the hip (Guddal et al., 2017). When young dancers attempt to increase their degree of external rotation throughout the lower extremity, the repetitive stress and strain on these structures can cause injury. The compensation many dancers develop as a means for increasing lower limb external rotation is pronation, which may put the dancer at increased risk for more detrimental pathologies than just excessive turnout (Sorbino et al., 2015).

Overuse injuries are not only seen within the connective tissue structures in the hips, but also in the knees and ankles of these dancers. Movements such as pointe, demi-pointe, and en dehors, which are extremely common in ballet, have been identified in the research as positions that cause joint overload and micro-traumas in the knee and especially within the ankle (Costa et al., 2016). Chronic anterolateral foot pain, which is described as the "pinching of soft tissues that can result from repetitive microtrauma, causing hemorrhaging and scar remodeling of the capsule within the ankle", can also occur within ballet dancers (Rehmani et al., 2015). Those screening ballet dancers for ankle pathology risk should be aware of this overuse injury's presentation of focal tenderness of the lateral ankle and limitations in ankle dorsiflexion (Rehmani et al., 2015).

Overuse of structures within the knee joint has been shown in research to place the dancer at higher risk for ACL injury. The "increase in exposure to intense training and more frequent competition puts athletes at increased risk for suffering from overuse injuries because ample rest periods are not achieved" (Anderson, Browning, Urband, Kluczynski, & Bisson, 2016). Patellofemoral pain syndrome (PFPS) is also a prevalent overuse injury within the dancing population manifested as anterior knee pain (Halabchi, Mazaheri, & Seif-Barghi, 2013). Because every sport has different demands, each population has its own risks for overuse injuries; however, if the coaching staff and medical support teams are well-educated on presentation and onset, many overuse injuries can be addressed early on (Sabato et al., 2016).

There were four effective screening tools identified in the literature to assess overuse. There has been evidence to suggest that the single leg squat (SLS) is the one of the best tests to utilize while screening for PFPS and other compensatory movements, such as functional leg alignment. The thought behind the single leg squat, is that this position will normally elicit pain to the anterior knee and those with PFPS may demonstrate increased compensatory movements as well. Other tools recommended to screen for overuse or overuse associated injuries include vertical jumping, anteromedial lunge, and the step-down test. (Halabchi et al., 2013; Waryasz & McDermott, 2008).

4.4. Degree of turnout

Turnout is defined as the amount of external rotation within the lower extremity. Total limb turnout is a combination of the rotation at the hip, knee, and ankle joints. Each person has a set degree of turnout, based on the individual's anatomical bony structure and alignment, which is naturally restricted by different soft tissue structures within the joint such as the joint capsule. When the extremes of this natural restriction are repetitively stressed, the total amount of turnout increases placing athletes at increased risk for lower extremity injuries (Bhakay, Waghwani, & Kaur, 2016).

Research suggests that increased turnout is the most common problem within ballet (Sobrino et al., 2015). While the ability to have extensive external rotation is an essential component to the aesthetics of ballet dance, forcing the range of this motion stretches the capsular structures that can lead to painful injuries within the hip such as labral tears, ligament injury, and therefore instability (Rehmani et al., 2015).

Research states that excessive amounts of turnout lead to a tilting pelvis and sickling of the feet, thereby setting the dancer up for a multitude of lower extremity pathologies. When dancers are limited in the amount of ankle plantarflexion they can achieve, there is a higher risk for knee pathology, back pathology, and other injuries (Steinberg et al., 2012). Steinberg et al. identified that when a dancer is unable to achieve perfect turnout they will often compensate by “rotating the knees, everting the heels, pronating the feet, and increasing the lordosis of the spine” which significantly impacts the mechanics of the lower limb and lumbar spine predisposing the dancer for further injury of the spine and lower extremity (Steinberg et al., 2012).

Research by Jenkins et al. determined values of compensation and muscular activation for turnout and how these related to increased risk of sustaining an injury. Jenkins et al.‘s research showed, “dancers with an increased compensated turnout were 9% more at risk for sustaining an injury.” (Jenkins, Wyon, & Nevill, 2013).

The research identified 2 effective screening tools to assess turnout. Filipa and colleagues suggested measuring the Functional Turnout Angle (FTA). If there were deficits noted, they suggested screening those dancers using the Star Excursion Balance Test (SEBT) to assess their risk for lower extremity injury (Filipa, Smith, Paterno, Ford, & Hewett, 2013). Additionally, turnout and other techniques such as fondu and temps levé were analyzed with a 2D measurement of knee and pelvis angles. The authors reported that the knee angles between the fondu and temps levé were strongly associated and asymmetries in these movements could potentially lead to injury. It is well known that asymmetry is a large risk factor, especially for the lower extremity, therefore screening for asymmetry in a dancer's form may be beneficial (Bowerman, Whatman, Harris, & Bradshaw, 2013; Hoogenboom & Voight, 2015). Two screens used in conjunction with each other were passive hip external rotation and total passive turnout (TPT). The authors of the study reported that if there was a difference in passive hip external rotation compared to TPT, the dancer would be at a higher risk of injury (Jenkins et al., 2013; Steinberg et al., 2013).

4.5. Neuromuscular dysfunction

As a result of increased training time, fatigue, and overuse, many dancers begin to develop compensatory strategies to continue at elite performance levels (Steinberg et al., 2012).

Changes within the neuromuscular control of an athlete will play a significant role in their risk of injury. For ballet dancers, the type of ballet they are practicing and performing may play a role in their risk for injury. Research showed that injuries in male ballet dancers were related to mechanical overload in contemporary ballet, where as their female counterparts experienced more overuse injuries in classical ballet (Sobrino et al., 2015). Deficiencies in the neuromuscular control of a dancer will impact their musculoskeletal systems, up and down the kinematic chain from the foot through the upper extremity. Changes in the neuromuscular control of dancers have been shown to manifest as, “impaired movement detection and peroneal muscle response, impaired balance, postural control and joint position sense, slowed nerve conduction velocity, strength deficits, and decreased dorsiflexion range of motion” (Clark & Redding, 2012). One study showed, “18.9% of the injury mechanisms were related to landings from jumps with no differences between the sexes” (Smith et al., 2015). A second study revealed 8.7% of all injuries reported, were related to alignment issues, and landing and/or twisting mechanics were responsible for 6.5% of all injuries (DiPasquale et al., 2015). Steinberg et al. found that excessive external rotation at the lower extremity, as demonstrated in turnout, may cause shortening of the musculature responsible for externally rotating the hip and therefore cause local injuries and even back pain in young dancers from ages eight to sixteen (Steinberg et al., 2013).

The research identified six effective screening tools to assess neuromuscular dysfunction, which include the following: Heel Rise Test, Passive inversion joint position sense, prone hip extension, Active Straight Leg Raise (ASLR), and Rolling. Zellers et al. was able to identify a loading dysfunction from inefficient movement patterns via the Heel Rise Test (Zellers, van Ostrand, & Grävare Silbernagel, 2017). Not surprisingly, a small amount of variation from optimal plantar flexion repeated numerous times is likely to manifest in a number of ways and be successfully identified. Another measure that has been found useful in identifying potential source of injury is passive inversion joint position sense. A decrease in accuracy has been shown to be an injury risk factor in the female population according to a study by Fong et al. (Fong, Chan, Mok, Yung, & Chan, 2009).

Timing of muscle firing of the lumbopelvic hip complex can be screened with, prone hip extension. The authors suggest activation of the transverse abdominis and the gluteal muscles should occur prior to the activation of the biceps femoris. Inadequate or late firing of the transverse abdominis has been connected with chronic low back pain and accompanying hip joint pathology. The Sahrmann series has been deemed useful for assessing core stability (Turner, O’Sullivan, & Edelstein, 2012).An additional screen reported for pelvic and core stability was the active straight leg raise (ASLR). The ASLR specifically screens the ability of the multifidi and transversus abdominis to contribute to the force closure of the pelvis during active movement of the lower extremity (Turner et al., 2012). One of the more interesting screenings found throughout the research was the use of rolling. Rolling has been established as a way to assess different abilities such as crossing midline, weight shift, and coordination of extremities with the core during active movement. The dissociation of upper and lower extremities from one another, as well as the use of the athlete's core to initiate movement, can be difficult to learn. Using rolling as a screening tool could be beneficial because incorrect form can easily be detected and different forms of rolling itself can be used in training and rehabilitation. (Hoogenboom & Voight, 2015).

4.6. Range of motion discrepancies of the lower extremities

It is well known throughout the physical therapy and rehabilitation communities that range of motion about a joint, whether it be excesses of motion or limitations in motion, affects the athlete's overall function. In dancers, much of the research suggested that injuries occurring in the lower extremity up through to the spine,

are a result of range of motion discrepancies at the ankle and hip joints (Rehmani et al., 2015; Steinberg et al., 2011). Examples of these injuries included posterior impingement, different knee pathologies such as patellofemoral pain syndrome, and ankle tendinopathies. In regard to posterior impingement at the ankle, forced and continuous ankle plantarflexion causes encroachment of the posterior structures which can cause os trigonum syndrome, talar compression syndrome, and posterior block of the ankle, all of which can have serious side effects such as fracture leading to increased time away from dance (Rehmani et al., 2015). Other research has shown that decreased ankle plantarflexion has caused back injuries as well (Steinberg et al., 2012). Range of motion limitations within the hip such as discrepancies in hip abduction and even differences in hip external rotation side-to-side have been proven to be indicators for increased injury risk in ballet dancers. Paratenonitis has been linked to dancers who exhibit greater hip external rotation (Steinberg et al., 2011). Femoral acetabular impingement (FAI) has also been linked to excessive hip range of motion requirements as well as the high demands of muscular control and training duration common to ballet (Kivlan, Carcia, Clemente, Phelps, & Martin, 2013).

There are numerous simple tests that can be performed to assess for deficits in ROM. Ely's Test and Ober's Test were used in Waryasz and McDermott's research and have been used to detect for range of motion deficits (Waryasz & McDermott, 2008). Passive ankle dorsiflexion was also identified as a useful way to screen for potential injury risk especially in regard to the ACL. Researchers found that the increased passive dorsiflexion allowed for decreased ground reaction forces when landing from a jump (Fong, Blackburn, Norcross, McGrath, & Padua, 2011; Gamboa, Roberts, Maring, & Fergus, 2008; Steinberg et al., 2012).

An additional screening of ballet dancers' right foot pronation could be seen as beneficial. Research has shown there was a significant difference between the right foot pronation of injured versus non-injured dancers (Gamboa et al., 2008). The significance of the right foot pronation could be that this is commonly the dominant stance leg of most ballet dancers. This altered movement at the foot and ankle could disperse force unfavorable up the lower extremity into other joints.

Measurement of a dancer's passive end-range hip motion may be one of the most important screening tools according to Harris-Hayes and colleagues. (Harris-Hayes, Sahrmann, & Van Dillen, 2009; Steinberg et al., 2012). Hip internal rotation ROM difference of more than 15% between each side has been associated with double the risk of injury according to research by Davenport et al. (Davenport, Air, Grierson, & Krabak, 2016). By measuring and comparing bilateral hip internal rotation ROM, it may be possible to screen for those ballet dancers who may be at a higher risk of injury.

4.7. Weakness of lower extremity and/or core musculature

Weakness anywhere within the body will affect the way an athlete performs. In ballet, looking at weakness within the lower extremity and core musculature will allow healthcare professionals to determine which athletes may be at risk for injury (McCriskin et al., 2015). Muscle weakness and fatigue are shown to exacerbate any neuromuscular dysfunctions present within the athlete (McCriskin et al., 2015).

Ankle injuries have been discussed extensively among the other risk factors and the topic appears again in regard to the weakness risk factor. For those who have experienced previous ankle injury, a decrease in eversion and inversion strength, as well as plantarflexion strength, within the ankle, sets the athlete up for an additional ankle sprain in the future (Fong et al., 2011).

It has been shown that weakness around the hip joint is common in those with hip pain (Kivlan et al., 2013). Strength imbalances at the hip can lead to compensations the dancer develops in response to this weakness. As discussed previously, these compensations can set the dancer up for further injury. Looking at the specific musculature of the lower extremity in the sense of weakness, the gluteus maximus can act as a trunk/core stabilizer and decelerator of internal rotation (Carcia, Kivlan, & Scibek, 2011). If the gluteus maximus muscle is demonstrating weakness, it may be responsible for dancers who land in a more flexed posture with the femur internally rotated which over time will lead to multiple pathologies not only in the hip but throughout the kinematic chain of the lower extremity.

Weakness is an intrinsic modifiable risk factor which can easily be identified by both healthcare professionals and coaches through proper screening and subsequent strengthening of the weakened muscle or muscle groups. Screening for muscle weakness and comparing left to right sides has been shown to be a helpful way of identifying those at risk for injury. The One-legged Hop Test has been reported to be a reliable measure to screen for weakness of the VMO (Halabchi et al., 2013). Other hop tests that have been found useful in identifying potential injury risk factors include the medial triple hop, lateral triple hop, and crossover hop tests. These tests were performed in those with and without injury of the hip and they resulted in significant difference in the distances achieved (Kivlan et al., 2013). The authors of this content theorized that the eccentric and concentric control of the hip abductors is what allows such a significance between testable groups (Kivlan et al., 2013).

The Trendelenburg Test was also reported to have good sensitivity and specificity for detecting hip abductor and hip external rotator weakness in ballet dancers (Halabchi et al., 2013). By assessing for the ipsilateral “hip drop” associated with the Trendelenburg Test, it can be noted that the dancer may have weakness of the hip abductors and/or weakness of the hip external rotators to the ipsilateral side. There has also been an association between dorsiflexor weakness and increased risk of injury. This risk has been correlated more strongly in males than females, however quantifying the measurement with a hand-held dynamometer or other device is something to consider, especially when discussing inversion ankle sprains (Fong et al., 2009).

4.8. Screening

Screening processes, whether during pre-season or mid-season, are an important part of maintaining athletes', especially ballet dancers', health. These screens should be completed on each dancer in a systematic and thorough manner in order for a comprehensive injury risk assessment to be formulated (Liederbach, Hagins, Gamboa, & Welsh, 2012). Through this literature review, there have been an extensive number of tests, measures, and screening tools recommended and deemed useful. Many of them are beneficial in identifying risk factors for injury and assessing quality of movement. There are varying degrees of evidence and varying reasons to administer each one, but there is at least relatively recent data to support them. Because it is not realistic to be able to administer all of these tests and screens on every ballet dancer, the authors of this literature review wanted to assemble a short battery of tests that health professionals could quickly complete to screen for injury risks or any of the intrinsic modifiable risk factors listed above. The Movement Competency Screening (MCS) is a combination of 5 movements, including the single leg squat, and 3 dynamic jumping movements and is based off the Functional Movement Screening (FMS), which has strong evidence supporting its ability to identify those at risk for lower extremity injury (Chimera, Smith, & Warren, 2015; Lee, Reid, Cadwell, & Palmer,

2017). Because the MCS incorporates aspects of several other tests that have been shown to assist in identifying risk factors, and its specific designation for dancers, the authors recommend including it within the battery of tests completed during a pre-season or while assessing for injury risk. Utilizing the Beighton Hypermobility Scale in a generalized screening process is advised (Waryasz & McDermott, 2008). It can quantify the degree of hypermobility that is possessed by each dancer, which can be equated to their risk for injury (Barber Foss et al., 2009). Rolling is another functional test that should be incorporated in the screening process. Its ability to detect compensation, neuromuscular dysfunction, as well as the ability to easily include it as a part of an exercise program shows its utility and practicality. The SEBT is a tool that should be strongly considered when screening ballet dancers as well. Not only will the test give numerical data on the inequalities of the dancers' movements, but it can also help to identify faulty movement patterns. Utilizing some form of fatigue protocol such as the FAST-FP would be highly recommended by the authors to examine how a dancer's form may change when they are fatigued. The final screening tools that should be included are a combination of passive hip external rotation measurement compared with the Total Passive Turnout (TPT) of the ballet dancer. The combination of these tools cover many of the aspects of the intrinsic modifiable risk factors that were identified throughout the research. With this collection of screening tools, a healthcare provider and the instructors should be able to determine what (if/any) risk factors a ballet dancer possess. At that point, it is the responsibility of the staff and dancer to address these deficits and make corrections to their training, which is an aspect this literature review does not address.

As stated in the introduction, the identification of potential screening tools is the secondary purpose of this literature review. It should be mentioned again that the specific psychometrics of these tests and their application to the ballet dancer population is outside the scope of this review and further investigation on this topic is needed. The sports medicine professional treating this group of athletes should proceed with caution in the use of these tests until further research is done on their reliability and predictive validity.

5. Limitations

This study had multiple limitations that should be addressed in further research. During this literature search, there were no specific criteria defined for “injury” that were used or established by the authors. No operational definition of an injury had been established in the studies reviewed; therefore, there were varying definitions which may have skewed some of the results of the literature review. Another limitation is the absence of the definition of a professional dancer. The research found no definition that differentiates dancers who are considered amateur or pre-professional from those who are considered professional. Any injuries associated with psychological or nutritional factors were not included in this literature review. The need for further investigation of the reliability, predictive validity and other psychometrics of the identified screening tools and tests is another limitation.

Ethical approval

Not applicable.

Conflicts of interest

There have not been any aspects of this literature review that have been identified or declared.

Funding

There were no sources of funding for this literature review.

6. Conclusion

This literature review identified seven different intrinsic modifiable risk factors commonly present in the ballet dancer population to be hypermobility, fatigue, overuse, neuromuscular dysfunction, core and lower extremity weakness, and range of motion limitations. Following the identification of these risk factors, seven screening tools were determined to be adequate for instructors and health professionals to utilize in order to identify dancers who are at increased risk for injury. Through the identification of the dancers at risk, rehabilitation and exercise programs can be implemented by strength and conditioning staff to address the deficits found. More research must be completed to determine if this battery of screening tools chosen by the authors is proficient in identifying the intrinsic modifiable risk factors listed, as well as others that were not discussed in this literature review. Based on the findings of this literature review, the sports medicine professionals are now in the position to proactively initiate evidence-based prevention programs, as well as help establish discharge criteria post-rehabilitation.

Appendix 1

Exclusion Criteria
Not within 10 years of publication
Full text not available
Not available in English
Not peer reviewed
Did not address injury risk factors
Did not identify screening tools for injury risk factors
Did not meet levels of evidence I–V

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2019.04.022.

References

Anderson, M. J., Browning, W. M., Urband, C. E., Kluczynski, M. A., & Bisson, L. J. (2016). A systematic summary of systematic reviews on the topic of the anterior cruciate ligament. *Orthopaedic Journal of Sports Medicine, 4*(3). https://doi.org/10.1177/2325967116634074, 2325967116634074.

Bahr, R., & Krosshaug, T. (2005). Understanding injury mechanisms: A key component of preventing injuries in sport. *British Journal of Sports Medicine, 39*, 324–329. https://doi.org/10.1136/bjsm.2005.018341.

Barber Foss, K. D., Ford, K. R., Myer, G. D., & Hewett, T. E. (2009). Generalized joint laxity associated with increased medial foot loading in female athletes. *Journal of Athletic Training, 44*(4), 356–362.

Bhakay, M., Waghwani, V., & Kaur, A. (July-Sept. 2016). Relationship between Ballet Dancer Turnout and Self Reported Lower Limb Injuries. *Indian Journal of Physiotherapy and Occupational Therapy - An International Journal, 10*(3), 151–156.

Bowerman, E., Whatman, C., Harris, N., & Bradshaw, E. (2013). Reliability of 2D lower extremity alignment measures in elite adolescent ballet dancers. *New Zealand Journal Of Sports Medicine, 40*(2), 70–73 [serial online]. December Available from: SPORTDiscus with Full Text, Ipswich, MA . (Accessed 28 September 2017).

Bowerman, E. A., Whatman, C., Harris, N., & Bradshaw, E. (2015). A review of the risk factors for lower extremity overuse injuries in young elite female ballet dancers. *Journal of Dance Medicine & Science: Official Publication Of The International Association For Dance Medicine & Science, 19*(2), 51–56. https://doi.org/10.12678/1089-313X.19.2.51.

Bronner, S., Codman, E., Hash-Campbell, D., & Ojofeitimi, S. (March 2016). Differences in preseason aerobic fitness screening in professional and pre-professional modern dancers. *Journal of Dance Medicine and Science: Official Publication Of The International Association For Dance Medicine & Science [serial online], 20*(1), 11–22. Available from: MEDLINE Complete, Ipswich, MA . (Accessed 28 September 2017).

Carcia, C. R., Kivlan, B., & Scibek, J. S. (2011). The relationship between lower extremity closed kinetic chain strength & sagittal plane landing kinematics in female athletes. *International Journal of Sports Physical Therapy, 6*(1), 1–9.

Chimera, N. J., Smith, C. A., & Warren, M. (2015). Injury history, sex, and performance on the functional movement screen and Y balance test. *Journal of Athletic Training, 50*(5), 475–485. https://doi.org/10.4085/1062-6050-49.6.02.

Clark, T., & Redding, E. (2012). The relationship between postural stability and dancer's past and future lower-limb injuries. Medical Problems of Performing Artists [serial online]. *27*(4), 197–204. December Available from: MEDLINE Complete, Ipswich, MA . (Accessed 28 September 2017).

Costa, M. S. S., Ferreira, A. S., Orsini, M., Silva, E. B., & Felicio, L. R. (2016). Characteristics and prevalence of musculoskeletal injury in professional and non-professional ballet dancers. *Brazilian Journal of Physical Therapy, 20*(2), 166–175. https://doi.org/10.1590/bjpt-rbf.2014.0142.

Davenport, K., Air, M., Grierson, M., & Krabak, B. (November 2016). Examination of static and dynamic core strength and rates of reported dance related injury in collegiate dancers. *Journal Of Dance Medicine & Science [serial online], 20*(4), 151–161. Available from: SPORTDiscus with Full Text, Ipswich, MA . (Accessed 28 September 2017).

De la Motte, S., Arnold, B. L., & Ross, S. E. (2015). Trunk-rotation differences at maximal reach of the star excursion balance test in participants with chronic ankle instability. *Journal of Athletic Training, 50*(4), 358–365. https://doi.org/10.4085/1062-6050-49.3.74.

DiPasquale, S., Becker, N., Green, S., & Sauers, K. (December 2015). Self-reported injury and management in a liberal arts college dance department. *Medical Problems Of Performing Artists [serial online], 30*(4), 224–230. Available from: MEDLINE Complete, Ipswich, MA . (Accessed 28 September 2017).

Filipa, A., Smith, T., Paterno, M., Ford, K., & Hewett, T. (November 2013). Performance on the star excursion balance test predicts functional turnout angle in pre-pubescent female dancers. *Journal Of Dance Medicine & Science [serial online], 17*(4), 165–169. Available from: SPORTDiscus with Full Text, Ipswich, MA . (Accessed 28 September 2017).

Fong, C.-M., Blackburn, J. T., Norcross, M. F., McGrath, M., & Padua, D. A. (2011). Ankle-dorsiflexion range of motion and landing biomechanics. *Journal of Athletic Training, 46*(1), 5–10. https://doi.org/10.4085/1062-6050-46.1.5.

Fong, D. T., Chan, Y.-Y., Mok, K.-M., Yung, P. S., & Chan, K.-M. (2009). Understanding acute ankle ligamentous sprain injury in sports. *Sports Medicine, Arthroscopy, Rehabilitation, Therapy and Technology: SMARTT, 1*, 14. https://doi.org/10.1186/1758-2555-1-14.

Gamboa, J., Roberts, L., Maring, J., & Fergus, A. (March 2008). Injury patterns in elite preprofessional ballet dancers and the utility of screening programs to identify risk characteristics. *The Journal Of Orthopaedic And Sports Physical Therapy [serial online], 38*(3), 126–136. Available from: MEDLINE Complete, Ipswich, MA . (Accessed 28 September 2017).

Groh, M. M., & Herrera, J. (2009). A comprehensive review of hip labral tears. *Current Reviews in Musculoskeletal Medicine, 2*(2), 105–117. https://doi.org/10.1007/s12178-009-9052-9.

Guddal, M. H., Stensland, S.Ø., Småstuen, M. C., Johnsen, M. B., Zwart, J.-A., & Storheim, K. (2017). Physical activity level and sport participation in relation to musculoskeletal pain in a population-based study of adolescents: The young-HUNT study. *Orthopaedic Journal of Sports Medicine, 5*(1). https://doi.org/10.1177/2325967116685543, 2325967116685543.

Halabchi, F., Mazaheri, R., & Seif-Barghi, T. (2013). Patellofemoral pain syndrome and modifiable intrinsic risk factors; how to assess and address? *Asian Journal of Sports Medicine, 4*(2), 85–100.

Harris-Hayes, M., Sahrmann, S. A., & Van Dillen, L. R. (2009). Relationship between the hip and low back pain in athletes who participate in rotation-related sports. *Journal of Sport Rehabilitation, 18*(1), 60–75.

Hoogenboom, B. J., & Voight, M. L. (2015). Rolling revisited: Using rolling to assess and treat neuromuscular control and coordination of the core and extremities of athletes. *International Journal of Sports Physical Therapy, 10*(6), 787–802.

Jacobs, C., Hincapié, C., & Cassidy, J. (2012). Musculoskeletal injuries and pain in dancers: A systematic review update. *Journal of Dance Medicine and Science: Official Publication Of The International Association For Dance Medicine & Science [serial online], 16*(2), 74–84. Available from: MEDLINE Complete, Ipswich, MA . (Accessed 28 September 2017).

Jenkins, J., Wyon, M., & Nevill, A. (2013). Can turnout measurements be used to predict physiotherapist-reported injury rates in dancers? Medical problems of performing artists [serial online]. *28*(4), 230–235. December Available from: MEDLINE Complete, Ipswich, MA . (Accessed 28 September 2017).

Kenney, S. J., Whittaker, J. L., & Emery, C. A. (2015). Risk factors for musculoskeletal injury in preprofessional dancers: A systematic review. *November, 0*, 1–8. https://doi.org/10.1136/bjsports-2015-095121.

Kim, S.-J., Kumar, P., & Kim, S.-H. (2010). Anterior cruciate ligament reconstruction in patients with generalized joint laxity. *Clinical Orthopaedic Surgery, 2*(3), 130–139. https://doi.org/10.4055/cios.2010.2.3.130.

Kivlan, B. R., Carcia, C. R., Clemente, F. R., Phelps, A. L., & Martin, R. L. (2013). Reliability and validity of functional performance tests in dancers with hip dysfunction. *International Journal of Sports Physical Therapy, 8*(4), 360–369.

Lee, L., Reid, D., Cadwell, J., & Palmer, P. (June 2017). Injury incidence, dance exposure and the use of the movement competency screen (mcs) to identify variables associated with injury in full-time pre-professional dancers. *International Journal Of Sports Physical Therapy [serial online], 12*(3), 352–370. Available from: SPORTDiscus with Full Text, Ipswich, MA . (Accessed 28 September 2017).

Lehr, M. E., Kime, D., Onks, C., Silvis, M., & Streisel, M. (2017). Development of a preliminary evidence-based neuromusculoskeletal exercise guideline to reduce injury risk in the lower limb. *Physical Therapy in Sport, 25*, 76–83. https://doi.org/10.1016/j.ptsp.2016.08.012.

Liederbach, M., Hagins, M., Gamboa, J., & Welsh, T. (November 2012). Assessing and reporting dancer capacities, risk factors, and injuries: Recommendations from the IADMS standard measures consensus initiative. *Journal Of Dance Medicine & Science [serial online], 16*(4), 139–153. Available from: SPORTDiscus with Full Text, Ipswich, MA . (Accessed 28 September 2017).

Mandarakas, M., Pourkazemi, F., Sman, A., Burns, J., & Hiller, C. E. (2014). Systematic review of chronic ankle instability in children. *Journal of Foot and Ankle Research, 7*, 21. https://doi.org/10.1186/1757-1146-7-21.

McCriskin, B. J., Cameron, K. L., Orr, J. D., & Waterman, B. R. (2015). Management and prevention of acute and chronic lateral ankle instability in athletic patient populations. *World Journal of Orthopedics, 6*(2), 161–171. https://doi.org/10.5312/wjo.v6.i2.161.

Quammen, D., Cortes, N., Van Lunen, B. L., Lucci, S., Ringleb, S. I., & Onate, J. (2012). Two different fatigue protocols and lower extremity motion patterns during a stop-jump task. *Journal of Athletic Training, 47*(1), 32–41.

Rehmani, R., Endo, Y., Bauman, P., Hamilton, W., Potter, H., & Adler, R. (2015). Lower extremity injury patterns in elite ballet dancers: Ultrasound/MRI imaging features and an institutional overview of therapeutic ultrasound guided percutaneous interventions. *HSS Journal, 11*(3), 258–277. https://doi.org/10.1007/s11420-015-9442-z.

Ruemper, A., & Watkins, K. (November 2012). Correlations between general joint hypermobility and joint hypermobility syndrome and injury in contemporary dance students. *Journal Of Dance Medicine & Science [serial online], 16*(4), 161–166. Available from: SPORTDiscus with Full Text, Ipswich, MA . (Accessed 28 September 2017).

Sabato, T. M., Walch, T. J., & Caine, D. J. (2016). The elite young athlete: Strategies to ensure physical and emotional health. *Open Access Journal of Sports Medicine, 7*, 99–113. https://doi.org/10.2147/OAJSM.S96821.

Scheper, M. C., de Vries, J. E., Juul-Kristensen, B., Nollet, F., & Engelbert, R hh (2014). The functional consequences of generalized joint hypermobility: A cross-sectional study. *BMC Musculoskeletal Disorders, 15*, 243. https://doi.org/10.1186/1471-2474-15-243.

Smith, P. J., Gerrie, B. J., Varner, K. E., McCulloch, P. C., Lintner, D. M., & Harris, J. D. (2015). Incidence and prevalence of musculoskeletal injury in ballet: A systematic review. *Orthopaedic Journal of Sports Medicine, 3*(7). https://doi.org/10.1177/2325967115592621, 2325967115592621.

Sobrino, F. J., de la Cuadra, C., & Guillén, P. (2015). Overuse injuries in professional ballet: Injury-based differences among ballet disciplines. *Orthopaedic Journal of Sports Medicine, 3*(6). https://doi.org/10.1177/2325967115590114, 2325967115590114.

Steinberg, N., Hershkovitz, I., Peleg, S., Dar, G., Masharawi, Y., & Siev-Ner, I. (December 2011). Paratenonitis of the foot and ankle in young female dancers. *Foot & Ankle International [serial online], 32*(12), 1115–1121. Available from: MEDLINE Complete, Ipswich, MA . (Accessed 28 September 2017).

Steinberg, N., Siev-ner, I., Hershkovitz, I., et al. (March 2012). Extrinsic and intrinsic risk factors associated with injuries in young dancers aged 8–16 years. *Journal Of Sports Sciences [serial online], 30*(5), 485–495. Available from: SPORTDiscus with Full Text, Ipswich, MA . (Accessed 28 September 2017).

Steinberg, N., Siev-Ner, I., Peleg, S., et al. (2013). Injuries in female dancers aged 8 to 16 years. *Journal of Athletic Training, 48*(1), 118–123. https://doi.org/10.4085/1062-6050-48.1.06.

Turner, R., O'Sullivan, E., & Edelstein, J. (2012). Hip dysplasia and the performing arts: Is there a correlation? *Current Reviews in Musculoskeletal Medicine, 5*(1), 39–45. https://doi.org/10.1007/s12178-011-9104-9.

Twitchett, E., Angioi, M., Koutedakis, Y., & Wyon, M. (2010). The demands of a working day among female professional ballet dancers. *Journal of Dance Medicine and Science, 14*(4), 127–132.

Waryasz, G. R., & McDermott, A. Y. (2008). Patellofemoral pain syndrome (PFPS): A systematic review of anatomy and potential risk factors. *Dynamic Medicine: DM., 7*, 9. https://doi.org/10.1186/1476-5918-7-9.

Zellers, J., van Ostrand, K., & Grävare Silbernagel, K. (May 2017). Calf endurance and achilles tendon structure in classical ballet dancers. *Journal Of Dance Medicine & Science [serial online], 21*(2), 64–69. Available from: SPORTDiscus with Full Text, Ipswich, MA . (Accessed 28 September 2017).