

INJURY PREVENTION AND PHYSIOTHERAPY PROCEDURES FOR ANKLE INJURIES IN BALLET DANCERS: A LITERATURE REVIEW

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ABSTRACT

The aim of this study was to investigate the most frequent, effective and up-to-date injury prevention and physiotherapy procedures used in relation to ballet dancers' ankle injuries. A literature review with a qualitative analysis was performed using the following databases: PubMed, SAGE, ScienceDirect, PlosOne and Cochrane Library. The inclusion criteria were: both genders, age > 18, journal impact factor > 0, age of study ≤ 10 years and the following search keywords were used: "ankle", "injury", "ballet", "dancers", "physiotherapy", "physical therapy" and "prevention". A total of 520 articles were found, out of which six were determined to be appropriate according to the inclusion and exclusion criteria. They dealt with the prevention/rehabilitation of ankle sprains (N=2), tendinopathy of the Achilles tendon (N=2), tendinitis of the m. hallucis longus (N=4), rupture of the Achilles tendon (N=2), and anterior (N=3) and posterior (N=4) impingement syndrome. It was found that for injury prevention in ballet, strengthening and stretching exercises are the most often used methods, while rest, ice therapy, muscle strengthening exercises, foot braces and dance technique optimisation are the most frequently used methods in injury management. These seem to also be the most up-to-date injury prevention and physiotherapy procedures, while the most effective procedures could not be retrieved due to a lack of relevant studies, which prevented the quantitative comparison of their effectiveness. The published clinical evidence endorses physiotherapy/kinesiotherapy as an effec-

tive ankle injury prevention and management modality in ballet dancers, although additional studies with a better quality of methodology are required.

Keywords: *rehabilitation, ballet, ankle, injury, physiotherapy, prevention*

PREVENTIVNA VADBA IN FIZIOTERAPEVTSKI POSTOPKI PRI POŠKODBAH GLEŽNJA BALETNIH PLESALCEV: PREGLED LITERATURE

IZVLEČEK

Cilj študije je bil raziskati najpogostejše, najučinkovitejše in najsodobnejše preventivne in fizioterapevtske postopke pri poškodbah gležnja baletnih plesalcev. Pregled literature s kvalitativno analizo je bil opravljen s pomočjo naslednjih podatkovnih baz: PubMed, SAGE, ScienceDirect, PlosOne in Cochrane Library. Pri tem smo uporabili naslednje vključitvene kriterije: oba spola, starost > 18 let, faktor vpliva publikacije > 0, starost študije ≤ 10 let ter naslednje iskalne ključne besede: »ankle«, »injury«, »ballet«, »dancers«, »physiotherapy«, »physical therapy« in »prevention«. Skupno smo našli 520 člankov, izmed katerih je bilo glede na vključitvene in izključitvene kriterije primernih 6 člankov. Ti so obravnavali preventivo/rehabilitacijo zvina gležnja (N=2), tendinopatijo Ahilove tetive (N=2), tendinitis m. hallucis longus (N=4), rupturo Ahilove tetive (N=2) ter anteriorni (N=3) in posteriorni (N=4) utesnitveni sindrom. Ugotovili smo, da se v preventivne namene najpogosteje uporabljajo krepilne in raztezne vaje, za fizioterapevtsko obravnavo poškodb pa počitek, terapija z ledom, vaje za krepitev mišic, nožne opornice in optimiziranje plesne tehnike. Slednji so kot kaže tudi najsodobnejši preventivni in fizioterapevtski postopki, medtem ko najučinkovitejših preventivnih in fizioterapevtskih postopkov ni bilo mogoče izluščiti, saj je bilo premalo študij za kvantitativno primerjavo učinkovitosti med postopki, kar nakazuje potrebo in možnosti za nadaljnje raziskovanje. Objavljeni klinični dokazi potrjujejo, da je fizioterapija/kinezioterapija učinkovito preventivo in kurativno sredstvo pri poškodbah gležnja baletnih plesalce, čeprav so potrebne dodatne študije z bolj kakovostno metodologijo.

Ključne besede: *rehabilitacija, balet, gleženj, poškodba, fizioterapija, preventiva poškodb*

INTRODUCTION

Classical ballet is considered a high-performance dance art form that requires an advanced level of technical skills (Campbell, Lehr, Livingston, McCurdy, & Ware, 2019). It demands from the dancer a similar level of development of motor and functional abilities and physiological characteristics as some top athletes have. Due to strict schedules and repetitive movements during exercise, training sessions and performances, where specific ballet movements are often performed with large amplitudes and in extreme positions at the limits of the range of motion, where muscles, tendons and other passive structures are weaker and thus more prone to injuries, ballet dancers experience relatively large loads on joints, muscles, tendons and ligaments. Therefore, they have an increased chance of acute and chronic injuries (Bickle, Deighan, & Theis, 2018; Leanderson et al., 2011; Nunes et al., 2019). Ballet dancers can jump up to 200 times in an hour and a half. The force acting on the lower limbs during jumps can represent up to 12 times their body weight, which increases the risk of injury to the lower limbs, especially the ankle (Steinberg et al., 2018).

Previous research has shown that the lower extremities account for the largest share (77%) of ballet dancer injuries (Bickle et al., 2018; Leanderson et al., 2011; Rietveld, 2013; Nunes et al., 2019). More specifically, ankle injuries account for up to 33% of all injuries (Ekegren, Quedsted, & Brodrick, 2014) in ballet, which, according to most authors, is also the most frequently injured body part in rhythmic gymnastics (Meeusen & Borms, 1992). In ballet, the most common of these injuries is the lateral sprain, which most often occurs during the landing phase or when rising to the tips of the toes, when the foot is less stable (Morton, 2013). In addition to ankle sprains, the following are common ankle injuries: fractures, Achilles tendinopathy, Achilles tendon ruptures, posterior and anterior impingement syndromes, and m. flexor hallucis longus tendinitis (Kadel, 2014; Morton, 2013). A meta-analysis by Doherty et al. (2014) found that the female gender is a risk factor for lateral ankle sprain (LAS), with a cumulative incidence rate for females of 13.6 per 1000 exposures (95% CI: 13.25, 13.94). Conflicting evidence exists that previous LAS elevates risk for a subsequent LAS (Vuurberg et al. 2018). There is also conflicting evidence on the role of injury severity in the clinical course after a LAS, as well as weak evidence for primary injury prevention regarding the use of prophylactic balance training exercises in individuals who have not experienced a first-time LAS (Martin et al. 2021). Regarding the secondary prevention of recurrent LAS following an initial sprain, there is strong evidence that physiotherapists should use proprioceptive and balance-focused therapeutic exercise training programmes to address impairments identified during physical examination to reduce the risk of a subsequent injury in patients with a first-time LAS (Martin et al. 2021), yet there is a lack of evidence for the use of these interventions for ballet dancers. Vuurberg and colleagues (2018) reported that while there is evidence to support the use of exercises to prevent recurrent sprains, there is a lack of evidence to support the use of prophylactic exercises to prevent first-time ankle sprains and a lack of evidence to support the use of these interventions in professional ballet dancers. According to Vera

and colleagues (2020), their randomised controlled investigation of an injury prevention programme was the first of its kind for professional ballet dancers. Due to the high incidence of ankle injuries (Bickle et al., 2018; Ekegren et al., 2014; Leanderson et al., 2011; Rietveld, 2013; Nunes et al., 2019) and based on current Clinical Practice Guidelines (CPG) (Martin et al., 2021) there is conflicting evidence as to the best way to augment the components of rehabilitation programmes (e.g. by written instructions, exercise-based videos or app-based instruction) in patients with acute and post-acute ankle sprains and other injuries. The physiotherapist should determine what actions to take according to the individual's specific motor and functional abilities, learning needs and access to relevant treatment options such as proprioceptive and neuromuscular therapeutic exercises in order to improve dynamic ankle stability and patient-perceived stability during function (ballet training sessions and performances) in individuals with chronic ankle instability (CAI) in order to prevent further injuries. Although the CPG describe evidence-based physiotherapy practice, including diagnosis, prognosis, intervention, and assessment of the outcome of patients with ankle injuries commonly managed by orthopaedic or sports physiotherapists, there is a lack of evidence for the use of these approaches for professional ballet dancers due to extremely high demands on dynamic ankle stability. As Biernacki, Stracciolini, Fraser, Micheli, & Sugimoto (2018) established, there is no consensus in the literature regarding risk factors for ballet-related injury in females, despite the high prevalence of dance injuries among this group. This may stem from methodological inconsistencies including a lack of standard definition of injury, time loss and medical attention, and limited high-quality original studies. In the previous systematic reviews of studies which assessed the effects of the therapeutic alliance on the effectiveness of primary and secondary prevention strategies for ankle injuries there is a lack of evidence pertaining to the therapeutic alliance in rehabilitation of musculoskeletal conditions (Doherty et al., 2014; Vuurberg et al., 2018). Due to the heterogeneity of impairments and activity limitation experienced by individuals with LAS and CAI, methods should be tailored to the specific needs of the patient. Furthermore, intrinsic and environmental factors that mediate outcomes should also be addressed when prescribing treatments for individuals with LAS and CAI (Martin et al., 2021).

Therefore, it was the aim of this study to determine, through a literature review, the most up-to-date, most common and most effective prevention and physiotherapy procedures for ballet dancers' ankle injuries. Based on this, the following two research questions were posed: i) *“What are the state-of-the-art physiotherapy treatments for ankle injuries in ballet dancers?”* and ii) *“What are the most common and the most effective prevention procedures for ankle injuries in ballet dancers?”*

METHODS

Procedures

In this literature review, a qualitative research method was used. A compilation method was used to collect the most relevant original scientific and review articles and to describe and summarise their findings. The method of analysis and synthesis was used to analyse and integrate the facts already known in order to deepen the knowledge of the problem we identified in this literature review. The method of comparison was used to compare the different findings and conclusions of the collected articles in an attempt to arrive at the most common, effective and up-to-date preventive and physiotherapeutic procedures in the management of various ankle injuries in ballet dancers. The conclusion and findings were thus formulated using the method of deduction.

In the introduction, the known facts were described and the key concepts, problem, aim and research questions were defined based on a review of domestic and international literature as well as based on our professional experience in the field of classical ballet. The literature review was performed using the following specialised scientific databases: PubMed, SAGE, ScienceDirect, PlosOne and Cochrane Library, and the following keywords: “ankle”, “injury”, “ballet”, “dancers”, “physiotherapy”, “physical therapy” and “prevention”.

The search syntax was performed in four stages, using four combinations of keywords (search strings). The first search string was related to rehabilitation with the following combination of keywords used in all databases: “rehabilitation” AND “ballet” AND “dancers” AND “ankle” AND “injury”, while the second one was related to prevention and was also used in all databases with the following keywords combination: “prevention” AND “ballet” AND “dancers” AND “ankle” AND “injury”. Since there were no hits in the Cochrane Library using the previous two search strings, the next two were used in the Cochrane Library only, first “ballet” AND “injury” AND “prevention” and then “ballet” AND “dancer” AND “ankle” (Table 1).

The literature review included articles that dealt with professional ballet dancers over the age of 18, to avoid the influence of growth and development on the results. The focus was on the most up-to-date, most common and most effective prevention and physiotherapy procedures for ballet dancers’ ankle injuries. All articles were first evaluated for adequacy based on title, then based on the abstract, then based on a quick full-text overview and finally based on the following specific inclusion and exclusion criteria. The inclusion criteria were: i) both genders, ii) age of dancers > 18 years, iii) professional ballet dancers with ankle injuries in rehabilitation, iv) prevention exercise for ankle injuries, v) age of the study ≤ 10 years, vi) publication impact factor > 0, and vii) articles accessible in full-text, while the exclusion criteria were other injuries of ballet dancers and/or no physiotherapy treatment and/or without ankle injury prevention exercises.

Data analysis

To facilitate editing and data collection, Microsoft Office Excel 2016 (Microsoft Corporation, New York, USA) was used and the results were presented with the help of tables and diagrams. The search process and the final selection of articles was performed and presented using the PRISMA diagram (Page et al. 2021). Also presented are all the physiotherapy procedures discussed in the studies. The content and characteristics of the studies found in the field of prevention exercises and physiotherapy for ankle injuries were qualitatively analysed and described in detail. On this basis, guidelines and practical examples of exercises and training methods for prevention of ankle injuries in ballet dancers were prepared.

RESULTS

Results of the search and selection procedure of articles

Based on search keywords and their combinations (search strings) in connection with ballet and ankle injuries of ballet dancers, we found a total of 520 articles in the research databases. Out of these, 30 were repeated in different databases, which gave a final total number of 490 articles. Of these, 130 matched by title, 60 by abstracts and 33 by quick full-text overview. Finally, there were 6 full-text articles on the defined topic matching also the inclusion and exclusion criteria. An overview of the search and selection procedure is presented in the PRISMA diagram in Figure 1, while the extended and detailed search results for individual databases using different search strings (syntaxes) are presented in Table 1. An overview of the finally selected articles' titles, journals' impact factors, field of study and injuries considered are shown in Table 2.

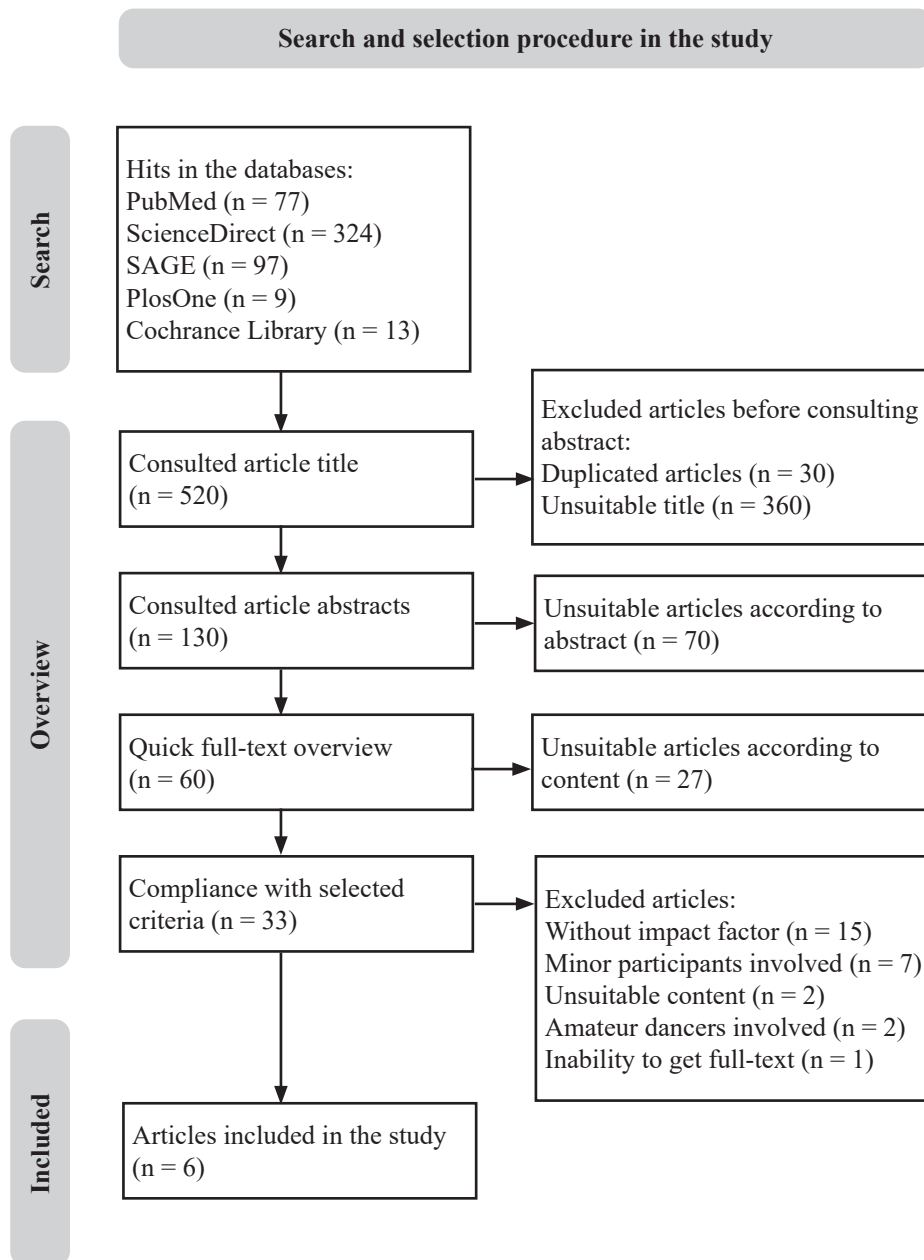


Figure 1: Search and selection procedure for the literature review

Table 1: Detailed search results across databases using different search strings (syntaxes)

No.	Search strings	Database	Total hits	Suitable articles by title	Duplicated articles	Suitable articles by title	Suitable articles by quick full-text overview	Suitable articles by impact factor	Suitable articles by the criteria and full-text
1	"rehabilitation" and "ballet" and "dancers" and "ankle" and "injury"	SAGE	42	7	1	5	5	0	0
		ScienceDirect	205	54	11	6	2	0	0
		Pubmed	31	17	0	14	8	6	3
		PlosOne	0	0	0	0	0	0	0
		Cochrane Library	0	0	0	0	0	0	0
			278	78	12	25	15	6	3
2	"prevention" and "ballet" and "dancers" and "ankle" and "injury"	SAGE	55	17	8	4	4	0	0
		ScienceDirect	119	34	3	13	5	2	1
		Pubmed	46	22	6	13	6	7	1
		PlosOne	9	2	0	1	1	0	0
		Cochrane Library	0	0	0	0	0	0	0
			229	75	17	31	16	9	2
3	"ballet" and "injury" and "prevention"	Cochrane Library	6	2	0	2	1	1	1
			6	2	0	2	1	1	1
4	"ballet" and "dancer" and "ankle"	Cochrane Library	7	5	1	2	1	2	0
			7	5	1	2	1	2	0
TOTAL			520	160	30	60	33	18	6

Table 2: Finally selected articles' titles, journals' impact factors, field of study, injuries considered and summary of studies' results

No.	Author (year of publication)	Title	Impact factor	Article type	Field of study (prevention, injury, rehabilitation)	Results	Ankle sprain	Ankle fracture	Achilles tendinopathy	Rupture of Achilles tendon	Posterior impingement syndrome	Anterior impingement syndrome	Tendinitis of flexor hallucis longus
1	Vera et al. (2020)	An Injury Prevention Program for Professional Ballet	2.492	Clinical study	Prevention (dance-specific injury prevention programme) injury	82% decrease in injury rate for the intervention group and an extended period from previous injury to subsequent injury. 1. Any injury to the foot and ankle will have a ripple effect further up the kinetic chain. 2. Any clinical examination should involve a global perspective. 3. Correct early diagnosis and treatment is vital to their physical, psychological and financial well-being. 4. When treating a dancer, the clinician should also be aware of the high tolerance for pain in this elite group of athletes.	x		x	x			x
2	Morton (2013)	The virtuoso foot	1.774	Review	rehabilitation				x	x			x
3	Rietveld (2013)	Dancers and musicians' injuries	1.774	Review	injury rehabilitation	1. Unilaterally painful arabesque is a spondylolysis / stress fracture of the vertebral arch until proven otherwise. 2. Posterior ankle impingement, with or without tenovaginitis of the m. flexor hallucis longus is the most common dancers' injury. 3. The rule of thumb is to not operate on a hallux valgus in an active dancer or dance-teacher.					x		x

No.	Author (year of publication)	Title	Impact factor	Article type	Field of study (prevention, injury, rehabilitation)	Results	Ankle sprain	Ankle fracture	Achilles tendinopathy	Rupture of Achilles tendon	Posterior impingement syndrome	Anterior impingement syndrome	Tendinitis of flexor hallucis longus
4	Vosseller et al. (2019)	Ankle Injuries in Dancers	2.286	Review	injury rehabilitation	<p>Results</p> <p>1. A team approach to treatment with knowledgeable physical therapists can obviate the need for surgical treatment. 2. If surgical treatment proves necessary, good results can be achieved with sound surgical technique and a well-thought-out rehabilitation programme.</p> <p>1. To keep dancers healthy, the health care team and the dancer must work together. 2. The physician must be an advocate for the dancer and work to provide an accurate diagnosis and an effective treatment strategy. 3. Monitoring performance and rehearsal load, fitness, and general health of the dancer will help to maximise the dancer's healing potential. 4. Correction of muscle imbalances, attention to proper technique, sequential skill progression, and proper shoe fit may help limit acute injuries to the dancer. 5. Creativity is needed to modify treatment plans to accommodate the dancer's need to maintain strength, flexibility, and fitness during recovery.</p>	x					x	
5	Kadel (2014)	Foot and Ankle Problems in Dancers	0.930	Review	injury rehabilitation	<p>Results</p> <p>1. To keep dancers healthy, the health care team and the dancer must work together. 2. The physician must be an advocate for the dancer and work to provide an accurate diagnosis and an effective treatment strategy. 3. Monitoring performance and rehearsal load, fitness, and general health of the dancer will help to maximise the dancer's healing potential. 4. Correction of muscle imbalances, attention to proper technique, sequential skill progression, and proper shoe fit may help limit acute injuries to the dancer. 5. Creativity is needed to modify treatment plans to accommodate the dancer's need to maintain strength, flexibility, and fitness during recovery.</p>	x						x

No.	Author (year of publication)	Title	Impact factor	Article type	Field of study (prevention, injury, rehabilitation)	Results	Ankle sprain	Ankle fracture	Achilles tendinopathy	Rupture of Achilles tendon	Posterior impingement syndrome	Anterior impingement syndrome	Tendinitis of flexor hallucis longus
6	Campbell et al. (2019)	Intrinsic modifiable risk factors in ballet dancers: Applying evidence-based practice principles to enhance clinical applications	1.926	Review	Prevention (risk factors and screening tools identification)	<p>1. Identification of seven intrinsic modifiable factors specifically for ballet dancers and seven appropriate screening tools.</p> <p>2. Intrinsic modifiable risk factors: hypermobility, fatigue, overuse, neuromuscular dysfunction, degree of turnout, weakness of core and lower extremity musculature, and lower extremity range of motion (ROM) discrepancies.</p> <p>3. Appropriate screening tools: Movement Competency Screening (MCS), Beighton Hypermobility Scale (BHS), Rolling (to detect compensation and neuromuscular dysfunction), Star Excursion Balance Test (SEBT), Functional Agility Short-Term Fatigue protocol (FAST-FP), Slow Linear Oxidative Fatigue protocol (SLO-FP) and Total Passive Turnout (TPT).</p>							

Results of the most common prevention and treatment procedures of ankle injuries in ballet dancers

The physiotherapy procedures discussed in the reviewed articles have been collected and arranged by individual types of injuries in Table 3. The review showed that the most common procedures in the treatment of ankle injuries in ballet dancers are the following: rest (Kadel, 2014; Morton, 2013), ice therapy (Kadel, 2014; Vosseller, Dennis, & Bronner, 2019), muscle strengthening (Kadel, 2014; Morton, 2013), night brace (Kadel, 2014; Vosseller et al., 2019) and optimising ballet technique (Morton, 2013; Kadel, 2014; Vosseller et al., 2019; Rietveld, 2013). For injury prevention purposes, mainly strengthening and stretching exercises are used, to which functional joint stabilisation and plyometric exercises can be added (Vera et al., 2020).

Results related to ankle sprain

Kadel (2014) states that the ankle sprain is the most common ballet injury. Most often, an inversion ankle sprain occurs (the foot turns inward). Conservative rehabilitation should thus include: a compression bandage, ice therapy, ankle brace, wearing good athletic shoes outside of ballet training and rest from training as long as the ankle is painful. Some sprains also require the wearing of a special therapeutic shoe, which the ballet dancer wears when walking and sleeping. It is recommended that dancers who have had multiple ankle sprains perform floor barre ballet classes, combined with pilates and gyrotonics training before returning to the ballet halls (Kadel, 2014).

Results related to Achilles tendinopathy

Morton (2013) states that Achilles tendinopathy occurs in both men and women and can be seen in many other dance styles as well. For conservative rehabilitation, both authors recommend rest, use of physiotherapy and careful active stretching of the Achilles tendon and triceps surae muscles. Kadel (2014) states that it is useful to add deep tissue massage, while Morton (2013) adds that it is also necessary to correct any incorrect ballet technique (e.g. foot tilt in the direction of pronation, incomplete landing) so that dancers avoid new injuries and, in their free time, to wear shoes that are large, wide, hard and supportive for the feet.

Results related to Achilles tendon rupture

Kadel (2014) and Morton (2013) state that Achilles tendon rupture occurs after the age of 30 and that the injury is more common in men than in women. Kadel (2014) adds that the rupture of the Achilles tendon is felt as a sharp pain and that the ballet dancer

Table 3: Physiotherapy and other procedures discussed in the articles included in the literature review

Author(s) (Year of publication)	Injury	Physiotherapy and other procedures
Morton (2013) Kadel (2014)	Sprain	Compression bandage, ice therapy, ankle brace, wearing good athletic shoes outside of ballet training and taking a rest from training, wearing a special therapeutic shoe, ankle and core strength exercises, sensorimotor training, range of motion (ROM) training, manual therapy (ankle mobilisation) and edema control
Morton (2013) Kadel (2014)	Achilles tendinopathy	Rest, physiotherapy, careful active stretching of the Achilles tendon and triceps surae muscles, deep tissue massage and elimination of incorrect ballet technique
Morton (2013) Kadel (2014)	Rupture of Achilles tendon	There is no conservative treatment, as surgery is recommended
Morton (2013) Kadel (2014) Rietveld (2013) Vosseller et al. (2019)	Posterior impingement syndrome	Limiting painful activities, including stopping tiptoe dancing, physiotherapy (muscle strengthening and ankle mobilisation), eliminating improper ballet technique, ice therapy and anti-inflammatory medications
Rietveld (2013) Vosseller et al. (2019) Kadel (2014)	Anterior impingement syndrome	Avoiding ballet jumps, squats/demi-pliés; raising the heel with an insole in both ballet shoes and day shoes; physiotherapy (correction of incorrect foot posture) and the use of day and night braces.
Morton (2013) Kadel (2014) Rietveld (2013) Vosseller et al. (2019)	Tendinitis of m. flexor hallucis longus	Rest; discontinuing the use of ballet pointe, grand plié and jumps; physiotherapy, stretching the flexor hallucis longus; optimising dance technique; anti-inflammatory medications, ice therapy, ultrasound therapy; functional exercise; good everyday footwear and use of a night brace.
/	Ankle fracture	/

is unable to rise to half-toes or demi-pointe. An Achilles tendon rupture usually occurs during a rebound or eccentric load landing. It also means that the Thompson's test is positive. The authors do not mention conservative treatment, as surgery is recommended for this injury. Despite undergoing surgery, the dancer will be able to continue their dance career, but rehabilitation may take up to a year (Morton, 2013; Kadel, 2014).

Results related to posterior impingement syndrome

The authors describe posterior impingement syndrome or “dancer's heel” as a painful condition occurring due to the compression of soft tissues on the back of the tibiae and calcaneus during plantar flexion (Rietveld, 2013; Vosseller et al., 2019; Kadel, 2014; Morton, 2013). For conservative treatment, it is first recommended to limit ballet activity that is painful, including ceasing to dance on the toes (Kadel, 2014; Morton, 2013; Vosseller et al., 2019), as well as using physiotherapy, where muscle strengthening and ankle mobilisation (Kadel, 2014; Morton, 2013), eliminating incorrect ballet technique (Kadel, 2014; Vosseller et al., 2019) and using ice therapy and anti-inflammatory drugs (Vosseller et al., 2019). Rietveld (2013) recommends that if the condition does not subsequently improve, an injection of cortisol is used, which also acts as an anti-inflammatory drug (corticosteroid). If conservative treatment does not help, surgery is recommended (Rietveld, 2013; Vosseller et al., 2019; Kadel, 2014; Morton, 2013).

Results related to anterior impingement syndrome

Anterior impingement syndrome can be the result of hypertrophied (thickened) soft tissues or osteophytes at the anterior edge of the tibiotalar joint (Kadel, 2014). Kadel (2014) hypothesises that osteophytes are the result of repeated ankle sprains or microtraumas from extreme dorsiflexion and plantarflexion positions. In conservative treatment, Kadel (2014) recommends avoiding ballet jumps and squats/demi-pliés and heel elevation with insoles in both ballet shoes and day shoes. Physiotherapy should also include correcting incorrect foot posture. Using day and night splints can relieve pain and inflammation. If the pain persists, surgery is recommended (Kadel, 2014).

Results related to tendinitis of flexor hallucis longus

Flexor hallucis longus tendinitis injury is very common in dancers. This injury is also called “dancer's tendinitis” (Morton, 2013; Kadel, 2014; Rietveld, 2013). It is more common in the female population due to the repetitive movement from dorsiflexion (demi-plié) to plantarflexion (standing on the tips of the toes). For conservative treatment, it is recommended to rest and stop using ballet pointe shoes, stop performing grand plié and jumps (Kadel, 2014; Morton, 2013; Vosseller et al., 2019), use physi-

otherapy (Kadel, 2014), stretch the flexor hallucis longus, optimise dance techniques (Rietveld, 2013; Vosseller et al., 2019), use anti-inflammatory drugs (Kadel, 2014; Vosseller et al., 2019), ice therapy, ultrasound, functional exercise, good daily footwear and, if necessary, night braces (Kadel, 2014; Vosseller et al., 2019).

Results related to ankle fracture

Unfortunately, the ankle fracture was not mentioned in the analysed articles, nor was rehabilitation.

Results related to the prevention of ballet dancers' injuries

Out of all the retrieved articles, injury prevention exercises in ballet dancers were discussed by Campbell et al. (2019) and Vera et al. (2020) only. Campbell et al. (2019) identify seven different intrinsic modifiable risk factors for injury: i) hypermobility, ii) fatigue, iii) overuse, iv) degree of turnout, v) neuromuscular dysfunction, vi) weakness of core and lower extremity musculature, and vii) lower extremity range of motion discrepancies, which are all commonly present in the ballet population. The authors emphasise that much care must be taken when creating an injury prevention programme for ballet dancers and take into account the mentioned seven internal factors in order to avoid the most common ballet injuries.

Vera et al. (2020), however, addressed a general whole-body injury prevention programme for ballet dancers. The study was conducted on 39 professional dancers with 19 dancers in the control group (9 men and 10 women, average age 26.6 ± 4.0 years) and 20 dancers in the experimental group (11 men and 9 women, average age 25.1 ± 5.1 years). The dancers carried out the injury prevention programme 3 times a week. It included a total of 24 exercises, which were arranged in such a way that each training day included different exercises. The injury prevention exercise programme lasted 30 minutes per session over a period of 52 weeks. Dancers performed 10–30 repetitions or 15–45 seconds of each exercise in 2 to 3 sets with 30 to 60 seconds of rest between sets. When the exercises were no longer challenging enough for the participants the intensity was increased by carrying out more difficult variants of the exercises, using stronger elastics and free weights. The dancers carried out the injury prevention programme without supervision, however, they had supervision for as long as they needed. The results of this study showed an 82% reduction in injuries and a longer period of time passing before the reappearance of old or appearance of new injuries.

DISCUSSION

The aim of this literature review was to identify the most common, most effective and up-to-date injury prevention and physiotherapy procedures for ankle injuries in ballet dancers. The results of the review and qualitative analysis performed showed that, despite the small number of studies in this field, the research questions on the state-of-the-art physiotherapy treatments and the most common and effective prevention procedures for ballet dancers' ankle injuries could be at least partly answered.

Most of the articles were review articles (5 out of 6), which means that relatively few original scientific studies on prevention and physiotherapeutic procedures for ankle injuries have been performed in the last 10 years. This prevented the authors from directly answering the question of which prevention and physical therapy procedures are most effective. However, it was possible to identify the state of the art and the most common physiotherapy treatments and prevention procedures for ankle injuries in ballet dancers.

It was found that among all injuries, ankle injuries are the most common in ballet dancers and seven different ankle injuries were most commonly evidenced in the reviewed literature. These are ankle sprain, Achilles tendinopathy, rupture of the Achilles tendon, anterior and posterior impingement syndromes, tendinitis of m. flexor hallucis longus and ankle fracture. This is in accordance with earlier studies, where the incidence of Achilles, peroneal, flexor hallucis longus and tibialis posterior tendinopathies, ankle impingement, stress fractures and metatarsalgia was the highest in ballet dancers (Nilsson et al., 2001 in Sobhani, Dekker, Postema, & Dijkstra, 2012) or in theatrical dancers (Rovere et al., 1983 in Sobhani et al., 2012), as well as in running and soccer (Sobhani et al., 2012). Comparing the results of this literature review to studies in other sports, where most frequently studied are soccer, running and gymnastics, it has been similarly shown that the most frequently studied overuse injuries are Achilles tendinopathy (in 44% of studies) and tendinopathy of other foot and ankle muscles, such as toe extensors and flexors, the tibialis anterior and posterior, and peroneal tendinopathies, as well as plantar fasciitis and stress fractures (Sobhani et al., 2012). However, weak methodology and poor reporting were highlighted, especially lack of a clear case definition, description of assessment procedures and reporting sample characteristics (Sobhani et al., 2012), showing the need for more and better original scientific studies.

Regarding rehabilitation, the most frequently used modalities and/or interventions for the management of ankle injuries in ballet dancers are rest, ice therapy, muscle strengthening exercises, foot braces and dance technique optimisation. Of course, treatment of each individual injury has also some individual and specific modalities and procedures, as presented in Table 3. Interestingly, among all evidenced injuries, specific physiotherapy treatments for ankle fractures could not be found in this literature review, even though earlier studies identified stress fractures as one of the prevalent injuries in ballet and theatrical dancers as well as in athletes of other sports (Sobhani et al., 2012).

For ankle sprains, as the most common injury in sports, at the time of injury, Chen, McInnis and Borg-Stein (2019) first recommend the application of the Ottawa Ankle

Rules to assess risk of fracture and reduce unnecessary radiographs, since these rules represent highly sensitive tools for detecting fracture in the setting of acute ankle sprain. Further, they report that modalities, such as RICE therapy (rest, ice, compression and elevation), electrical stimulation, oral and topical nonsteroidal anti-inflammatory drugs (NSAID) and Tylenol do not accelerate recovery, but are reasonable interventions for short term pain reduction. They also suggest early mobilisation (manual therapy) after acute lateral sprain as it has been shown to improve ankle dorsiflexion, pain reduction and stride length and thus accelerate return to play. Besides this, the introduction of early neuromuscular training programmes, typically balance and proprioception tasks with recurrent voluntary or involuntary destabilisation during exercise showed to be beneficial in all athletes with ankle sprains to reduce the risk of recurrent sprains, since ankle joint position sense, muscle reaction time and functional outcome scores improve with such exercises (Chen et al., 2019). In addition, the same authors found that although neuromuscular training programmes are effective for the prevention of recurrent sprains, the evidence for reducing the rate of first-time ankle sprains is not so robust. In addition, non-rigid ankle bracing is recommended for 1 year after ankle sprain to prevent recurrent sprain. Finally, Chen et al. (2019) endorse surgical referral and consideration of stabilisation for cases of chronic ankle instability that do not respond to non-operative measures after concomitant pathologies have been ruled out.

The retrieved studies in this literature review and the presented physiotherapy modalities, procedures and/or treatments are also the most up-to-date ones for ballet dancers' ankle injuries, which are in line also with professional guidelines for physical therapy, medical and sports rehabilitation such as the Clinical Practice Guidelines (Martin et al., 2021).

Regarding the most up-to-date and effective prevention procedures for ankle injuries in ballet dancers, based on the only available study of Vera et al. (2020) it is clear that too little original scientific studies, especially randomised controlled investigations, have been performed in the last 10 years. Nevertheless, Vera et al. (2020) found out as much as an 82% reduction in injuries after a 52-week period of a whole-body prevention exercise, as well as longer period of time for the recurrence of old or occurrence of new injuries in ballet dancers. However, for all sports/athletes in general, Chen et al. (2019) recommend the introduction of early mobilisation after acute ankle sprain injuries and early (as soon as tolerated after injury) as well as preventive neuromuscular training programmes for reducing the risk of recurrence of ankle sprains, resulting in higher overall activity levels without increasing pain, swelling, or the rate of reinjury when compared with traditional RICE therapy (Bleakley et al., 2010).

On the other hand, due to lack of original scientific studies it was not possible to determine whether and which of these procedures are the most effective. To answer this question, we would need to quantitatively analyse, using meta-analysis, the results of the control and experimental groups before and after the intervention in a larger or more relevant number of original scientific articles/studies and compare the effect sizes of each intervention in these studies.

In addition to an injury prevention programme, which should be implemented by all ballet dancers regardless of age and gender, the authors believe that it is also necessary to reduce or limit the risk factors of elite/professional ballet injuries, as found out by Biernacki et al. (2018) and Campbell et al. (2019). These parameters are: alignment, poor lumbopelvic movement control, inappropriate transversus abdominis contraction, decreased lower-extremity strength, and poor aerobic fitness (Biernacki et al., 2018), and hypermobility, fatigue, overload, degree of leg opening, neuromuscular dysfunction, trunk and lower extremity weakness, and lower extremity range of motion commonly present in the ballet dancer population (Campbell et al., 2019).

This means that firstly, the duration of the ballet class could be reduced by focusing on the quality of the training and optimising the training techniques, means and methods used. This could reduce one of the essential training parameters that affects injuries, i.e. the extent or the volume of exercise (duration, number of repetitions, sets, etc.), which would affect both the onset of fatigue and the possibility of acute and chronic overuse injuries. Secondly, nutritional consultants or nutritionists should be involved in ballet institutions, as this would avoid injuries resulting from malnutrition or nutritional deficiencies, as well as too frequent nutritional disorders, especially among female ballet dancers (Obrul, 2020). Thirdly, as far as environmental conditions are concerned, the ballet dancers themselves have no influence on them, but the management of the ballet institution has and as such should ensure that the dancers have optimal and safe working or training conditions (e.g. suitable temperatures, the right choice of floor and work space). Ballet dancers are ultimately responsible for choosing suitable training/dance shoes – ballet point shoes, but also for choosing suitable everyday shoes, because the wrong ones can also cause certain micro-injuries, which over time can lead to other, more serious injuries. Unfortunately, the individual has no influence on certain causes or risk-factors, such as general accidents and anatomical factors. However, they have an influence on previous injuries or on their occurrence in the future, namely by following prevention guidelines and recommendations as much as possible in the given situation.

This literature review showed that in the future more original scientific studies based on different injury prevention programmes for the whole body or specific body parts, for instance for the foot and ankle, are needed or studies older than 10 years should be analysed. However, by analysing older studies, it would be inappropriate to consider the prevention procedures to be the most up-to-date.

In addition, future research should involve more professional ballet dancers so that the findings have less variance and greater statistical power. It would also be advisable for researchers to work with dance or ballet institutions so that ballet dancers would have injury prevention exercise programmes included in their daily or at least weekly schedules. In this way, a greater and more accurate insight into the effectiveness of injury prevention procedures could be achieved.

The findings of this literature review should also be tested with further studies to determine which physiotherapy and injury prevention procedures are the most appropriate and efficient in the treatment or prevention of ankle or other injuries in ballet dancers.

It would thus make sense to conduct randomised controlled clinical research to verify the success and effectiveness of specific injury prevention programmes in practice.

Limitations of the study

One of the major limiting factors of this study was the quite restrictive inclusion and exclusion criteria, which most probably significantly limited the amount of literature retrieved. Especially the age of the study and the impact factor, as could be seen from the PRISMA diagram in the Methods section (Figure 1).

CONCLUSION

In this literature review the most common, effective and up-to-date injury prevention and physiotherapy procedures for ballet dancers' ankle injuries were qualitatively analysed. It was found that ballet dancers experience a high incidence of ankle injuries, which is also the case in other sports, especially in soccer, running and gymnastics, yet there have been very few in-depth and original scientific studies on this topic in the last 10 years, with only one randomised controlled investigation in the field of prevention of ballet injuries in general. Due to the small number of retrieved articles, it was not possible to directly answer the question on what the most successful physiotherapy procedures for the treatment of ankle injuries in ballet dancers are. However, it was possible to determine the most up-to-date procedures that were used in the reviewed literature, which actually represent the general guidelines for treatment, regardless of where the injury occurs.

The most common procedures for treating ankle injuries in ballet dancers were shown to be rest, ice therapy, muscle strengthening, use of a night brace and optimising ballet technique (Morton, 2013; Kadel, 2014; Vosseller et al., 2019; Rietveld, 2013). For prevention purposes, mainly strengthening and stretching exercises are used, to which functional joint stabilisation and plyometric exercises can be added (Vera et al., 2020). Clearly, further high-quality research designs with a low risk of bias are necessary to further evaluate the effectiveness of specific prevention exercises programme and the optimal timing of the intervention for the prevention of ankle injuries in ballet dancers. Also, future studies are needed to validate this conclusion regarding injury prevention exercise programmes to properly and efficiently address future ankle injuries and to reduce the risk of a subsequent injuries in professional ballet dancers.

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