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Review

Thieme

The Efficacy of Physical Fitness Training on Dance Injury: A Systematic Review

Die Wirksamkeit von körperlichem Fitnesstraining bei Tanzverletzungen: Ein systematischer Review

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ABSTRACT

Greater levels of physical fitness have been linked to improved dance performance and decreased injury incidence. The aim was to review the efficacy of physical fitness training on dance injury. The electronic databases CINAHL, Cochrane Library, PubMed, Web of Science, MEDLINE, China National Knowledge Infrastructure were used to search peer-reviewed published articles in English or Chinese. Studies were scored using Strength of the Evidence for a Conclusion and a risk bias checklist. 10 studies met the inclusion criteria from an initial 2450 publications. These studies offered physical fitness training for professional (n = 3) and pre-professional dancers (n = 7), participant sample size ranged between 5 to 62, ages from 11 to 27 years, and most participants were females. Assessment scores were classified as Fair (n = 1), Limited (n = 7), and Expert Opinion Only (n = 2) and risk of bias scores ranged from 22.7–68.2 %. After physical fitness training, 80 % of studies reported significant benefits in injury rate, the time between injuries, pain intensity, pain severity, missed dance activities and injury count. This review suggests that physical fitness training could have a beneficial effect on injury incidence in dance. The evidence is limited by the current study methodologies.

ZUSAMMENFASSUNG

Ein höheres Maß an körperlicher Fitness wurde mit einer besseren Tanzleistung und einer geringeren Verletzungshäufigkeit in Verbindung gebracht. Ziel war es, die Wirksamkeit von körperlichem Fitnesstraining bei Tanzverletzungen zu untersuchen. Die elektronischen Datenbanken CINAHL, Cochrane Library, PubMed, Web of Science, MEDLINE und China National Knowledge Infrastructure wurden für die Suche nach Peer-begutachteten vVEröffentlichungen in englischer oder chinesischer Sprache genutzt. Die Studien wurden in Bezug auf deren Evidenz für eine Schlussfolgerung und einer Checkliste zum Risiko von Verzerrungen bewertet. 10 Studien erfüllten die Einschlusskriterien von ursprünglich 2450 Veröffentlichungen. In diesen Studien wurde körperliches Fitnesstraining für professionelle (n = 3) und semiprofessionelle Tänzer (n = 7) angeboten, die Teilnehmerzahl lag zwischen 5 und 62, das Alter zwischen 11 und 27 Jahren, und die meisten Teilnehmer waren weiblich. Die Bewertungsergebnisse wurden als befriedigend (n = 1), eingeschränkt (n = 7) und als reine Expertenmeinung (n = 2) eingestuft. Die Werte für das Risiko von Verzerrungen reichten von 22,7 bis 68,2 %. Nach einem körperlichen Fitnesstraining zeigten 80 % der Studien signifikante Vorteile bei der Verletzungsrate, der Zeit zwischen den Verletzungen, der Schmerzintensität, der Schmerzstärke, den verpassten Tanzaktivitäten und der Anzahl der Verletzungen. Diese Übersicht legt nahe, dass körperliches Fitnesstraining eine positive Wirkung auf die Verletzungshäufigkeit im Tanzsport haben könnte. Die Beweise sind durch die derzeitige Studienmethodik begrenzt.

Practical Implications

- Supplemental physical fitness training seems to have a beneficial effect on injury rate for dancers
- Supplemental training reduced the number of missed dance sessions
- A wide range of training methods were implemented that had beneficial effects possibly due to the relatively low physical fitness levels of dancers
- Further studies using advanced methodologies (RCTs), or replication of current studies, are required to improve intervention efficacy

Introduction

A number of previous systematic reviews have highlighted that dancers have a high incidence of injury with chronic injuries being more prevalent than acute [1, 2, 3, 4, 5]. Despite movement differences between dance genres, the most affected sites are the lower extremity and lower back [6, 7, 8, 9, 10], with fatigue, overwork, and repetitive movement being reported as the main causes [5, 10, 11, 12, 13]. However, inadequate physical fitness levels, such as muscular strength [14, 15] and muscular endurance [12, 16], have often been cited as principal causes of dance injuries. As a result, it has been argued that optimal physical fitness for dancers may be as important as skill development [17].

Research over the past two decades has started to examine the association between physical conditioning and dance injuries [11, 18, 19, 20]. Research also revealed that physical fitness increases even improve dance performance without any unwanted effects on the aesthetics of the art [21, 22, 23]. However, only a few studies directly examined the relationship between physical fitness training interventions and dance injury [24], and the evidence has not been reviewed yet. Therefore, this present study aims to systematically review the efficacy of physical fitness interventions programs and on dance injury across different dance genres and participant skill levels.

Materials and Methods

Search strategy

Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA, 2020) [25], the following databases were searched: CINAHL, Cochrane Library, PubMed, Web of Science, MEDLINE, China National Knowledge Infrastructure (CNKI), and related journals such as Journal of Dance Medicine and Science (JDMS) and Medical Problems of Performing Artists (MPPA) were used to search peer-reviewed published articles in English or Chinese.

These electronic databases were searched using the Medical Subject Heading (MeSH) terms, free-text words, keywords, and subheadings: ("Physical Fitness [MeSH Terms]" OR strength OR condition * OR fitness OR power OR endurance OR mobility) AND (Injuries [MeSH Terms] or Injury) AND (Dance * OR Ballet OR "Hip Hop" OR Jazz).

A hand search of reference lists and citations to identify other studies was also conducted. The whole searching process occurred over three months, from March to June 2021.

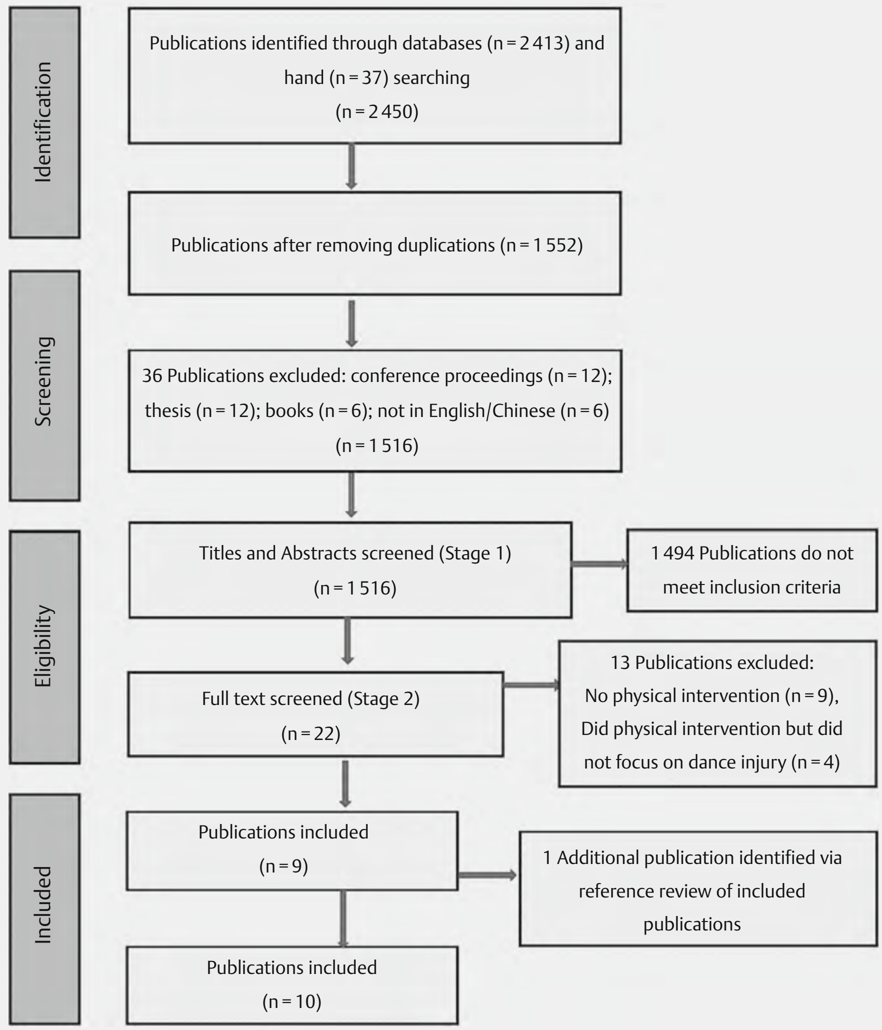
Inclusion and exclusion criteria

Inclusion criteria incorporated peer-reviewed publications in English or Chinese. These articles had to deliver physical fitness intervention training to impact injury incidence in dancers, with no limitation of nature of the injury, injury sites, injury severity, dance genres, the levels of dance, gender, and age. All study designs were included from case studies to random controlled trials. Exclusion criteria comprised non-peer-reviewed sources such as books, conference proceedings, and thesis.

Database searches were downloaded into EndNote (ver. 20, Clarivate). Articles were removed if they did not directly relate to the inclusion criteria if it was not in either English or Chinese (▶ **Fig. 1**). There are two stages when screening articles: we screened all titles and abstracts (Stage 1) and then full texts were assessed for inclusion (Stage 2). Any discrepancies between the two reviewers (YD and MW) were discussed and mutually agreed decisions were reached. The selected articles were subsequently reviewed in full.

Methodological quality assessment

The included studies' designs were ranked according to the Oxford Centre for Evidence-Based Medicine [26]. Studies were further analyzed using Strength of the Evidence for a Conclusion (GRADE) [27]. The GRADE evaluated five aspects: Quality, Consistency, Quantity, Clinical Impact and Generalizability, and which gave five outcomes: Good, Fair, Limited, Expert Opinion Only, and Not Assignable [28]. The risk of bias was evaluated using Kmet et al. [29] checklist. Studies were scored on 14-item that assessed the internal validity or the extent to which the design, con-



▶ **Fig. 1** PRISMA Flow Diagram [25].

duct, and analyses minimized errors and biases. The assessment of the included studies was evaluated separately by two reviewers (YD and MW).

Results

Descriptive information

A total of nine studies (1998 to 2021) met the inclusion criteria from an initial pool of 2450 publications, and a further one additional publication was identified via a reference review of the included studies (▶ **Fig. 1**). These ten studies offered physical fitness training for professional (n = 3) and pre-professional dancers (n = 7) whose dance genres were ballet (n = 7), contemporary (n = 3), DanceSport (n = 1), hip-hop (n = 1), and Korean traditional dance (n = 1). The sample sizes ranged between 5 to 62, ages from 11 to 27 years, and most of them were females (F = 117–119; M = 65–69). However, only six studies provided information on the dancers' injury status [30, 31, 32, 33, 34, 35] and affected sites [32, 33, 34, 35] prior to intervention (▶ **Table 1**).

Study design and assessment scores

The included studies had a range of methodologies, including two randomized controlled trial studies, one prospective randomized clinical trial, one un-controlled trial, one mixed-methods quasi-experimental study, one non-randomized longitudinal study, and four cohort studies. These studies included four levels of evidence according to the Oxford Centre for Evidence Levels [26], which were comprised of Level 1 (n = 1), Level 2 (n = 4), Level 3 (n = 3), and Level 4 (n = 2).

Based on five aspects of GRADE, the mean scores ranged from 3.8 [32, 36] to 1.6 [37], and assessment scores were classified as Fair (n = 1), Limited (n = 7), and Expert Opinion Only (n = 2) (▶ **Table 2**). The overall scores of the risk of bias to the method ranged from 68.2 % to 22.7 % (mean: 48.7 % ± 13.1 %) (▶ **Table 1, Supplemental Table A and B**).

Physical fitness tests and training

All studies did physical fitness tests pre- and post-intervention. The majority of them did muscular strength tests [31, 32, 33, 34, 37, 38, 39] (n = 7), whilst other tests included stability [30, 31, 37]

▶ **Table 1** Included studies description, Strength of Evidence and Risk of Bias.

Study	Cohort					Method		Strength of Evidence		Risk of Bias	
	Genre	Dance level	Age (yrs)	Gender	N	Design	Condition pre-intervention	Mean	Mean ± SD	Actual score/possible score	%
Long et al., 2021 [26]	Ballet	Professional	23	M = 2 F = 4	6	Cohort	Un-injured	3	3 ± 0.7	11/22	50
Vera et al., 2020 [32]	Ballet	Professional	27	M = 20 F = 19	39	RCT	NR	4	3.8 ± 0.5	15/28	53.6
Viktória et al., 2016 [27]	Ballet, hip-hop	Pre-professional	13	NR	62	Cohort	Un-injured	3	2.8 ± 0.8	12/22	54.6
Welsh et al., 1998 [28]	Modern, ballet	Pre-professional	19	M = 1 F = 7	8	Cohort	Back pain history but not current	4	3.8 ± 0.5	5/22	22.7
Kline et al., 2013 [29]	Ballet	Pre-professional	11–18	NR	5	Cohort	Back pain and radicular symptoms	3	3.2 ± 0.5	8/22	36.4
Roussel et al., 2014 [34]	Modern, ballet	Pre-professional	20	M = 6 F = 38	44	RCT	NR	3	2.8 ± 0.8	16/28	57.1
KiM et al., 2018 [31]	Traditional Korean	Professional	24	M = 3 F = 10	13	RCT	Grade 2 unilateral hamstring strain	3	3 ± 0	15/28	53.6
Mistiaen et al., 2012 [35]	NR	Pre-professional	20	NR	27	Cohort	NR	3	3 ± 0.7	12/22	54.6
Allen et al., 2013 [33]	Ballet	Pre-professional	23–26	M = 25–29, F = 27–29	52–58	Cohort	NR	2	1.6 ± 0.6	15/22	68.1
Chong et al., 2011 [30]	Dance-Sport	Pre-professional	NR	M = 8 F = 12	20	Cohort	Ankle soft tissue injury	3	2.6 ± 0.6	8/22	36.4
Summary			11–27	M = 65–69 F = 117–119	5–62			3	3.1 ± 0.6	48.4 ± 13.1	

Age = average age or age range; N = Number of participants; NR = Not Reported; M = Male; F = Female; RCT = Randomize Control Trail and balance [30, 36], mobility [35, 36, 37] and flexibility[34], and cardiovascular endurance [33, 38, 39].

These physical intervention training included strength training [30, 31, 32, 33, 35, 37, 38, 39] (n = 8), stability training (included balance training, motor control training, stabilization training, proprioception training) [31, 33, 34, 35, 38] (n = 5), mobility training [34, 35] (n = 2), endurance training [38, 39] (n = 2) and agility training [30] (n = 1).

Five studies reported their training methods were comprised of resistance training [30, 35, 37], circuit training [38, 39], and crosstraining [37]. In which there were twenty-four exercise movements offered in their physical fitness training (▶ **Table 2**).

Physical fitness training load and outcome

The studies that did provide detailed interventions reported that they mainly lasted between 30–90 minutes per session [30, 33, 35, 36, 38, 39] (n = 6), 2–3 times per week [30, 32, 33, 34, 36, 38, 39] (n = 7) for 4–16 weeks [30, 31, 32, 33, 34, 35, 36, 38] (n = 8). Two studies involved long-term interventions ranging between 6–36 months [37, 39].

Post-intervention testing reported significant improvements in physical fitness elements, this included stability and balance [30, 31], strength [31, 34, 39], flexibility [34, 35], and endurance [39]. Two studies reported non-significant improvements in strength from 14 % to 151 % [32, 33] and another physical fitness parameters remained consistent (▶ **Table 2**).

Physical fitness training and dance injury outcome

The majority of studies (80 %) reported a positive improvement in injury reporting. The eight studies stated that the physical fitness interventions had a range of positive outcomes, for instance, a significant decrease (82 % reduction, $p = 0.002$) in injury rate [36], pain intensity (ballet: 9 vs 1.3, $p = 0.004$; Hip-hop 8 vs 2.8, $p = 0.002$) [31], pain severity (4.2 vs 2.1, $p = 0.017$) [34], and injury count (355 vs 174, $p < 0.01$; 5 vs 0, $p = 0.019$) [37, 38], and also a significant increase in time between injuries (130 vs 219 days, $p = 0.028$) [36]. Furthermore, two studies reported a non-significant decrease in the numbers of dance activities missed due to pain [32], relief of symptoms [33].

Two studies [30, 39] used the SF-36 questionnaire to track injuries, neither reported overall change in SF-36 scores post intervention, but one noted a significant decrease in physical pain (83.2 vs 67.6, $p = 0.009$) [39]. The other study [30] recorded no injuries during the study period.

Physical fitness interventions significantly decreased dancers' injury incidence across five different dance genres; Ballet [31, 32, 33, 36, 37, 38], Modern [32, 38], Hip-hop [31], DanceSport [35] and traditional Korean [34] (▶ **Table 3**).

Dance injury tracking methods

Eight studies defined dance injury [30, 31, 32, 33, 34, 36, 37, 38] with 6 using a time-loss definition, including dance activities missed and symptoms forcing the student to interrupt classes [30, 32, 36, 37, 38, 39]; and the other studies reported injury as pain, strain, spasms, pull, tingling, numbness, weakness, acute trauma, or overuse injury [33, 36, 37, 38].

The severity of dance injury was monitored using a number of scales that included the Visual Analogue Scale [31, 34, 38, 39] and Patient Specific Functional Scale and Numerical Pain Rating Scale [33]. Injury incidence and aetiology were tracked using the Short Form 36-Questionnaire [38, 39] and Hamstring Injury Questionnaire [34], and clinician and dancer records (Electronic Medical Record System [36], Self-record [32] and Injury Surveillance Program [37] and Ankle System Functional Score [35]). One study [30] also incorporated interviews with their study design (▶ **Table 3**).

Intervention location, equipment and supervision

Seven studies reported where the intervention occurred these included the dance studio [30, 34, 36, 37], the clinic [32, 33, 34], a rehabilitation laboratory [35], home [33], or pool [37]. Six studies had supervised interventions by either a physician [32, 33], physical therapist [30, 32, 33, 34, 38, 39], fitness trainer [32], dance teacher/dancers [30, 38, 39]; while only one was un-supervised and used a booklet, graphic and video [36]. Finally, three studies did not report how the intervention was carried out [31, 35, 37]. The most popular item of equipment for the interventions was a resistance band [30, 34, 35, 36, 38] (**Supplemental Table C**).

Discussion

This systematic review aimed to examine the efficacy of physical fitness intervention training programs on dance injury across different dance genres and participant skill levels. It was found that such programs led to decreased dance injuries [30, 31, 33, 34, 35, 36, 37, 38, 39]. Although 80 % of the identified studies reported a positive effect, the number of these studies (n = 7) and their sample size were rather limited. Furthermore, the quality of these studies was rated between Fair to Expert Opinion Only, and scores of the risk of bias ranged from 68.2 % to 22.7 %, with only two Randomized Controlled Trail studies [36, 38].

Although physical fitness training significantly reduced dance injuries across the included studies, no meta-analysis could be performed (heterogeneity) and therefore the evidence is based on few or individual studies. For instance, injury rate ($p < 0.05$) [36], extended time between injuries ($p < 0.05$) [36], reduced pain intensity ($p < 0.01$) [31], relieved pain severity ($p < 0.05$) [34], and reduced injury count ($p < 0.01$, $p < 0.05$) [37, 38], and decreased the circumference of swelling ankles ($p < 0.01$) [38]. However, the current level of evidence highlights the need for improved methodologies, such as using an inclusive injury definition and reporting full intervention details. Although six studies used a time loss as dance injury definition [30, 32, 36, 37, 38, 39], this could underestimate the injury burden as the majority of dance injuries are minor or moderate and do not require time away from dancing [40, 41].

The majority of studies had limited sample sizes, using convenience samples, seven studies had sample sizes smaller than 30 participants. No studies reported power analysis a priori, which weakens the generalizability of the link between physical fitness training and performance or injury risk [24]. Further, the lack of details regarding training frequency [31, 37] and training load [31, 32, 34, 37] means study replication or clinical implementation is impossible.

▶ **Table 2** Physical Test, Intervention and Results.

Studies	Physical Fitness Test	Physical Intervention Training			Results		
		Training	Exercises	Intensity	Physical Fitness	Mean ± SD (Pre vs Post; E vs C)	P value
Long et al., 2021 [26]	Motor control test, balance test, and stability tests on knees and ankle, hip and upper extremity.	Agility and strength training	Bridges, planks, deadlifts, lunges, squats, step ups and jumping	2-time/week 30-minute 5-week	Balance	260.1 ± 18.0 vs 291.6 ± 30.5	0.028*
					Ankle and knee stability	119.6 ± 12.3 vs 147.6 ± 25.0	0.043*
					Upper extremity stability	25.4 ± 3.2 vs 31.3 ± 4.3	0.042*
Vera et al., 2020 [32]	Balance test, turnout test, hypermobility test	Resistance training (with elastic bands or free weights)	Bridges, planks, deadlifts, lunges, squats, step ups,, jumping; fire hydrants; resistance band toe points, foot flexion and pointed eversion; Star drill; lower extremity stretching; Nordic hamstring; dead bird and dog; Prone leg lift; Glute kicks; Wall sits; Step-downs; Single-leg stance.	3-time/week 30-minute 4-week	NR	NR	NR
Viktória et al., 2016 [27]	Static core strength test, motor control stability test.	Core strengthening and stretching, balance and lumbar motor control. Correct dance posture.	NR	NR NR 12-week	Core muscles static strength (Ballet)	58.9 ± 30.5 vs 88.7 ± 21.3	0.00†
					Core muscles static strength (Hip-hop)	67.6 ± 32.5 vs 83.7 ± 25.7	0.015†
					Lumbar motor control (Ballet)	5.3 ± 0.3 vs 3.7 ± 0.3	0.00†
					Lumbar motor control (Hip-hop)	4.0 ± 1.3 vs 3.9 ± 1.0	0.000†
Welsh et al., 1998 [28]	Spine (back) extensor strength test.	Back strengthening (abdominal, rotary torso, hip and knee extensor, knee curl)	NR	2-time/week NR 7- to 10-week	Lumbar extensor strength	14 % to 151 %	NR
					Dancers' ratings of strength	2.5 vs 6.25	NR
Kline et al., 2013 [29]	Core strength and endurance test	Traditional lumbar stabilization and core strengthening program	Plank, bridge	2-time/week 25–30-mins 6-week	Strength in positions	NR	NR
					Straight leg raise range (PROM)	85 vs 111	NR

Table 2 (Continuation)

Studies	Physical Fitness Test	Physical Intervention Training			Results		
		Training	Exercises	Intensity	Physical Fitness	Mean ± SD (Pre vs Post; E vs C)	P value
Roussel et al., 2014 [34]	Aerobic capacity test, lower limb explosive muscle strength test	Endurance, strength, proprioception, motor control training, circuit	Exercises on bicycles, steps, rowing machines, and dancespecific exercises	2-time/week 75-minute 16-week	Aerobic capacity	211.1 ± 3.4 vs 202.1 ± 3.6	0.079
					Explosive strength	1.83 ± 0.03 vs 1.81 ± 0.03	0.630
KiM et al., 2018 [31]	Flexibility and isometric strength of the hamstring muscle test	Postural stabilization, Concentric and eccentric ROM	Static and active stretching, straight leg raising, leg curls, anterior and posterior pelvic tilt.	3-time/week NR 8-week	Flexibility and Strength	121.9 ± 8.4 vs 139.6 ± 5.9	< 0.001†
Mistiaen et al., 2012 [35]	Aerobic endurance test, explosive muscle strength of lower limbs test	A circuit (endurance and strength), "Start-To-Run" program.	Dance-specific exercises	3-time/week 90-minute 24 weeks	Aerobic power	2.3 ± 0.6 vs 2.4 ± 0.6	0.025*
					Oxygen consumption	1.6 ± 0.5 vs 1.7 ± 0.5	0.045*
					Resistance level	129.6 ± 40.5 vs 139.8 ± 43.5	0.019*
					Strength increased	NR	NR
Allen et al., 2013 [33]	Strength test (core strength and lower limbs), shoulder and trunk (rotary) mobility test.	Strength and conditioning (cross-training, resistance training).	Jumping and NR	NR NR 144-week	Functional Movement Screen	15 vs 13	> 0.05
Chong et al., 2011 [30]	AROM and PROM test	Ankle muscle strength (resistance training), ROM, proprioception	Ankle flexion and extension, Power bike exercise, closed-chain exercise, diagonal, heel lift, jumping, balance exercise on device	7-time/week ~75-minute 6-week	Ankle Functional score	57.6 ± 8.7 vs 89.3 ± 7.9	< 0.001†
					AROM	21.5 ± 5 .4 vs 59.7 ± 15.2	< 0.001†
					PROM	33.3 ± 6 .1 vs 67.9 ± 11.9	

* $p < 0.05$ and † $p < 0.01$; NR = Not Reported; AROM = Active Range of Motion; PROM = Passive Range of Motion; E = Experiment group; C = Control group; SD = Standard Deviation;

▶ **Table 3** The Methodology and Results of Dance Injury.

Studies	Genres	Methodology of Dance Injury			Results of Dance Injury			
		Definition	Injury Tracking	Aspects	Mean ± SD		P value	Differences
					Pre or C	Post or Exp		
Long et al., 2021 [26]	Ballet	Time-loss and time requiring modify dance activity.	Interview	Time-loss	0	0	NR	ND
Vera et al., 2020 [32]	Ballet	Full-time lose, adaptation of NASA injury guidelines.	Electronic medical record system	Injury rate was 82 % less	0.52–0.90	0.18	0.022*	Decreased
				Time between injuries	130	219	0.028*	Increased
Viktória et al., 2016 [27]	Ballet	Low back pain	Visual analogue scale (VAS)	Pain intensity (Ballet)	9.0 ± 18.2	1.3 ± 3.3	0.004†	Decreased
	Hip-hop			Pain intensity (Hip-hop)	8.0 ± 10.9	2.8 ± 8.7	0.002†	
Welsh et al., 1998 [28]	Modern and Ballet	The number of dance activities missed due to pain (time-loss)	The number of dance activities missed due to back pain	The numbers of dance activities missed reduced	NR	NR	NR	Decreased
Kline et al., 2013 [29]	Ballet	Pain, strain, spasms, pull, tingling, numbness, weakness.	Patient Specific Functional Scale, Numerical Pain Rating Scale	Relief of symptoms	NR	NR	NR	Decreased
Roussel et al., 2014 [34]	Modern and Ballet	Acute trauma; repetitive stress in dancing; missed dance activities	VAS, Short Form 36-questionnaire	Less low back injuries (count)	5	0	0.019*	Decreased
Kim et al., 2018 [31]	Traditional Korean	NR	Hamstring injury questionnaire, VAS	Pain severity (VAS)	4.2 ± 1.2	2.1 ± 0.9	0.017*	Decreased
Mistiaen et al., 2012 [35]	NR	Symptoms forcing the student to interrupt classes (time-loss)	Medical and the short-form 36 questionnaires, VAS	The total score of the SF-36 remained unchanged	663 ± 105	612.7 ± 122.6	0.122	ND
Allen et al., 2013 [33]	Ballet	Time-loss (≥ 24 hrs), classified either as traumatic or overuse	Injury surveillance program (in-house physiotherapists)	Injury count	355	174	< 0.01†	Decreased
				Injury incidence (M)	4.76	2.22	NR	Decreased
				Injury incidence (F)	4.14	1.81	NR	
Chong et al., 2011 [30]	DanceSport	NR	Ankle Functional Score	Ankle circumference	26.4 ± 2.9	24.8 ± 2.8	< 0.01†	Decreased

* p < 0.05 † p < 0.01; ND = no difference after intervention; NR = not reported; C = Control group; Exp = Experiment group; SD = Standard Deviation;

For a study to have a clinical perspective, the length of the exercise intervention and the number of participants was essential to provide relevance. Welsh et al. [32] recruited eight dancers for a 7–10 week back strengthening intervention training and reported a non-significant reduction in the numbers of dance activities missed from 16 to 4 sessions. In contrast, Allen et al. [37] recruited 52 to 58 dancers over three years and reported a significant reduction in injury counts from 355 to 183 in the second year. However, the later study lacked specific intervention protocols, as they implemented an individualized program approach. This study and another long-term study [37, 39] were also limited due to their lack of a control group.

Vera et al. [36] attempted to implement a 52-week randomized controlled study with a professional ballet company setting. The authors reported an 82 % decrease in injury rate and an extended period between injury episodes, but these results can't truly be put down to the intervention due to the low compliance (45 % dropped out) and completion rate (4-week intervention). Home-based [33] or self-executed intervention with a handout outlining [30, 39] using portable apparatus [30, 33, 34] is undoubtedly convenient but goes against the idea that unsupervised sessions [36] may be incorrectly executed [24] .

The majority of included studies (n = 7) tested strength [31, 32, 33, 34, 37, 38, 39] and provided successful strength training interventions [30, 31, 32, 33, 35, 37, 38, 39], but only a couple evaluated cardiorespiratory parameters in their conditioning interventions [38, 39]. However, previous research has shown that dance class and rehearsal are at a lower cardiorespiratory demand than dance performance [42]. During the performance, dancers work at close to their maximum capacities [43]. This reinforces a link between poor cardiorespiratory fitness, fatigue and injury incidence [19, 44, 45]. The lack of cardiorespiratory interventions within the included studies highlights the need for a more holistic approach to injury prevention.

Intervention frequency and duration ranged between 2–3 times per week [30, 32, 33, 34, 36, 38, 39] and 30–60 minutes per time [24, 30, 33, 36, 38] which is often lower than other interventional regimens. Unless their injury prevents dancing, dancers usually train 4–6 hours a day, 5–6 days [46] a week, and therefore a limited intervention can produce beneficial effects [47, 48].

Although the selected studies reported significant positive benefits for the use of physical fitness training as an intervention, they used a variety of scales with only pain intensity or injury severity in common [31, 33, 34, 38, 39, 49, 50]. These are both subjective scales, and more replicable methods are needed as the case in sports injury surveillance [51].

The overall quality of included studies was relatively low. The majority demonstrated inadequate sample sizes [30, 32, 33, 34, 35, 36], weak design [30, 32, 33], incomplete evidence [31, 32, 34, 36], and very poor execution [36]. Moreover, the methodological risk of bias is high. Although the purpose of their studies was easily identified, half of them failed to completely describe the purposes [31, 32, 35, 36, 39]. Some of them lacked inclusion/exclusion criteria of subject selection [32], or their selection strategy was not ideal [35, 37, 38, 39], some didn't report the basic descriptive data (age or sex) of dancers [31, 33, 39], whereas in some studies statistical analysis was not reported [32, 33]. Therefore, the significant results reported in insufficient details with low evidence [30, 31, 32, 33, 34, 35, 36] lack validity.

Conclusion

The included studies suggest that physical fitness training could positively affect dance injury rate, injury intensity, injury severity, extend the time between injuries, and reduce injury count. However, the heterogeneity of the studies, the low sample sizes and weak methodological designs prevent a meta-analysis and therefore evidence is based on few or single studies. Therefore, more RCTs with high-quality designs are needed to strengthen the evidence on whether physical fitness training can positively affect injury incidence in dancers.

Contributors' Statement

YD.: method design, searched studies, assessment scores, writing of article; Y.K. & R.C.: writing of article; M.W.: method design, assessment scores, writing of article.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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