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



Authors

Yanan Dang^{1, 2}, Ruoling Chen³, Yannis Koutedakis⁴, Matthew Alexander Wyon^{1, 5}

Affiliations

- 1 School of Sport, University of Wolverhampton, Walsall, United Kingdom of Great Britain and Northern Ireland
- 2 Faculty of Humanities, Beijing Dance Academy, China
- 3 School of Health, University of Wolverhampton Faculty of Education Health and Wellbeing, Walsall, United Kingdom of Great Britain and Northern Ireland
- 4 Sport Sciences, University of Thessaly, Trikala, Greece
- 5 National Institute of Dance Medicine and Science, Birmingham, United Kingdom of Great Britain and Northern Ireland

Key words

rehabilitation, prehabilitation, ballet, muscle strength

accepted 23.08.2022 published online 04.11.2022

Bibliography

Int J Sports Med 2023; 44: 108–116 DOI 10.1055/a-1930-5376 ISSN 0172-4622

© 2022. The Author(s).

This is an open access article published by Thieme under the terms of the Creative Commons Attribution-NonDerivative-NonCommercial-License, permitting copying and reproduction so long as the original work is given appropriate credit. Contents may not be used for commecial purposes, or adapted, remixed, transformed or built upon. (https://creativecommons.org/licenses/by-nc-nd/4.0/)

Georg Thieme Verlag KG, Rüdigerstraße 14, 70469 Stuttgart, Germany

Correspondence

Prof. Matthew Alexander Wyon University of Wolverhampton, School of Sport, Gorway Rd, Walsall WS1 3BD United Kingdom of Great Britain and Northern Ireland Tel.: 01902323144, Fax: 01902323228 m.wyon@wlv.ac.uk



Supplementary Material is available under https://doi.org/10.1055/a-1930-5376

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.

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 [1–5]. Despite movement differences between dance genres, the most affected sites are the lower extremity and lower back [6–10], with fatigue, overwork, and repetitive movement being reported as the main causes [5, 10–13]. 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, 18–20]. Research also revealed that physical fitness increases even improve dance performance without any unwanted effects on the aesthetics of the art [21–23]. 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, conduct, 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 (\blacktriangleright **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 [30–35] and affected sites [32–35] prior to intervention (\blacktriangleright **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) (\triangleright 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%) (\triangleright 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 [31–34, 37–39] (n=7), whilst other tests included stability [30, 31, 37] and balance [30, 36], mobility [35–37] and flexibility[34], and cardiovascular endurance [33, 38, 39].

These physical intervention training included strength training [30-33, 35, 37-39] (n = 8), stability training (included balance training, motor control training, stabilization training, proprioception training) [31, 33-35, 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 cross-training [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–

34, 36, 38, 39 (n = 7) for 4–16 weeks [30-36, 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

באכווףנוטוו, אופווקנוו ט	-		ort of the second se				Method	Strength	of Evidence	Risk of Bias	
Genre Dance level Age (yrs)	Dance level Age (yrs)	Age (yrs)		Gender	z	Design	Condition pre-inter- vention	Mean	Mean±SD	Actual score/ possible score	%
Ballet Professional 23 1	Professional 23 1	23	~	d = 2 F = 4	9	Cohort	Un-injured	3	3±0.7	11/22	50
Ballet Professional 27	Professional 27	27		M = 20 F = 19	39	RCT	NR	4	3.8±0.5	15/28	53.6
Ballet, hip-hop Pre-professional 13	Pre-professional 13	13		NR	62	Cohort	Un-injured	3	2.8 ± 0.8	12/22	54.6
Modern, ballet Pre-professional 19	Pre-professional 19	19	_	M=1 F=7	8	Cohort	Back pain history but not current	4	3.8±0.5	5/22	22.7
Ballet Pre-professional 11–18	Pre-professional 11–18	11–18		NR	2	Cohort	Back pain and radicular symptoms	e	3.2±0.5	8/22	36.4
Modern, ballet Pre-professional 20 N	Pre-professional 20 N	20 A	2	1=6 F=38	44	RCT	NR	e	2.8±0.8	16/28	57.1
Traditional Korean Professional 24 M	Professional 24 N	24 N	2	I=3 F=10	13	RCT	Grade 2 unilateral hamstring strain	ñ	3±0	15/28	53.6
NR Pre-professional 20 N	Pre-professional 20 N	20 N	2	IR	27	Cohort	NR	m	3±0.7	12/22	54.6
Ballet Pre-professional 23–26 h	Pre-professional 23–26 P	23–26 h	2 11	A = 25–29, : = 27–29	52-58	Cohort	NR	2	1.6±0.6	15/22	68.1
DanceSport Pre-professional NR N	Pre-professional NR N	NR	2	<i>A</i> = 8 F = 12	20	Cohort	Ankle soft tissue injury	3	2.6±0.6	8/22	36.4
11–27 h	11–27 h	11–27 h	2 11	A = 65–69 : = 117–119	5-62			3	3.1±0.6	48.4 ±13.1	
nge; N=Number of participants; NR=Not Reported; M=Male;	rticipants; NR = Not Reported; M = Male;	orted; M = Male;	ar I	: F = Female; RCT	= Randomiz	e Control Tr	ail				

th of Evidence and Risk of Bias
Streng
description,
Included studies
Table 1

► Table 2 Physical Test, Intervention and Results

Studies	Physical Fitness Test	Physical Intervention	on 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,	Agility and strength training	Bridges, planks, deadlifts, lunges, squats, step ups and jumping	2-time/ week	Balance	260.1 ± 18.0 vs 291.6 ± 30.5	0.028 *
	balance test, and stability			30-minute 5-week	Ankle and knee stability	119.6±12.3 vs 147.6±25.0	0.043 *
	tests on knees and ankle, hip and upper extremity.				Upper extremity stability	25.4±3.2 vs 31.3±4.3	0.042 *
Vera et al., 2020 ³²	Balance test, turnout test, hypermobil- ity 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	Core strengthening and stretching,	NR	NR NR 12-week	Core muscles static strength (Ballet)	58.9±30.5 vs 88.7±21.3	0.00†
	test, motor control stability test	balance and lumbar motor			Core muscles static strength (Hip-hop)	67.6±32.5 vs 83.7±25.7	0.015†
	submy test.	dance posture.			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	Back strengthening (abdominal, rotary	NR	2-time/ week NR	Lumbar extensor strength	14% to 151%	NR
	strength test.	torso, hip and knee extensor, knee curl)		7- to 10-week	Dancers' ratings of strength	2.5 vs 6.25	NR
Kline et al., 2013 ²⁹	Core strength and	Traditional lumbar stabilization and	Plank, bridge	2-time/ week	Strength in positions	NR	NR
	endurance test	core strengthening program		25–30-mins 6-week	Straight leg raise range (PROM)	85 vs 111	NR
Roussel et al., 2014 ³⁴	Aerobic capacity	Endurance, strength,	Exercises on bicycles, steps, rowing machines, and dance-	2-time/ week	Aerobic capacity	211.1±3.4vs 202.1±3.6	0.079
	test, lower limb explosive muscle strength test	proprioception, motor control training, circuit	specific exercises	75-minute 16-week	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 stabiliza- tion, 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.,	Aerobic endurance test, explosive	A circuit (endur- ance and strength), "Start-To-Run" program.	Dance-specific exercises	3-time/ week	Aerobic power	2.3±0.6 vs 2.4±0.6	0.025 *
2012 ³⁵				90-minute 24 weeks	Oxygen consump- tion	1.6±0.5 vs 1.7±0.5	0.045 *
	strength of				Resistance level	129.6±40.5 vs 139.8±43.5	0.019 *
	test				Strength increased	NR	NR

► Table 2 Continued.

Studies	Physical Fitness Test	Physical Intervention	on Training		Results				
		Training	Exercises	Intensity	Physical Fitness	Mean±SD (Pre vs Post; E vs C)	P value		
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	Ankle flexion and extension, Power bike exercise, closed-chain	7-time/ week	Ankle Functional score	57.6±8.7 vs 89.3±7.9	<0.001†		
		(resistance training), ROM, proprioception	exercise, diagonal, heel lift, jumping, balance exercise on device	~75-minute 6-week	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 a SD=Standa	nd †p<0.01; NR rd Deviation:	=Not Reported; ARON	Λ = Active Range of Motion; PROM = P	assive Range o	f Motion; E = Experimer	nt group; C=Contro	group;		

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 [31–33, 36–38], Modern [32, 38], Hip-hop [31], DanceSport [35] and traditional Korean [34] (► **Table 3**).

Dance injury tracking methods

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

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 [32–34], a rehabilitation laboratory [35], home [33], or pool [37]. Six studies had supervised interventions by either a physician [32, 33], physical therapist [30, 32–34, 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, 34–36, 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, 33–39]. 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, 36–39], 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

Studies	Genres	Met	hodology of Dance I	njury	Results of Dance Injury			
	1	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	Electronic medical record system	Injury rate was 82 % less	0.52-0.90	0.18	0.022 *	Decreased
		NASA injury guidelines.		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	Tradi- tional 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.,	Ballet	Time-loss (≥24	Injury surveillance	Injury count	355	174	<0.01†	Decreased
201333		hrs), classified	program (in-house	Injury incidence (M)	4.76	2.22	NR	Decreased
		or overuse	physiotherapists)	Injury incidence (F)	4.14	1.81	NR	
Chong et al., 2011 ³⁰	DanceS- port	NR	Ankle Functional Score	Ankle circumference	26.4±2.9	24.8±2.8	<0.01†	Decreased
* p<0.05 † p<0.0)1; ND = no d	difference after interve	ntion; NR = not report	ed; C=Control group; E	xp = Experime	nt group; SD = Sta	andard Devi	iation;

► Table 3	The Methodology and Results of Dance Inju	агу
-----------	---	-----

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.

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 an

other 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– 34, 37–39] and provided successful strength training interventions [30–33, 35, 37–39], 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, 32–34, 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, 32–36], 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, 37–39], 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 [30–36] 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.

Funding

This work was supported by the China Scholarship Council for their financial contribution (YD.).

Author Contributions

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.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

- [1] Allen N, Ribbans W, Nevill AM et al. Musculoskeletal injuries in dance: a systematic review. Int J Phys Med Rehabil 2014; 3: 1–8. doi: 10.4172/2329-9096.1000252
- [2] Hincapié CA, Morton EJ, Cassidy JD. Musculoskeletal injuries and pain in dancers: a systematic review. Arch Phys Med Rehabil 2008; 89: 1819–1829. doi:10.1016/j.apmr.2008.02.020
- [3] Smith PJ, Gerrie BJ, Varner KE et al. Incidence and prevalence of musculoskeletal injury in ballet: a systematic review. Orthop J Sports Med 2015; 3: 2325967115592621. doi:10.1177/2325967115592621
- [4] Swain CT, Bradshaw EJ, Ekegren CL et al. The epidemiology of low back pain and injury in dance: a systematic review. J Orthop Sports Phys Ther 2019; 49: 239–252
- [5] Vassallo AJ, Trevor BL, Mota L et al. Injury rates and characteristics in recreational, elite student and professional dancers: A systematic review. J Sports Sci 2019; 37: 1113–1122. doi:10.1080/02640414.201 8.1544538
- [6] Biernacki JL, Stracciolini A, Fraser J et al. Risk factors for lowerextremity injuries in female ballet dancers: a systematic review. Clin J Sport Med 2021; 31: e64–e79
- [7] Henn E, Smith T, Ambegaonkar J et al. Low back pain and injury in ballet, modern, and hip-hop dancers: a systematic literature review. Int J Sports Phys Ther 2020; 15: 671–687. doi:10.26603/ijspt202001
- [8] Bowerman EA, Whatman C, Harris N et al. A review of the risk factors for lower extremity overuse injuries in young elite female ballet dancers. J Dance Med Sci 2015; 19: 51–56
- [9] van Seters C, van Rijn RM, van Middelkoop M et al. Risk factors for lower-extremity injuries among contemporary dance students. Clin J Sport Med 2020; 30: 60–66
- [10] Dang Y, Koutedakis Y, Wyon M. Fit to Dance Survey: elements of lifestyle and injury incidence in Chinese dancers. Med Probl Perform Art 2020; 35: 10–18. doi:10.21091/mppa.2020.1002
- [11] Kenny S, Whittaker J, Emery C. Risk factors for musculoskeletal injury in preprofessional dancers: a systematic review. Br J Sports Med 2016; 50: 997–1003. doi:10.1136/bjsports-2015-095121
- [12] Laws H. Fit to Dance 2 Report of the Second National Inquiry into dancers' Health and Injury in the UK. London: Newgate Press;; 2005
- [13] Riding-McCabe T, Ambegaonkar J, Redding E et al. Fit to Dance Survey: a comparison with DanceSport injuries. Med Probl Perform Art 2014; 29: 102–110. doi:10.21091/mppa.2014.2021
- [14] Koutedakis Y, Cross V, Sharp N. The effects of strength training in male ballet dancers. Impulse 1996; 4: 210–219
- [15] Koutedakis Y, Khalouha M, Pacy P et al. Thigh peak torques and lower-body injuries in dancers. J Dance Med Sci 1997; 1: 12–15
- [16] Swain C, Redding E. Trunk muscle endurance and low back pain in female dance students. J Dance Med Sci 2014; 18: 62–66
- [17] Koutedakis Y, Jamurtas A. The dancer as a performing athlete: physiological considerations. Sports Med 2004; 34: 651–661. doi:10.2165/00007256-200434100-00003
- [18] Angioi M, Metsios G, Koutedakis Y et al. Physical fitness and severity of injuries in contemporary dance. Med Probl Perform Art 2009; 24: 26–29
- [19] Twitchett E, Brodrick A, Nevill AM et al. Does physical fitness affect injury occurrence and time loss due to injury in elite vocational ballet students? . J Dance Med Sci 2010; 14: 26–31

- [20] Campoy FAS, de Oliveira Coelho LR, Bastos FN et al. Investigation of risk factors and characteristics of dance injuries. Clin J Sport Med 2011; 21: 493–498
- [21] Angioi M, Metsios G, Twitchett E et al. Effects of supplemental training on fitness and aesthetic competence parameters in contemporary dance: a randomised controlled trial. Med Probl Perform Art 2012; 27: 3–8
- [22] Twitchett E, Angioi M, Koutedakis Y et al. Do increases in selected fitness parameters affect the aesthetic aspects of classical ballet performance. Med Probl Perform Art 2011; 26: 35–38
- [23] Koutedakis Y, Hukam H, Metsios G et al. The effects of three months of aerobic and strength training on selected performance and fitness-related parameters in modern dance students. J Strength Cond Res 2007; 21: 808–812. doi:10.1519/R-20856.1
- [24] Ambegaonkar JP, Chong L, Joshi P. Supplemental training in dance: a systematic review. Phys Med Rehabil Clin N Am 2021; 32: 117–135. doi:10.1016/j.pmr.2020.09.006
- [25] Page MJ, Moher D, McKenzie JE. Introduction to PRISMA 2020 and implications for research synthesis methodologists. Res Synth Methods 2022; 13: 156–163
- [26] Howick J, Chalmers I, Glasziou P et al. The 2011 Oxford CEBM Levels of Evidence (Introductory Document). Oxford Centre for Evidence-Based Medicine. Available from https://www.cebm.ox.ac.uk/resources/ levels-of-evidence/ocebm-levels-of-evidence
- [27] Schünemann H, Brożek J, Guyatt G et al. GRADE Handbook: Handbook for Grading the Quality of Evidence and the Strength of Recommendations Using the GRADE Approach, 2013. Available from https://gdt.gradepro.org/app/handbook/handbook.html
- [28] (Academy) AoNaD. Grade Definitions and Chart Strength of the Evidence for a Conclusion. In; 2021: www.andeal.org
- [29] Kmet LM, Lee RC, Cook LS. Standard Quality Assessment Criteria for Evaluating Primary Research Papers from a Variety of Fields. Edmonton: Alberta Heritage Foundation for Medical Research (AHFMR). AHFMR - HTA Initiative #13. 2004
- [30] Long KL, Milidonis MK, Wildermuth VL et al. The impact of dancespecific neuromuscular conditioning and injury prevention training on motor control, stability, balance, function and injury in professional ballet dancers: a mixed-methods quasi-experimental study. Int J Sports Phys Ther 2021; 16: 404–417. doi:10.26603/001c.21150
- [31] Viktoria KB, Brigitta S, Gabriella K et al. Application and examination of the efficiency of a core stability training program among dancers. Eur J Integr Med 2016; 8: 3–7. doi:10.1016/j.eujim.2016.11.004
- [32] Welsh TM, Jones GP III, Lucker KD et al. Back strengthening for dancers a within-subject experimental analysis. J Dance Med Sci 1998; 2: 141–148
- [33] Beckmann Kline J, Krauss JR, Maher SF et al. Core strength training using a combination of home exercises and a dynamic sling system for the management of low back pain in pre-professional ballet dancers a case series. J Dance Med Sci 2013; 17: 24–33. doi:10.12678/1089-313X.17.1.24
- [34] Kim G, Kim H, Kim WK et al. Effect of stretching-based rehabilitation on pain, flexibility and muscle strength in dancers with hamstring injury: a single-blind, prospective, randomized clinical trial. J Sports Med Phys Fitness 2018; 58: 1287–1295. doi:10.23736/s0022-4707.17.07554-5
- [35] Xiangxian CYaC. Exercise prescription for DanceSports ankle injury: an intervention study. Journal of Chuzhou University 2011; 13: 70–72

- [36] Vera AM, Barrera BD, Peterson LE et al. An injury prevention program for professional ballet: a randomized controlled investigation. Orthop J Sports Med 2020; 8: 12. doi:10.1177/2325967120937643
- [37] Allen N, Nevill AM, Brooks JHM et al. The effect of a comprehensive injury audit program on injury incidence in ballet: a 3-year prospective study. Clin J Sport Med 2013; 23: 373–378. doi:10.1097/ JSM.0b013e3182887f32
- [38] Roussel NA, Vissers D, Kuppens K et al. Effect of a physical conditioning versus health promotion intervention in dancers: A randomized controlled trial. Man Ther 2014; 19: 562–568. doi:10.1016/j.math.2014.05.008
- [39] Mistiaen W, Roussel NA, Vissers D et al. Effects of aerobic endurance, muscle strength, and motor control exercise on physical fitness and musculoskeletal injury rate in preprofessional dancers: an uncontrolled trial. J Manipulative Physiol Ther 2012; 35: 381–389. doi:10.1016/j. jmpt.2012.04.014
- [40] Kenny SJ, Palacios-Derflingher L, Whittaker JL et al. The influence of injury definition on injury burden in preprofessional ballet and contemporary dancers. J Orthop Sports Phys Ther 2018; 48: 185–193
- [41] Stephens N, Nevill A, Wyon M. Injury incidence and severity in pre-professional musical theatre dancers: a 5-year prospective study, Int J Sports Med 2021; 42: 1222–1227. doi: 10.1055/a-1393-6151
- [42] Wyon MA, Abt G, Redding E et al. Oxygen uptake during modern dance class, rehearsal, and performance. J Strength Cond Res 2004; 18: 646–649
- [43] Schantz P, Åstrand P-O. Physiological characteristics of classical ballet. Med Sci Sports Exerc 1984; 16: 472–476
- [44] McCabe TR, Ambegaonkar JP, Redding E et al. Fit to dance survey: a comparison with dancesport injuries. Med Probl Perform Art 2014; 29: 102–110. doi:10.21091/mppa.2014.2021
- [45] Dang Y, Koutedakis Y, Chen R et al. Prevalence and risk factors of dance injury during COVID-19: a cross-sectional study from university students in china. Front Psychol 2021; 12: 759413
- [46] Kozai AC, Twitchett E, Morgan S et al. Workload intensity and rest periods in professional ballet: Connotations for injury. Int J Sports Med 2020; 41: 373–379
- [47] Angioi M, Metsios G, Twitchett EA et al. Effects of supplemental training on fitness and aesthetic competence parameters in contemporary dance: a randomised controlled trial. Med Probl Perform Art 2012; 27: 3–8
- [48] Twitchett EA, Angioi M, Koutedakis Y et al. Do increases in selected fitness parameters affect the aesthetic aspects of classical ballet performance? Med Probl Perform Art 2011; 26: 35–38
- [49] Nowacki RM, Air ME, Rietveld AB. Use and effectiveness of orthotics in hyperpronated dancers. J Dance Med Sci 2013; 17: 3–10. doi:10.12678/1089-313x.17.1.3
- [50] van Rijn RM, Stubbe JH. Characteristics, properties, and associations of self-assessed pain questionnaires a literature review and prospective cohort study among dance students. Med Probl Perform Art 2020; 35: 103–109. doi:10.21091/mppa.2020.2016
- [51] Ekegren CL, Gabbe BJ, Finch CF. Sports injury surveillance systems: a review of methods and data quality. Sports Med 2016; 46: 49–65