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Authors	Ngo, Jake K.;Lu, Jie;Cloak, Ross;Wong, Del P.;Devonport, Tracey;Wyon, Matthew
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# Strength and conditioning in dance: A systematic review and meta-analysis

Jake K. Ngo<sup>1,2</sup>  | Jie Lu<sup>2</sup> | Ross Cloak<sup>2</sup> | Del P. Wong<sup>3,4</sup> | Tracey Devonport<sup>2</sup> | Matthew A. Wyon<sup>2,5</sup>

<sup>1</sup>Dance Science Laboratory, School of Dance, The Hong Kong Academy for Performing Arts, Wan Chai, Hong Kong

<sup>2</sup>Sport and Physical Activity Research Centre, University of Wolverhampton, Wolverhampton, UK

<sup>3</sup>College of Education, Psychology and Social Work, Flinders University, Adelaide, South Australia, Australia

<sup>4</sup>School of Nursing and Health Studies, Hong Kong Metropolitan University, Kowloon, Hong Kong

<sup>5</sup>National Institute of Dance Medicine and Science, Birmingham, UK

## Correspondence

Jake K. Ngo, The Hong Kong Academy for Performing Arts, X617, 6/F, TML Block, 1 Gloucester Road, Wan Chai, Hong Kong.  
 Email: [jakengo@hkapa.edu](mailto:jakengo@hkapa.edu)

## Abstract

To assess the evidence for the effect of strength and conditioning on physical qualities and aesthetic competence in dance populations, three electronic databases (PubMed, Scopus, SPORTDiscus) were searched (until September 2022) for studies that met the following criteria: (i) dancers aged >16 years; (ii) structured strength and conditioning intervention; and (iii) with physical qualities and aesthetic competence as outcome measures. Methodological quality and risk of bias of the included studies were assessed through the systematic review tool “QualSyst”. Meta-analyses of effect sizes (Hedges'  $g$ ) with forest plots explored the effects of the strength and conditioning interventions. Thirty-six studies met the inclusion criteria and were included in this review. Meta-analysis indicated strength and conditioning significantly ( $p < 0.05$ ) improved lower body power ( $g = 0.90$ , 95% CI: 0.53–1.27), upper body strength ( $g = 0.98$ , 95% CI: 0.39–1.57), lower body strength ( $g = 1.59$ , 95% CI: 0.97–2.22), and flexibility ( $g = 0.86$ , 95% CI: 0.05–1.66). Strength and conditioning interventions were found to be effective at improving physical qualities in dancers, recommending their participation in additional sessions to enhance overall fitness and ultimately dance performance. It is recommended that future strength and conditioning intervention research should include sample size calculations, with participants recruited from a specific dance genre and skill level in order to evaluate how strength and conditioning influences dance performance.

## KEYWORDS

aesthetics, dancing, physical fitness, plyometric exercise, resistance training, vibration

## Highlights

- Resistance training, plyometric training, whole body vibration training, and combined training are the most common strength and conditioning interventions in dance.
- Strength and conditioning, regardless of modalities, are found effective at improving some physical qualities in dancers.
- Dancers are recommended to participate in additional strength and conditioning for overall dance performance enhancement.

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## 1 | INTRODUCTION

Dance is a well-established performing art that includes a wide variety of genres. While dance is primarily recognized as an art form, it has been classified as an activity with high intensity intermittent in nature, and leading dancers to be regarded as performing athletes (Koutedakis & Jamurtas, 2004; Smol & Fredyk, 2012). Unlike most sports, where performance success can be characterized by goals scored, height jumped, or distance thrown, dance performance has a closer affinity to aesthetic sports such as synchronized swimming and gymnastics. Despite the similarities with aesthetic sports, dance performance lacks a universally recognized marking system. Instead, the term “aesthetic competence” is utilized. Unfortunately, recent literature does not offer a clear, objective definition of aesthetic competence. It is merely mentioned in dance performance assessment studies as one of the outcomes (Angioi et al., 2012; Koutedakis et al., 2007; Needham-Beck et al., 2019; Stalder et al., 1990). This ambiguity may lead to confusion, as the term appears to be solely technically related to dancers. To address this issue, we refer to the original definition of aesthetic competence by Friesen (1975), which defines it as the capacity to effectively convey the sensory, formal, and expressive attributes intended by the choreographer through the precise execution of movements characterized by energy, quality, and rhythm. This definition expands the meaning of a dancer's physical performance to include body alignment, movement dynamics, artistic interpretation, emotional expressivity, and the ability to engage and establish a connection with the audience.

Regardless of dance styles, dancers' physiological capabilities need to be developed to cope with their performance demands and sustain their bodies throughout the demanding daily schedule of classes, rehearsals and/or performances. Prioritizing dancers' physical conditioning supports their technical development, dance performance quality, training and performance schedules, as well as career longevity. Numerous studies have investigated the importance of physical fitness for dancers, with evidence suggesting a strong correlation between fitness levels, aesthetic competence, and dance techniques (Angioi et al., 2012; Annino et al., 2007). For example, Stalder et al. (1990) suggested that ballet technique performance scores significantly improved after including supplemental resistance training in ballet dancers. However, a recent study by Farmer and Brouner (2021) surveyed professional dancers, dance teachers, and student dancers across various dance genres, showing that the fear of muscle hypertrophy and implications for aesthetics still existed in the dance sector, presenting as a barrier to the adoption of physical training in dancers' training routines. Over time, discrepancies between technical abilities and physical fitness may pose potential physical issues to dancers, such as a higher risk of injury in hips or lower extremities (Koutedakis et al., 1999; Rajic et al., 2020) and dance-related aches or pains (Ramel et al., 1997). Therefore, strength and conditioning work can be introduced to minimize injury risk factors and promote well-being among dancers (Ambegaonkar et al., 2021).

Strength and conditioning (SC) is a commonly used training modality to improve an individual's physical fitness, enhancing performance, and ultimately developing overall athletic abilities (Weldon

et al., 2022). Within the context of dance, the integration of SC practices can offer similar benefits. SC is not only crucial for injury prevention but also plays a vital role in enhancing aesthetic competence during stage performances. Dancers, especially those involved in demanding dance routines, often struggle to maintain adequate physical conditioning due to tightly packed daily schedules (Roussel et al., 2014). By implementing SC training, dancers can improve their physical fitness, thereby positively influencing their technical execution, artistic expression, and overall stage presence (Angioi et al., 2012; Twitchett et al., 2011).

However, it should be acknowledged that SC requirements may vary depending on the dancer's role and gender within specific dance styles. In dance, certain roles involve lifting and supporting work with other dancers, which places greater demands on the musculoskeletal system and requires significant strength and stability (Wyon et al., 2011). Dancers in these roles, such as male ballet dancers or partners in contemporary dance, often need to possess a relatively higher level of upper body strength to execute lifts and partnering techniques safely. Building muscular strength, power, and endurance is essential to perform these roles effectively and reduce the risk of injury. It's important to note that the specific requirements of SC can vary among dance styles and individual choreographic works. Some dance styles may prioritize athleticism and physicality, while others emphasize grace, fluidity, and artistic expression. Therefore, the emphasis on SC may differ based on the stylistic demands and choreographic choices within a particular dance context.

Previous studies implemented extra supplemental training sessions in dancers' programmes and significantly improved the physical abilities of dancers. Some of them utilized combined training which incorporated more than one training modality into their programs (e.g., high-intensity interval training combined circuit training, plyometric and resistance combined training) significantly improved jumping and overall performance (Escobar-Álvarez et al., 2022; Twitchett et al., 2011). The mixed results of the review showcased that additional physical training, regardless of modalities, could boost dancers' fitness levels to meet the physical needs of their technical training. Although Ambegaonkar et al. (2021) provided an overview of the supplemental training with a systematic review, it did not answer the fundamental question as to whether there is a relationship between selective physical fitness parameters and dance performance (aesthetic competence), and if the implementation of SC interventions improves dance performance.

Through systematic review and meta-analyses, the current study aims to examine the strength of evidence that supplemental SC has a beneficial effect on physical qualities and aesthetic competence regardless of dance genre. This can provide a general overview of supplemental SC training for dance SC coaches or personnel.

## 2 | METHODS

This systematic review and meta-analysis were conducted and reported in accordance with the Cochrane Handbook (Higgins & Green, 2011) and the Preferred Reporting Items for Systematic

Reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al., 2021).

## 2.1 | Literature search

Three electronic databases (PubMed, Scopus, and SPORTDiscus) were searched systematically to identify eligible studies from the earliest date available to September 16, 2022. Using Boolean logic, authors used a set of search terms to locate experimental research articles in English language only (Supplementary Table S1). Following the formal systematic searches, manual searches were conducted on the reference list of included studies and review papers related to the topic for identifying pertinent literature.

## 2.2 | Study selection and eligibility criteria

Studies were included if they (i) published in English as peer-reviewed empirical research; (ii) included participants above the age of 16 years old and from a dance population (defined as participants who engaged in dance training from universities, vocational institutes, or dance companies); (iii) were primary sources that evaluated the effects of SC intervention on measures of aesthetic competence or physical qualities (including physical and physiological aspects); and (iv) included participants with no clinical symptoms. To be included in the meta-analysis, studies needed to meet the following additional criteria: (i) studies that examined the effects of SC intervention compared to a control or comparison group; and (ii) data were reported in means and standard deviations for the intervention and control groups at pre- and post-test. Studies were excluded if they (i) had insufficient data or unclear description of interventions; (ii) had participants below the age of 16 years old; (iii) were systematic or narrative reviews, observational studies, case reports, letters to the editor, or conference abstracts; (iv) did not include and report on measures of aesthetic competence or physical qualities.

After retrieving articles from databases, all duplicates and non-peer-reviewed articles were first removed by the database filters. Based on the above-defined inclusion and exclusion criteria, two independent reviewers (JKN and JL) screened the titles and abstracts using a standardized form to determine their eligibility. They were blinded to decisions until the end of the screening process. Full-text screening followed the same procedures and included articles that were agreed upon through discussion. Potential discrepancies between the two reviewers on study conditions were resolved by consensus with a third reviewer (MW). A flowchart of the search process and study selection is presented in Figure 1.

## 2.3 | Data extraction

The first reviewer (JKN) extracted data from the included studies using a standardized form created in Microsoft Excel, and then the

second reviewer (JL) independently verified all results. If there were any discrepancies between these two reviewers in the extracted data, a re-check of the study information was conducted. The following data were extracted from each included study: (1) general characteristics of publication (e.g., study design, year of publication); (2) participant characteristics (e.g., sample size, age, training status); (3) intervention data (e.g., intervention duration, frequency, type of interventions); (4) outcome measures (e.g., lower body power, lower body strength); (5) results in respect to the SC interventions. In addition, if studies measured outcomes multiple times, results from the last time point were extracted for data synthesis. If studies used multiple testing items (i.e., leg press vs. leg extension) for a single physical quality (i.e., lower body strength), only the most commonly used item among studies was extracted. A combined mean and standard deviation were calculated if there were separated unilateral measurements (i.e., left vs. right). If there were incomplete or unclear data in a given study, authors of the primary studies were contacted to request the data during pre- and post-intervention.

## 2.4 | Methodological quality of included studies

All included studies were assessed for methodological quality using the systematic review tool "QualSyst" by Kmet et al. (2004). The tool consists of a total of 14 items rated as Yes = 2, Partial = 1, No = 0, and NA = not applicable in the checklist for assessing the quality of quantitative studies and risk of bias for the included studies. The summary score was calculated using the total sum ((number of "yes" \* 2) + (number of "partials" \* 1)) divided by the total possible sum (28 - (number of "NA" \* 2)) in each study assessed. Summary scores ranged from 0 to 28 points with higher scores representing higher quality research. Studies were rated independently by two reviewers (JKN and JL) and disagreements between ratings were resolved by discussion or sought from a third reviewer (MW) if no consensus was reached by discussion. The data extraction and rating process were assisted by a reference manager software (Endnote™ 20.4.1, Clarivate Analytics) and a data extraction form in Microsoft Excel 365.

## 2.5 | Meta-analyses

All analyses were conducted using Cochrane Collaboration Review Manager (RevMan) 5.4.1. Meta-analysis was carried out when there was sufficient data ( $\geq 3$  studies) in an outcome measure (Ramirez-Campillo et al., 2020). Low sample sizes (fewer than 20 participants) were found in most of the included studies and an adjustment in the calculation for a small sample was needed (Yagiz et al., 2022). For this reason, Hedges' (adjusted)  $g$  effect sizes (standardized mean difference) were calculated using the mean difference from baseline and the standard deviation of these mean differences for the conditioning and control groups. When the mean and standard deviation of the change of scores or correlation values were not presented in the studies, the change of scores of the conditioning and control groups were

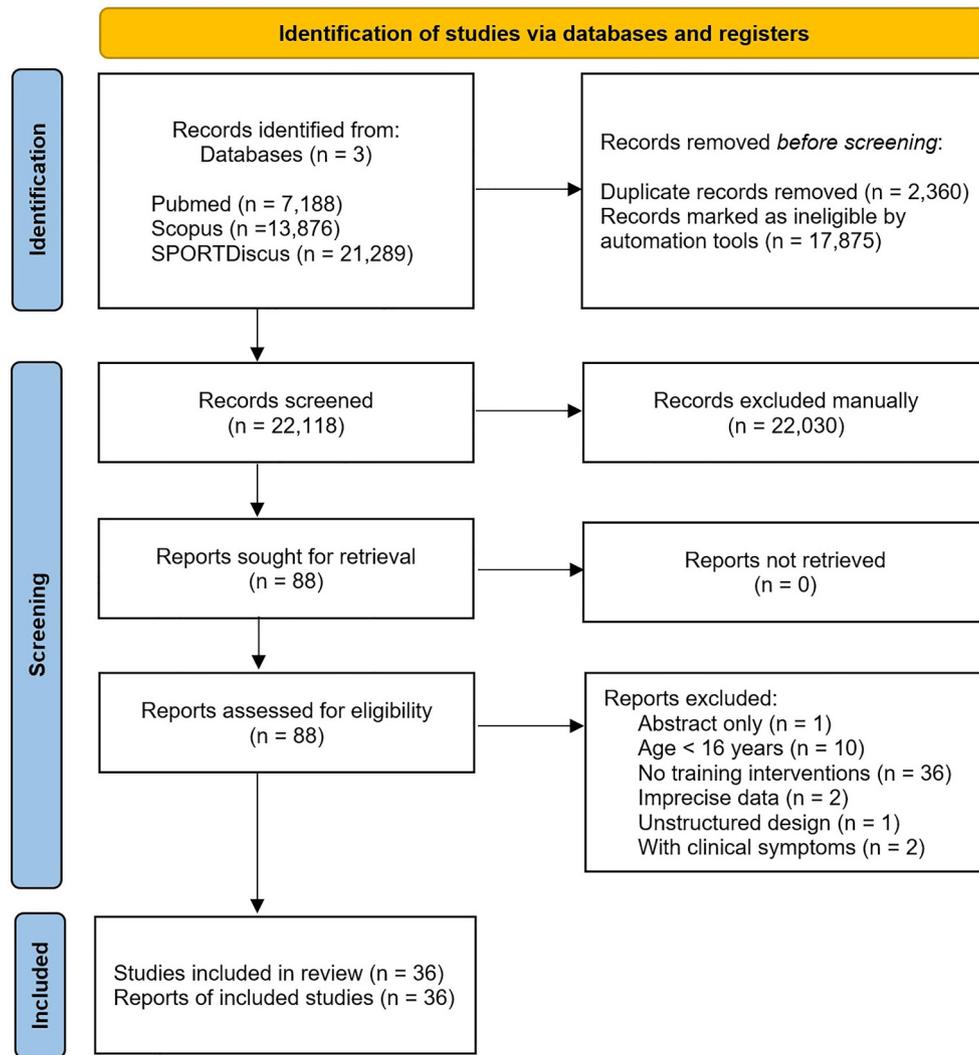


FIGURE 1 2020 Preferred reporting items for systematic reviews (PRISMA) flow chart.

calculated by a formula used in Yagiz et al. (2022) and applied a conservative estimate of correlation value 0.7 to the formula. Effect sizes were considered as small (0.2), medium (0.5) or large (0.8) (Brydges, 2019), and were considered statistically significant at a  $p$  value of  $<0.05$ . A random effect model for continuous data, inverse variance, and a 95% CI were used in the meta-analysis. Between-study variability was examined using the  $I^2$  measure of heterogeneity. It is expressed as a percentage between 0 and 100, and provides a measure of how much of the variability between studies is due to heterogeneity rather than chance. Heterogeneity thresholds were set as  $I^2 = 25%$  (low),  $I^2 = 50%$  (moderate) and  $I^2 = 75%$  (high) (Higgins et al., 2003).

### 3 | RESULTS

#### 3.1 | Study selection and characteristics

The database search preliminarily obtained 42,353 potential studies and was documented in the PRISMA flow diagram (Figure 1). After

the screening process, a total of 36 studies met the criteria and 17 out of 36 studies were included in the meta-analysis eventually. Out of the initial pool of 36 studies, eight did not incorporate a comparison group, such as a control group or a group utilizing a different training method. Furthermore, the formation of the forest plot for the meta-analysis only included physical parameters with more than three studies available. Due to these two factors, the final meta-analysis consisted of 17 studies only. All included studies provided mean and standard deviation of pre- and post-training data for group comparison. Overall, 29 effect sizes could be extracted from these studies in the meta-analysis.

#### 3.2 | Risk of bias in studies and reporting biases

Results of the methodological quality assessment are provided in Table 1. The mean rating of study quality assessed by the standard quality assessment criteria was 70%. Three out of 34 included studies (Karim et al., 2019; Roussel et al., 2014; Wyon et al., 2013) had a

TABLE 1 Quality assessment of the intervention studies according to Kmet et al. (2004).

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Total sum	Total possible sum	Summary score (%)
Ahearn et al. (2018)	2	2	1	2	0	0	0	1	0	1	0	0	1	1	11	28	39
Angioi et al. (2012)	2	2	2	2	2	0	0	2	0	2	2	2	2	2	22	28	79
Annino et al. (2007)	1	2	2	2	1	0	0	2	0	2	2	1	2	2	19	28	68
Brown et al. (2007)	2	2	2	1	1	0	0	2	0	2	2	2	2	2	20	28	71
Escobar Álvarez et al. (2020)	2	2	2	2	0	0	0	2	1	2	2	1	2	2	20	28	71
Escobar-Álvarez et al. (2022)	2	2	2	2	0	0	0	2	2	2	2	1	2	2	21	28	75
Grigoletto et al. (2020)	2	2	2	2	1	0	0	2	0	2	2	2	2	2	21	28	75
Griner et al. (2003)	2	1	2	2	NA	0	0	1	0	1	1	0	1	1	12	26	46
Grossman and Wilmerding (2000)	2	2	2	0	0	0	0	2	0	1	2	1	2	2	16	28	57
Kalaycioglu et al. (2020)	2	2	2	2	NA	0	0	2	0	2	2	2	2	2	20	26	77
Karim et al. (2019)	2	2	2	2	1	0	0	2	2	2	2	2	2	2	23	28	82
Kolokythas et al. (2022)	2	2	2	2	2	0	0	2	0	2	2	2	2	2	22	28	79
Koutedakis and Craig Sharp (2004)	2	2	2	1	1	0	0	2	0	2	2	1	2	2	19	28	68
Koutedakis et al. (1996)	2	2	2	1	1	0	0	2	0	2	2	0	2	2	18	28	64
Koutedakis et al. (2007)	2	2	2	2	1	0	0	2	1	2	2	2	2	2	22	28	79
Lin et al. (2021)	2	2	2	2	NA	0	0	2	0	2	2	2	2	2	20	26	77
Long et al. (2021)	2	1	1	1	NA	0	0	2	0	2	2	2	2	2	17	26	65
Marshall and Wyon (2012)	2	2	2	2	1	0	0	2	0	2	2	2	2	2	21	28	75
McLain et al. (1997)	1	1	1	2	0	0	0	1	0	1	2	0	2	2	13	28	46
Mistiaen et al. (2012)	2	2	0	2	0	0	0	2	0	2	2	1	2	2	17	28	61
Rajic et al. (2020)	2	2	2	2	0	0	0	2	0	2	2	2	1	2	19	28	68
Ramel et al. (1997)	2	2	2	2	1	0	0	2	0	2	1	0	1	2	17	28	61
Rice et al. (2021)	2	2	2	2	0	0	0	2	0	2	2	2	2	2	20	28	71
Roussel et al. (2014)	2	2	2	2	2	2	0	2	1	2	2	2	2	2	25	28	89
Sanders et al. (2020)	2	2	2	2	1	0	0	2	0	2	2	2	2	2	21	28	75
Skopal et al. (2020)	2	2	2	2	1	0	0	2	0	2	2	2	2	2	21	28	75
Smol and Fredyk (2012)	2	2	2	2	NA	0	0	2	0	2	2	2	1	2	19	26	73
Stalder et al. (1990)	2	2	1	2	0	0	0	2	0	2	2	2	2	2	19	28	68
Stošić et al. (2019)	2	2	2	2	0	0	0	2	2	2	2	2	2	2	22	28	79
Twitchett et al. (2011)	2	2	2	2	1	0	0	2	0	2	2	2	2	2	21	28	75
Vetter and Dorgo (2009)	2	2	2	2	0	0	0	2	0	2	2	2	2	2	20	28	71
Watson et al. (2017)	2	2	2	2	NA	0	0	2	1	2	2	1	2	2	20	26	77
Welsh et al. (1998)	2	1	2	1	0	0	0	2	0	2	0	0	2	2	14	28	50
Wyon et al. (2010)	2	2	2	2	1	0	0	2	0	2	2	2	2	2	21	28	75
Wyon et al. (2013)	2	2	2	2	2	0	0	2	2	2	2	2	2	2	24	28	86
Zhang et al. (2021)	2	1	2	2	2	0	0	2	1	2	2	2	2	2	22	28	79

Note: Item 1: Question or objective sufficiently described?; Item 2: Design evident and appropriate to answer study question?; Item 3: Method of subject selection (and comparison group selection, if applicable) or source of information/input variables (e.g., for decision analysis) is described and appropriate.; Item 4: Subject (and comparison group, if applicable) characteristics or input variables/information (e.g., for decision analyses) sufficiently described?; Item 5: If random allocation to treatment group was possible, is it described?; Item 6: If interventional and blinding of investigators to intervention was possible, is it reported?; Item 7: If interventional and blinding of subjects to intervention was possible, is it reported?; Item 8: Outcome and (if applicable) exposure measure(s) well defined and robust to measurement/misclassification bias? Means of assessment reported?; Item 9: Sample size appropriate?; Item 10: Analysis described and appropriate?; Item 11: Some estimate of variance (e.g., confidence intervals, standard errors) is reported for the main results/outcomes (i.e., those directly addressing the study question/objective upon which the conclusions are based?); Item 12: Controlled for confounding?; Item 13: Results reported in sufficient detail?; Item 14: Do the results support the conclusions?.

Abbreviations: 0, no; 1, partial; 2, yes; NA, not applicable.

rating higher than 80%. Three studies scored lower than 50% (Ahearn et al., 2018; Griner et al., 2003; McLain et al., 1997). The range of quality scores is between 39% (Ahearn et al., 2018) and 89% (Roussel et al., 2014) for all the included studies. The two reviewers agreed with 95.2% of the 504 assessment criteria (36 studies  $\times$  14 scores). Twenty-four scoring items were moderated by the third reviewer (Table 1).

### 3.3 | Study characteristics

The main characteristics of the participants and interventions are presented in Table 2. The included studies involved 890 participants, of which 629 participants were in training intervention groups and 261 were in control groups. Of the included studies, 22 assessed only females; 1 assessed only males; 10 studies assessed both sexes and the remaining 3 studies did not clearly state the sex of participants.

### 3.4 | Meta-analyses results

There were sufficient data in four physical parameters for meta-analysis of the SC effect. (1) 411 participants (223 conditioning vs. 188 control, Supplementary Figure S1) in lower body power (Angioi et al., 2012; Annino et al., 2007; Brown et al., 2007; Escobar Álvarez et al., 2020, 2022; Grigoletto et al., 2020; Karim et al., 2019; Marshall & Wyon, 2012; Sanders et al., 2020; Stošić et al., 2019; Wyon et al., 2010), (2) 52 participants (28 conditioning vs. 24 control, Supplementary Figure S2) in upper body strength (Koutedakis et al., 1996; Sanders et al., 2020; Vetter & Dorgo, 2009), (3) 61 participants (31 conditioning vs. 30 control, Supplementary Figure S3) in lower body strength (Brown et al., 2007; Sanders et al., 2020; Vetter & Dorgo, 2009), and (4) 77 participants (42 conditioning vs. 35 control, Supplementary Figure S4) in flexibility (Koutedakis et al., 2007; Marshall & Wyon, 2012; Skopal et al., 2020; Stalder et al., 1990). Due to high variation in scales used in studies (Angioi et al., 2012; Koutedakis et al., 2007; Stalder et al., 1990) assessing aesthetic competence, meta-analysis was failed to conduct on this parameter. The rest of the parameters such as balance, isometric strength were insufficient for meta-analysis.

The pooled estimate of effect for SC showed a large effect on lower body power ( $g = 0.90$ , 95% CI: 0.53–1.27,  $I^2 = 65\%$ ,  $p < 0.05$ ), upper body strength ( $g = 0.98$ , 95% CI: 0.39–1.57,  $I^2 = 0\%$ ,  $p < 0.05$ ), lower body strength ( $g = 1.59$ , 95% CI: 0.97–2.22,  $I^2 = 0\%$ ,  $p < 0.05$ ), and flexibility ( $g = 0.86$ , 95% CI: 0.05–1.66,  $I^2 = 61\%$ ,  $p < 0.05$ ). We found no evidence of publication bias for these outcome measures.

## 4 | DISCUSSION

This systematic review with meta-analysis examined physical qualities and aesthetic competence changes by SC interventions as dancers' supplemental training. The included studies involved dance

participants from ballet, classic ballet, contemporary dance, modern dance, jazz, and ballroom dance, with participants aged between 16 and 47 years old and dance experience between 5.0 and 19.9 years. Intervention periods lasted between four (Marshall & Wyon, 2012) to twenty-four (Mistiaen et al., 2012) weeks with one (Roussel et al., 2014; Twitchett et al., 2011) to six (Smol & Fredyk, 2012) sessions a week. The main findings in this meta-analysis showed large effects on improving lower body power ( $g = 0.90$ ), upper body strength ( $g = 0.98$ ), lower body strength ( $g = 1.59$ ), and flexibility ( $g = 0.86$ ) when applying conditioning interventions to dance populations, suggesting SC provided beneficial effects toward the physical parameters assessed. Training modalities reported from these studies included resistance training (Brown et al., 2007; Escobar Álvarez et al., 2020; Grigoletto et al., 2020; Koutedakis et al., 1996; Sanders et al., 2020; Stalder et al., 1990; Stošić et al., 2019; Vetter & Dorgo, 2009), plyometric training (Brown et al., 2007; Escobar-Álvarez et al., 2022; Skopal et al., 2020), whole body vibration (Annino et al., 2007; Karim et al., 2019; Marshall & Wyon, 2012; Wyon et al., 2010), and combined training (Angioi et al., 2012; Koutedakis et al., 2007).

### 4.1 | Lower body power

Eleven studies examined the effect of SC on lower body power. Lower body power is often considered one of the most important physical attributes for dancers as jumping is an integral part of most dance performances (Rafferty, 2010). The included studies utilized various SC intervention modalities including resistance training (Brown et al., 2007; Escobar Álvarez et al., 2020; Grigoletto et al., 2020; Sanders et al., 2020; Stošić et al., 2019), plyometric training (Brown et al., 2007; Escobar-Álvarez et al., 2022), whole-body vibration (Annino et al., 2007; Karim et al., 2019; Marshall & Wyon, 2012; Wyon et al., 2010), and combined training (Angioi et al., 2012). The small to large effects of these SC methods suggested they can be tools to improve jump performance. Furthermore, the included studies assessed lower body power differently in terms of testing protocol, for example, Brown et al. (2007) performed a standing jump while Annino et al. (2007) performed a counter-movement jump. The difference in jumping techniques may pose a potential jump height variation among dancers as reflected by moderate heterogeneity ( $I^2 = 65\%$ ).

### 4.2 | Upper and lower body strength

Four studies examined the effect of SC on the upper body (Koutedakis et al., 1996; Sanders et al., 2020; Vetter & Dorgo, 2009) and lower body strength (Brown et al., 2007; Sanders et al., 2020; Vetter & Dorgo, 2009). Significant improvements were observed in studies involving both upper and lower body strength interventions. The reported resistance training intervention studies (Koutedakis et al., 1996; Sanders et al., 2020; Vetter & Dorgo, 2009) all increased dancers' upper body strength possibly through neuromuscular

TABLE 2 Summary of included studies.

Participant characteristics										Intervention			Outcomes	
Study	Study design	Study group	Sample	Age	Training level	Dance experience (year)	Dance genre	Conditioning method	Session length (min)	Frequency (per week)	Duration (week)	Outcomes measure(s)	Response(s)	
Ahearn et al. (2018)	CR	Conditioning (n = 20)	20F	16–21 (mean = 19.3)	Post-secondary dance program	13.5	NR	Pilates training with one apparatus and one mat session	45	2	14	Postural misalignment, abdominal strength, flexibility	↓ number of postural misalignments ↑Hamstring flexibility ↓Lower abdominal muscle strength	
Angioi et al. (2012)	RCT	Conditioning (n = 12) Control (n = 9)	24F	Conditioning: 27.0 ± 4.3 Control: 27.0 ± 7.9	Preprofessional and professional	NR	Contemporary	10-station circuit training followed by whole-body vibration training	60	2	6	Lower body muscular power, upper body muscular endurance, aerobic capacity, aesthetic competence	↓Lower body muscular power ↑Upper body muscular endurance ↑Aerobic fitness ↑Aesthetic competence	
Annino et al. (2007)	RCT	Conditioning (n = 11) Control (n = 11)	22F	Conditioning: 21.0 ± 1.3 Control: 21.2 ± 1.6	Full-time dance students	≥8	Ballet	Vertical sinusoidal whole-body vibration	NR	3	8	Lower body power, mechanical power	↑Countermeovement jump ↑Average leg-press power and velocity	
Brown et al. (2007)	RCT	Plyometrics (n = 6) Resistance training (n = 6) Control (n = 6)	18F	Plyometric training: 20.3 ± 1.5 Resistance training: 19.3 ± 1.2 Control: 19.5 ± 1.0	Collegiate dancers	NR	NR	Plyometric training for total of 96 touches per session, resistance training	NR	2	6	Lower body power, aesthetic jumping ability, maximal strength	Plyometric group: ↑ leg press strength ↑Standing vertical jump height ↑Aesthetic jump height Resistance training group: ↑Leg press strength ↑Leg curl strength ↑Mean anaerobic power ↑Aesthetic jump height ↑Aesthetic ability to point the feet in the air	
Escobar Álvarez et al. (2020)	NRCT	Low force-velocity deficit (n = 16) High force-velocity deficit (n = 20) Control (n = 10)	46F	18.9 ± 11	Professional	≥6	Classic ballet	Strength training	60	2	9	Lower body power, force-velocity profile	↑Countermeovement jump height ↑Theoretical maximal force and theoretical maximal velocity Detrimental increase of the actual imbalance between force and velocity	
Escobar Álvarez et al. (2022)	NRCT	Plyometric training (n = 26) Combined training (n = 29) Control (n = 26)	41F 40M	22.9 ± 3.7	Professional	≥12	Classic ballet	Plyometric training, combined training (resistance and plyometric training)	60	2	9	Lower body power	↑Countermeovement jump height, squat jump height, and sauté height for both plyometric and combined training	
Grigoletto et al. (2020)	NRCT	Kettlebell training (n = 13) Control (n = 10)	23F	21.7 ± 3.1	NR	≥10	Ballet	Strength training: One hand 100 swings (50 on the left and 50 on the right) in 5 min and 10 Turkish get-ups (TGUs) in 10 min	NR	3	20	Balance, lower body power, maximal oscillation in the antero-posterior (AP) and medio-lateral (ML)	↑Balance in the kettlebell group (antero-posterior and medio-lateral oscillation) with both legs and eyes open in all (Continues)	

TABLE 2 (Continued)

Study	Participant characteristics				Intervention			Outcomes					
	Study design	Study group	Sample	Age	Training level	Dance experience (year)	Dance genre	Conditioning method	Session length (min)	Frequency (per week)	Duration (week)	Outcome measure(s)	Response(s)
Griner et al. (2003)	CR	Plyometric training (n = 12)	12F	19.7 ± 1.5	Collegiate dancers	NR	NR	Plyometric training	40	3	7	Lower body power, strength	↑Right quadriceps peak torque at 180 deg/s ↑Vertical jump height ↑Two-step jump off the right foot
Grossman & Wilmerding (2000)	NRCT	Treatment (n = 8) Control (n = 8)	16F	NR	Intermediate and advanced dance students	NR	Modern dance or ballet	Therapeutic exercises following technique class	5	3	6	Leg height of extension in à la seconde	↑Mean height of the gesture leg
Kalaycioglu et al. (2020)	CR	Treatment (n = 24)	24F	21.8 ± 2.2	Pre-professional	≥7	Ballet and contemporary dance	Core strengthening training program, pilates	45-60	3	8	Lower body power, flexibility, dynamic balance, coordination, proprioception, hip flexion & extension isokinetic strength	↑Vertical jump performance ↑Dynamic balance ↑Proprioception ↑Coordination ↓Peak torque values for the hip flexor muscle isokinetic test of the dancers
Karim et al. (2019)	RCT	Static demi-plié (0 Hz) (n = 15) Static demi-plié (30 Hz) (n = 14) Dynamic demi-plié (0 Hz) (n = 15) Dynamic demi-plié (30 Hz) (n = 15)	59F	25.8 ± 3.8	Professional	NR	Contemporary	Whole-body vibration	1.25	NR	24	Lower body power, dynamic balance	↑Jump height in static demi-plié group 30 Hz frequency resulted in ↑static balance for both static and dynamic demi-plié
Kolokythas et al. (2022)	RCT	Intervention (n = 11) Control (n = 11)	17F 5M	16.6 ± 0.5	Pre-professional	NR	Ballet	Neuromuscular training	20-30	5	10	Lower body power, isometric strength	No significant effect
Koutedakis & Sharp (2004)	RCT	Experimental (n = 12) Control (n = 10)	22F	25.0 ± 1.3	Professional	NR	Ballet	Strength training on hamstrings and quadriceps	50	3	12	Quadriceps and hamstring torque level, sum of skinfolds, fat-free mass, circumference	↑Hamstring and quadriceps peak torque ↓Sum of skinfolds ↑Fat-free mass
Koutedakis et al. (1996)	RCT	Experimental (n = 9) Control (n = 6)	15M	24.1 ± 5.2	Professional	≥10	Ballet	Upper body strength training	90	3	12	Sum of skinfolds, upper body strength, handgrip strength, peak torques for elbow flexion and extension	↓Percent body fat ↑Handgrip strength ↑Upper body strength ↑Elbow flexion and extension peak torques

TABLE 2 (Continued)

Study	Participant characteristics					Intervention			Outcomes				
	Study design	Study group	Sample	Age	Training level	Dance experience (year)	Dance genre	Conditioning method	Session length (min)	Frequency (per week)	Duration (week)	Outcome measure(s)	Response(s)
Koutedakis et al. (2007)	RCT	Exercise (n = 19) Control (n = 13)	27F 5M	Exercise: 20.1 ± 2.7 Control: 19.4 ± 2.1	Dance students	NR	Modern dance	Aerobic training, strength training	20-50	2-3	12	Sum of skinfolds, flexibility, maximal oxygen uptake, leg strength, technique	↑Flexibility ↑VO2max ↑Leg strength ↑Dance score
Lin et al. (2021)	CR	Training (n = 16)	16F	17.5 ± 1.4	College dancers	10.7 ± 2.9	Ballet	Plyometric training, proprioception training, core stability training, ankle muscle strengthening and stretching	60	3	6	Absolute error of active joint reposition sense, balance, center of pressure parameters	↓Absolute ankle joint reposition errors in dorsiflexion, plantarflexion, eversion ↓Average COP speed at pre-equilibrium during grand-ple movement and pre-equilibrium phase of releve en demi-pointe ↓Maximum COP displacement in the medial-lateral direction at pre-equilibrium phase during grand-ple and releve en demi-pointe movements
Long et al. (2021)	CR	Training (n = 6)	4F 2M	22.8 ± 1.5	4 professionals, 2 apprentice/trainees	≥10	Contemporary ballet	Agility, plyometric and strength training	30	2	5	Motor control, balance, ankle and knee stability, hip stability, upper extremity stability	↑Composite modified star excursion balance test ↑Single leg hop for distance ↑Upper extremity closed kinetic chain test
Marshall & Wyon (2012)	RCT	Intervention (n = 10) Control (n = 10)	20F	Intervention: 22.0 ± 1.2 Control: 25.0 ± 5.9	Full time dance students	Intervention: 16.0 ± 5.7 Control: 13.0 ± 6.4	Modern dance	Whole-body vibration	NR	2	4	Lower body power, active hip range, circumference	↑Vertical jump ↑Active ROM
McLain et al. (1997)	NRCT	Experimental (n = 14) Control (n = 10)	19F 5M	Experimental: 21.9 Control: 20.4	University dance students	6.8 Control: 9.0	Ballet and/or modern dance	Pilates training on reformer	60-90	2	8	Supined jump height, pelvic alignment while executing jumps in a standing position	↑ Jump height for each group, but no significant difference in the amount of improvement between the groups (Continues)

TABLE 2 (Continued)

Participant characteristics										Intervention			Outcomes		
Study	Study design	Study group	Sample size	Age	Training level	Dance experience (year)	Dance genre	Conditioning method	Session length (min)	Frequency (per week)	Duration (week)	Outcome measure(s)	Responses		
Mistiaen et al. (2012)	CR	Training (n = 27)	27	20.3 ± 2.4	Preprofessional dancers	NR	NR	Endurance, strength, and motor control exercise program	90	3	24	Aerobic endurance, aerobic power index, power output, percentage decrease of heart rate 1 minute after maximal heart rate during recuperation, lower body power, body composition	↓Waist:hip ratio ↓Sum of subcutaneous skin thickness ↑Aerobic endurance ↑Muscle strength		
Rajic et al. (2020)	NRCT	Intervention (n = 10) Control (n = 12)	22F	Intervention: 24.4 ± 6.3 Control: 22.9 ± 5.6	Professional dancers, freelance dancers, collegiate level dancers, or retired dancers within 2 years from professional dance	≥8	NR	Resistance training	45-60	2-3	9	Lower body power, net joint moments, propulsive and landing moments, joint angles	↑Peak hip joint moment ↑Jump height		
Ramel et al. (1997)	RCT	Training (n = 10) Control (n = 10)	10F 10M	Training: 19-47 Control: 20-41	Professional dancers	NR	Ballet	Aerobic training	30	≥2	10	Maximal oxygen uptake, lactic acid level, workload	↑Maximal oxygen uptake		
Rice et al. (2021)	NRCT	Training (n = 7) Control (n = 7)	NR	Training: 24.9 ± 6.3 Control: 23.3 ± 4.4	NR	Training: 19.9 ± 5.6 Control: 19.4 ± 5.0	Ballet, jazz, modern, contemporary	Ankle-specific block progression training (isometric, dynamic constant external resistance (DCER), accentuated eccentric loading (AEL), and plyometric training)	30-45	2	12	Maximal voluntary isometric plantarflexion strength, Saut de chat, leap height, and peak power, Saut de chat, leap joint kinetics and kinematics, Achilles tendon stiffness	↑Saut de chat ankle peak power ↑Braking ankle stiffness ↑Center of mass peak power ↑Leap height ↑MVIC at 10° and 0° along with ↑AT stiffness		
Roussel et al. (2014)	RCT	Conditioning (n = 23) Intervention (n = 21)	38F 6M	Conditioning: 19.9 ± 2.0 Intervention: 19.6 ± 2.4	Preprofessional dancers	NR	NR	Conditioning: Aerobic endurance, strength, proprioception and motor control training Intervention: Theoretical and practical educational sessions, but no active exercises	150	1	16	Aerobic capacity, explosive strength	No significant effect		
Sanders et al. (2020)	RCT	Experimental (n = 8) Control (n = 8)	16F	Experimental: 19.3 ± 1.3 Control: 19.6 ± 1.3	Collegiate dancers	≥5	NR	Resistance training either an upper or lower body routine	NR	3	8	Body composition, lower body power, muscular strength, maximal oxygen uptake	↑Strength ↑Power		

TABLE 2 (Continued)

Participant characteristics										Intervention			Outcomes	
Study	Study design	Study group	Sample	Age	Training level	Dance experience (year)	Dance genre	Conditioning method	Session length (min)	Frequency (per week)	Duration (week)	Outcome measure(s)	Response(s)	
Stopal et al. (2020)	RCT	Intervention (n = 6) Control (n = 5)	11F	19.0 ± 2.0	Intermediate level	9.0 ± 5.3	Contemporary	Rhythmic gymnastics-based supplementary training (plyometric training)	60	2	8	Power, flexibility, range of motion	↑Right and left leg grand jeté ROM ↑Right leg peak kicking torque ↑Left leg grand jeté height	
Smol & Fredyk (2012)	CR	Training (n = 6)	6F	27.5 ± 6.5	Professional	≥12	Ballet	Low-intensity aerobic training	30	6	6	Body composition, maximal oxygen uptake, blood lactate concentration	↑Maximal oxygen uptake Markedly shifted AT toward higher absolute workload	
Stalder et al. (1990)	NRCT	Resistance-trained (n = 7) Control (n = 7)	14F	Resistance-trained: 23.3 ± 4.3 Control: 20.4 ± 3.3	College dancers	5-12	Ballet	Resistance training	NR	3	9	Isometric strength, flexibility, anaerobic power, muscular endurance, ballet technique performance	↑ adductor strength ↑Lateral hip flexibility ↑Anaerobic power ↑Muscular endurance ↑Ballet precision and overall performance in ballet technique	
Stošić et al. (2019)	NRCT	Experimental (n = 27) Control (n = 27)	54F	19-24	University dance students	NR	NR	Circuit training (4 weeks), plyometric training (4 weeks), then strength plus plyometric training (2 weeks)	90	3	10	Coordination, lower body power	↑ Coordination (5 items except agility test) ↑ Power	
Twitchett et al. (2011)	RCT	Intervention (n = 9) Control (n = 8)	14F 3M	Intervention: 19.0 ± 1.0 Control: 19.0 ± 2.34	Pre-professional	NR	Ballet	High-intensity interval training, circuit training	60	1	10	Performance proficiency	↑Total performance score ↑Control of movement ↑Skill level (virtuosity) ↑Overall performance	
Vetter & Dorgo (2009)	NRCT	Experimental (n = 11) Control (n = 8)	19F	Experimental: 20.1 ± 2.3 Control: 21.0 ± 1.9	College dancers	Experimental: 7 Control: 12	NR	Partner's improvisational resistance training	60	3	8	Muscular strength, circumference, body composition	↓ Waist and hip circumference measures ↑All seven 1RM strength measures and absolute and relative strength improvements in 5 measures	
Watson et al. (2017)	CR	Intervention (n = 24)	24F	19.7 ± 1.1	University dance team	9.3 ± 4.6	NR	Supervised and non-supervised core (trunk musculature) exercise training program	NR	3	9	Transversus abdominis activation, dance performance, balance, muscle performance	↑Transverse abdominals activation and thickness ↑Number of pirouettes ↑ Single leg balance in 'pas de deux' ↑Bilateral anterior reach for the SEBT ↑All strength measures except single leg heel raise	

(Continues)

TABLE 2 (Continued)

Study	Participant characteristics					Intervention			Outcomes				
	Study design	Study group	Sample	Age	Training level	Dance experience (year)	Dance genre	Conditioning method	Session length (min)	Frequency (per week)	Duration (week)	Outcome measure(s)	Response(s)
Welsh et al. (1998)	CR	Group a (n = 4) Group B (n = 2) Group C (n = 2)	7F 1M	19.0	University dancers	8	NR	Back strengthening program	NR	2	7–10	Spine extensor strength, arabesque height	↑ Lumbar extensor strength ↑ Arabesque height
Wyon et al. (2010)	RCT	Intervention (n = 9) Control (n = 9)	18F	Intervention: 19.0 ± 2.3 Control: 21.1 ± 2.0	Undergraduate dance majors	NR	NR	Whole-body vibration	5	2	6	Lower body power, circumference	↑ Vertical jump height
Wyon et al. (2013)	RCT	Strength conditioning (n = 11) Low-intensity stretch (n = 13) Moderate-intensity or high-intensity stretch (n = 11)	35F	Strength conditioning: 17.0 ± 1.6 Low-intensity stretch: 17.0 ± 2.0 Moderate-intensity or high-intensity stretch: 17.0 ± 1.9	Moderately trained college dancers	NR	NR	3 strengthening/stretching interventions	NR	NR	6	Active and passive ranges of movement	↑ Active range of movement (range increase: 20–300) in both the strength training and the low-intensity stretch groups when compared with the moderate-intensity or high-intensity stretch group
Zhang et al. (2021)	RCT	Neuromuscular training (n = 22) Control (n = 20)	21F 21M	Training male: 19.8 ± 1.7 Training Female: 19.0 ± 2.0 Control male: 20.8 ± 1.2 Control Female: 20.9 ± 1.6	Elite collegiate ballroom dancers	Training male: 13.9 ± 2.9 Training Female: 13.2 ± 3.8 Control male: 14.7 ± 3.6 Control Female: 14.1 ± 4.1	Ballroom	Neuromuscular training	60	3	10	Balance, postural control performance	↑ Reach in the posterolateral and posteromedial directions for the right and left lower limb ↑ Errors of the double-leg floor, single-leg foam, double-leg foam, tandem floor, and tandem foam

Note: Data are reported as mean ± SD.

Abbreviations: CR, Case report; F, Female; M, Male; NR, Not reported; NRCT, Non-randomized controlled trial; RCT, Randomized controlled trial.

adaptations (Sanders et al., 2020). Koutedakis et al. (1996) used a progressive load resistance training program, with 5 sets of 8 repetitions which aimed for muscular strength development. However, it is worth mentioning that the exercises included in the program were structured around specific movement patterns from resistance training exercises, but they may not directly correspond to dance movements. Vetter and Dorgo (2009) utilized the dance partner to provide resistance during training, and the effect was as beneficial as more traditional resistance training with a significant improvement of 1RM strength measures ( $p < 0.01$ ). Participants in this study performed 8 partner exercises with 2 sets of 10 repetitions in addition to their technique classes. Sanders et al. (2020) also used 3 sets of 10–12 repetitions for multi-joint exercises and 2 sets of 12–15 repetitions for single-joint or abdominal exercises. This indicates that a systematic approach to SC could elicit increases in muscular strength in dance populations, as shown by medium to large effects among studies (Hedges'  $g$  from 0.60 to 1.44). However, the short study duration of these studies ranging from 8 to 12 weeks may not foresee further muscular adaptations and thus subsequent investigations are needed for long-term strength development in dance.

Similarly, lower body strength can be improved through SC ( $g = 1.59$ ). Brown et al. (2007) incorporated plyometric training with female collegiate dancers resulting in a similar absolute strength improvement compared with resistance training, but a larger effect ( $g = 1.33$ ) in the plyometric group was found when compared with resistance training group ( $g = 1.16$ ). The exercises (e.g., leg press, leg curl, calf raise, step-ups, and depth jumps) included in these SC focused on hamstrings, quadriceps, and calves. These interventions can lead to improvements in leg strength, without interfering with key artistic and physical performance requirements in dance (Koutedakis et al., 2005). The assessment of muscular strength generally used is the bench press for upper body strength (Koutedakis et al., 1996; Sanders et al., 2020; Vetter & Dorgo, 2009) and either the leg press (Brown et al., 2007; Vetter & Dorgo, 2009) or squat (Sanders et al., 2020) for lower body strength.

### 4.3 | Flexibility

Four studies (Koutedakis et al., 2007; Marshall & Wyon, 2012; Skopal et al., 2020; Stalder et al., 1990) examined the effect of SC on flexibility. The result suggested that plyometric training ( $g = 0.84$ ) (Skopal et al., 2020) and whole-body vibration training ( $g = 0.62$ ) (Marshall & Wyon, 2012) had a medium to large effect on flexibility, however, resistance training ( $g = 0.00$ ) (Stalder et al., 1990) seemed to have no effect on improving flexibility. Among different conditioning methods, combined training ( $g = 1.83$ ) (Koutedakis et al., 2007) had a significantly large effect toward the range of movement improvement. In addition, whole-body vibration improved active range of movement of the hip, as previously reported by Marshall and Wyon (2012) and Newhart et al. (2019). A literature review by Fowler et al. (2019) also suggested acceleration using 5–10  $g$  in whole-body vibration training provides the best effect in

increasing flexibility. In view of this, whole-body vibration could be as another form of supplemental training that may have similar beneficial effects as plyometric or resistance training for dancers. It is also worth noting that the moderate heterogeneity ( $I^2 = 61\%$ ) may be due to variability in assessment methods among studies.

### 4.4 | Aesthetic competence

In addition to improved physical fitness abilities, SC may improve aesthetic competency. Although we failed to conduct meta-analysis, we would like to draw the attention on the dance performance assessment as an important outcome of SC in dance. A difficulty with evaluating aesthetic competence is the diversity of different dance styles that have different concepts of excellence and are open to subjectivity. It is important to acknowledge that artistic goals and aesthetic principles significantly vary among dance styles. Traditionally the assessment of aesthetic competence involves subjective judgments, and currently there is a lack of standardized tools available for technique evaluation and aesthetic competency. For these reasons establishing a universally accepted tool for evaluating technique and aesthetic competency is still a challenge in the dance area. Only three studies (Angioi et al., 2012; Koutedakis et al., 2007; Stalder et al., 1990) met the inclusion criteria, and the use of various assessment items and scoring methods in the evaluation may be contributed to a high variation when normalizing the data for a pooled effect. Stalder et al. (1990) subjectively rated stamina, precision and performance in ballet technique, while Angioi et al. (2012) assessed control of movement, spatial skills, accuracy of movement, techniques, dynamics, timing, and rhythmical accuracy, performance qualities, and overall performance of pre-professional and professional contemporary dancers. In addition, Koutedakis et al. (2007) used posture and alignment, use and articulation of upper body and arms, lower body and feet, total body coordination, and presentation of movement as assessment criteria for modern dance students. As a result, there may be a need to standardize the assessment tools for physical and technical aspects across different dance styles.

### 4.5 | Study limitations, future research, and practical implications

This systematic review with meta-analysis has several limitations. Most notably the heterogeneity sample included in the selected studies is characterized by a wide range of ages (>16 years old), different training levels (university students, professional dancers), skill levels (amateur, sub-elite, and elite), and the variety of assessment tools. The low-quality scores of several studies were due to no randomization of grouping, low sample size, no control for confounding variables, and unclear reporting of data. Therefore, strength and conditioning specialists should consider the conclusions and practical implications with caution. As there are plenty of studies focused on lower body power, other fitness parameters such as

balance, upper body strength, and most importantly aesthetic competence are under-examined and should be a focus of future strength and conditioning studies. This will better inform the conditioning work for dancers.

## 5 | CONCLUSION

Our analysis suggested strength and conditioning modalities such as resistance training, whole body vibration training, or combined conditioning programs had beneficial effects in improving aesthetic competence, lower body power, upper and lower body strength, and flexibility. These modalities are found to be the most common strength and conditioning interventions in dance. From this standpoint, dancers who wish to improve their aesthetic competency are recommended to participate in extra SC sessions and discover suitable training modalities with attempts at various forms of training. Although large effects can be found in these physical parameters, only a few eligible studies rated a high level of evidence as reflected by the quality assessment scores and high heterogeneity exists among studies (e.g., aesthetic competence, lower body strength, flexibility) thus the results should be interpreted with caution. Furthermore, we did not categorize dancers by skill levels or dance genres in this meta-analysis due to low sample size, and subsequently no subgroup analysis for training modalities has been carried out. It is recommended that future strength and conditioning intervention research should include sample size calculations, with participants recruited from a specific dance genre and skill level in order to evaluate how SC influences dance performance.

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## CONFLICT OF INTEREST STATEMENT

The authors report there are no competing interests to declare.

## ORCID

Jake K. Ngo  <https://orcid.org/0000-0001-7397-1340>

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### SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.