

Fitness in Contemporary Dance: A Systematic Review

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Key words

- dancers
- aerobic
- anaerobic
- muscular strength
- body composition

Abstract

has been suggested that dancers are less fit compared to other athletes. However, the majority of studies make their arguments based on data deriving mainly from ballet. Therefore, the aim of the current review was to investigate: a) aerobic and anaerobic fitness, muscular strength and body composition characteristics in contemporary dancers of different levels, and b) whether supplementary exercise interventions, in addition to normal dance training, further improves contemporary dance performance. Three databases (Medline, Cochrane and the Cumulative Index to Nursing & Allied Health research database) were searched to identify publications

regarding the main fitness components of contemporary professional and student dancers. At a professional level, it appears that contemporary dancers demonstrate higher maximal oxygen uptake and higher scores in muscular endurance than ballet dancers. However, contemporary dance students are equally fit compared to their ballet counterparts and their body composition is also very similar. Only two studies have investigated the effects of supplementary exercise training on aspects of dance performance. Further research is needed in order to confirm preliminary data, which suggest that the implementation of additional fitness training is beneficial for contemporary dance students to achieve a better performance outcome.

Introduction

Contemporary (or modern) dance has emerged in the last century. As form of expression dance can be traced as long back to human culture and history as ancient Egypt and Greece. The muscle's ability to convert chemical energy from food into muscular work is directly related to performance in dance and sport alike. Moreover, similar to other sports, dance performance depends on a large number of technical, medical, psychological, nutritional, economic, environmental and physiological elements. At professional level, for instance, dancers must be experts in the aesthetic and technical side of the art, psychologically prepared to handle the stress of critical situations and be free from injury; most importantly they must be physically 'fit' [28]. The last three decades have witnessed an unprecedented exercise and fitness- "boom", reflected in the large number of people engaged in some forms of physical activity. Never before has so much capital and effort been invested in an attempt to maintain/improve physical fitness and

increase performance both in the exercise field and the working environment. Physical fitness may be defined as "the individuals' ability to meet the demands of a specific physical task"[26], and primarily consists of aspects related to muscle and its function. It depends on the individuals' ability to work under aerobic and anaerobic conditions, and on their capacity to develop high levels of muscular tension (or strength); muscular power, joint mobility, muscle flexibility and body composition are also equally important components of physical fitness [18]. The physical demands placed on dancers from current choreography and performance schedules make their physiology and fitness just as important as skill development. As a result, they have been referred to as "performing" [26] and/or "aesthetic" [53] athletes who remain subject to the same unyielding physical laws as in other athletes. It has been suggested that there are two main physiological requirements necessary for dancers [26]: one is a large reserve of power, required for explosive jumps and high elevation, which lasts just a few seconds, energised by

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phosphocreatine; and the other requirement suggested is muscular endurance, and occurs when a relatively high power output is maintained for 30–60 seconds. This could be, for example, in a series of jumps. Available data also suggest that dance performance benefits from enhanced physiological capabilities such as muscular strength and power [11,25], in line with other aesthetic sports, such as gymnastics [1,19]. Since contemporary dance is predominantly an intermittent type of exercise [52], similar to soccer or tennis where explosive bursts of action are followed by moments requiring precision and skill, dancers would further benefit from a good aerobic foundation [2], while a high anaerobic threshold would limit the deleterious effects of metabolite accumulation in activities requiring balance, poise and co-ordination [6]. However, although dance involves several hours of daily practice, published data reveal that dancers have reduced fitness levels compared to athletes from other sports [6].

When studies report that dancers are less fit compared to other athletes, they make their arguments based on data deriving mainly from ballet [22,26,56]. Moreover, when referred to dancers, authors rarely make a differentiation regarding the levels of dancers (i.e. student and professional); such differentiation may be important since non professional and professional athletes have significant differences in fitness levels, which in turn, have significant implication in performance. In general, ballet dancers have been consistently found to demonstrate reduced fitness levels than other athletic populations [8,14,41]. It has been postulated that contemporary dancers may also be relatively unfit as the main sections of their training (i.e. class and rehearsal) do not adequately stress the physiological system [54–56].

Contemporary dance emerged at the beginning of the 20th century as a breakaway from the rigid constraints of classical ballet which itself started as a performance art in the French courts in the 16th and 17th century. Despite its many years of life, contemporary dance has not yet developed the fitness standards which might be considered as appropriate for the task [26]. Furthermore, it remains unclear whether improved physical fitness affects aspects of dance performance in student and professional contemporary dancers. Therefore, the aims of this systematic review were to investigate: a) the aerobic/anaerobic fitness, muscular strength and body composition characteristics of contemporary dancers and b) whether supplementary exercise training improves aspects of contemporary dance performance.

Method

Three databases [Medline, Cochrane and the Cumulative Index to Nursing & Allied Health (CINAHL) research database] were searched to identify publications in English (published from 1978 until May 2008) regarding fitness components of contemporary dancers. The Medical Subject Heading (MeSH) terms “physical fitness”, “exercise”, “performance”, “training”, “aerobic”, “anaerobic”, “strength”, “body composition”, “fat free mass”, were employed in combination with “modern dance”, “contemporary dance”, “dance” and “dancers”. Full articles were retrieved for assessment if the information in the abstract fulfilled the following inclusion criteria: (i) studying any of the main fitness components in combination with contemporary dance, and (ii) involving professional dancers and dance students in vocational

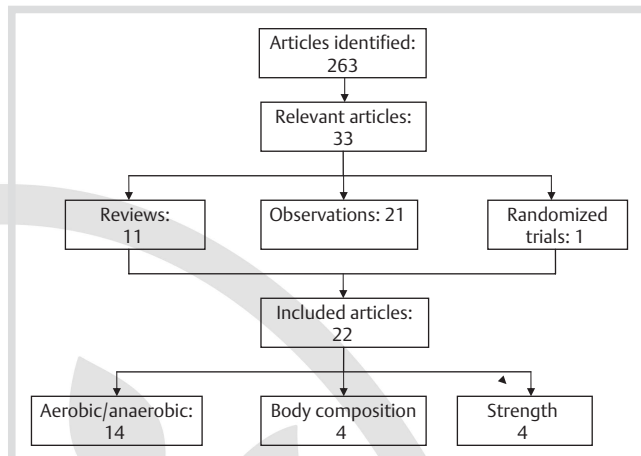


Fig. 1 Studies included in the systematic review.

and university training. We chose to include dance students enrolled in both vocational and university courses because their training involves contemporary dance alone or in combination with other dance styles. Editorials, conference proceedings and studies incorporating only ballet or other dance styles alone were excluded. If the abstract did not provide sufficient information for this process, then the full-text manuscript was examined. A flow diagram of the studies identified and included appears in **Fig. 1**.

Results

Initial search revealed 263 articles. From those articles, 24 fulfilled the inclusion criteria and thus were included for further analysis. The references of all of these articles were examined in order to further identify relevant publications; nine more studies were found. From the 33 included articles, 11 publications were reviews (none of which was a systematic review); only one article was a randomised controlled trial (RCT), while the remaining 21 publications were non-randomised research investigations. The RCT investigated the effects of a combined aerobic and strength exercise intervention on contemporary dance performance. From the non-randomised studies, 13 primarily investigated aerobic/anaerobic related physiological variables in relation to contemporary dancers, four studies were on strength-related parameters and four were on body composition. The comparisons for maximal oxygen uptake (VO_{2max}) and body composition characteristics between female professional and student contemporary dancers as well as the equivalent values from other sports appear in **Table 1**.

Aerobic/Anaerobic fitness

A number of authors have investigated the aerobic and anaerobic fitness levels of contemporary dancers and dance students, using laboratory-based maximal exertion tests. From the total of the 13 studies, VO_{2max} was found to range from 39.2 ± 1.9 to 50.7 ± 7.5 $ml \cdot kg^{-1} \cdot min^{-1}$. However, these data refer to both male and female professional dancers and dance students. As such, different values for males and females could not be reported in **Table 1**.

Three authors investigated the VO_{2max} among different level of contemporary dance students and they found no significant dif-

Table 1 Maximal oxygen uptake and body composition characteristics of female contemporary professional dancers and dance students compared to other athletes.

Sport/Activity	Level	VO _{2max} (ml.kg ⁻¹ min ⁻¹)	Body Composition)		References
			Fat Mass (%)	Fat-Free Mass (kg)	
contemporary dance	professional	49.1	21.4	42.9	[9, 13, 17]
	students	39.2	21.3	42.5	[50, 59]
ballet	professional	42.2	17.4	42.3	[13, 21, 46]
	students	40.8	19.9	41.5	[50]
gymnastics		49.6	14.4	33.7	[16, 48]
football		50.0	20	50.3	[7, 35]
endurance running		77	35.8	23.8	[10, 34]
volleyball		46.5	53.2	23.4	[32, 45]
swimming		58	47.6	20.2	[3, 42]
sedentary		44	24.4	26.5	[4, 36, 46]

ferences existed in a) university, graduate and professional [55], b) performing and recreational adolescent dancers [38] and c) intermediate and advanced dance students [12]. One study revealed that VO_{2max} was higher in students undertaking ballet and modern dance as majors, compared to other dance combinations in a vocational institution [15]. Moreover, ballet and contemporary dance students did not demonstrate significant differences in cardiorespiratory fitness [50], while professional contemporary dancers exhibited significant higher values of VO_{2max} than their ballet counterparts [13].

In comparison to non-dancers, it was found that the VO_{2max} values of intermediate and advanced dancers' was significantly increased. However, no significant differences were detected between beginners and non-dancers [12]. These results are in line with the study of Novak [36] who found that female dancers had a significantly higher mean VO_{2max} value compared to sedentary females of a similar age range. Despite the consistently higher aerobic capacity of dancers compared to controls, an investigation revealed no significant differences for all structural and functional cardiac indices between full-time contemporary dance students and age-gender matched controls [51].

Anaerobic power, determined by the Wingate test, was primarily investigated in two studies. Chatfield and colleagues [12] reported that advanced level contemporary dancers showed anaerobic capacity mean values of 907.5 ± 140.7 Kgm.30 sec⁻¹ which was somewhat lower (but not significantly) compared to beginners (922.5 ± 195.4 Kgm.30 sec⁻¹). These results, however, were relatively higher (but not significantly) compared to non-dancers (○ **Table 2**). Non significant differences were also detected in anaerobic mean power between adolescent dance students compared to either recreational dancers or non-dancers [38]. Significant differences were instead depicted in post exercise blood lactate levels, where professional contemporary dancers exhibited higher values than their ballet counterparts [13].

By investigating the effects of supplementary exercise training on jumping ability and dance performance [11, 25], these recent studies form the only known examples where aspects of fitness and contemporary dance performance were simultaneously considered. Brown and colleagues [11] recruited three experienced dance teachers to assess four aspects of the dancers jumping ability including: the aptitude to hang suspended in the air during a jump (*ballon*), height of the jumps, the ability to point the feet in the air and the overall aesthetic jumping ability. Overall aesthetic competence and dance technique were assessed by

Koutedakis and colleagues [25], who specially designed a dance performance test. By adopting the marking procedures used in sports (e.g. gymnastics and ice skating), two teachers and former professional dancers, were recruited as markers. Combined evidence from both studies reveals that aerobic and strength training increases VO_{2max}, strength and aspects of dance performance in contemporary dance students [11, 25]. Most importantly, these results are in line with the only RCT which is currently available in dance literature [25].

○ **Table 2** depicts the individual results from all studies conducted in relation to aerobic/anaerobic capacity of contemporary dancers.

Muscular strength

One maximum repetition for leg press in dance students has been found to range from 183.3 ± 30.9 to 222.7 ± 65.0 kg, while knee curl and extension ranges from 34.8 ± 4.5 to 40.0 ± 5.7 kg and from 58.7 ± 6.5 to 62.5 ± 9.1 kg, respectively [11]. Moreover, muscular strength and power of knee and ankle in both intermediate and/or advanced dance students has been found to be not significantly different between them or when compared to sedentary individuals [12]. No significant differences were observed in the quadriceps and hamstring peak torque between ballet and contemporary dance students and professionals [13]; however, in comparison to ballet, contemporary dancers reported higher scores in muscular endurance but lower compared to folk dancers [44]. Finally, it was found [27] that the knee extensor and flexor muscle peak power of female professional contemporary dancers was 151.0 ± 26.0 and 63.0 ± 11.0 Nm at 1.04 rad/sec while at 4.19 rad/sec the equivalent values were 83.0 ± 11.0 and 60.0 ± 8.4 Nm. Isokinetic measurements of muscular strength [17] revealed that semi-professional dancers compared to athletes, have a greater quads muscle output during a five sec maximal voluntary isometric contraction but they do not jump higher than controls.

Two studies investigated the effects of supplementary strength training (both plyometric and weight training) on dance students, and both studies revealed that a significant increase in muscular strength resulted in significant benefits for enhancing aesthetic jump performance [11] and overall aesthetic competence and dance technique, assessed via a specifically designed dance performance test [25].

○ **Table 3** depicts the individual evidence from all studies conducted in relation to strength related parameters of contemporary dancers.

Table 2 Studies primarily investigating the aerobic/anaerobic capacity of contemporary dancers.

Author (reference)	Participants	Method	Results
Koutedakis et al. 2007 [25]	32 dance students	F = 2–3 h/wk Intensity-Aerobic = 70–75% of VO ₂ max	Intervention group before intervention: VO ₂ max: 50.7 ± 7.5 ml·kg ⁻¹ ·min ⁻¹ Strength both legs: 90.6 ± 16.0 kg Skinfolds: 39.4 ± 10.5 mm
	intervention group n = 19	Intensity-Strength = 6 weeks: < 70% of 1 repetition maximum high repetitions	Intervention group after intervention: VO ₂ max: 56.6 ± 9.3 ml·kg ⁻¹ ·min ⁻¹ * Strength both legs: 102.0 ± 17.4 kg * Skinfolds: 35.7 ± 9.3 mm
	control group n = 13	6 weeks: >70% of 1 repetition maximum low repetitions	Control group before intervention: VO ₂ max: 49.2 ± 5.5 ml·kg ⁻¹ ·min ⁻¹ Strength both legs: 94.1 ± 15.8 kg Skinfolds: 40.9 ± 11.7 mm
	RCT	PD = 12 weeks	Control group after intervention: VO ₂ max: 48.5 ± 5.4 ml·kg ⁻¹ ·min ⁻¹ Strength both legs: 83.1 ± 11.2 kg Skinfolds: 44.6 ± 13.3 mm * = Significant differences
White et al. 2004 [50]	ballet students n = 10	Aerobic capacity and body composition	Ballet: VO ₂ max: 40.8 ± 1.6 ml·kg ⁻¹ ·min ⁻¹ %BF: 19.9 ± 1.5 FFM: 41.5 ± 1.1 kg
	contemporary students n = 7		Contemporary: VO ₂ max: 39.2 ± 1.9 ml·kg ⁻¹ ·min ⁻¹ %BF: 19.3 ± 1.4 FFM: 43.2 ± 1.6 kg
			No significant differences
Wyon et al. 2002 [55]	27 dancers university n = 10 graduate n = 7	Cardiorespiratory responses (mean VO ₂) to dance class	University: Mean VO ₂ : 16.8 ± 2.3 ml·kg ⁻¹ ·min ⁻¹
	professional n = 10		Graduate: Mean VO ₂ : 20.4 ± 4.8 ml·kg ⁻¹ ·min ⁻¹
			Professional: Mean VO ₂ : 18.3 ± 3.8 ml·kg ⁻¹ ·min ⁻¹ No significant differences
Whyte et al. 2003 [51]	dance students n = 44	Echocardiography and Electrocardiography	No significant differences between dancers and controls for structural and functional cardiac indices.
	females non-active n = 30		Contemporary students: % BF: 18.7 ± 3.4 FFM: 48.2 ± 6.3 kg
			Controls: %BF: 19.9 ± 4.4 FFM: 47.3 ± 5.8 kg
Redding et al. 2003 [40]	19 professional females n = 12 males n = 7	Validity of using HR as a predictor of mean VO ₂ consumption in dance	It is unacceptable to predict the mean VO ₂ from HR values, based on the HR–VO ₂ relationship established from a progressive treadmill protocol
Wyon et al. 2003 [57]	56 dancers females n = 32 males n = 24	VO ₂ max during a dance specific aerobic test	Females: VO ₂ max: 46.0 ± 3.5 ml·kg ⁻¹ ·min ⁻¹
			Males: VO ₂ max: 56.0 ± 3.5 ml·kg ⁻¹ ·min ⁻¹
Padfield et al. 1993 [38]	performing adolescent dancers n = 24	VO ₂ max, %BF, jump height, anaerobic mean power	Performing dancers: VO ₂ max: 45.6 ± 4.8 ml·kg ⁻¹ ·min ⁻¹ %BF: 8.7 ± 6.5 Jump height: 26.7 ± 3.5 cm Anaerobic mean power: 6.6 ± 0.7 Watts kg ⁻¹
	recreational adolescent dancers n = 16		Recreational dancers: VO ₂ max: 46.3 ± 6.0 ml·kg ⁻¹ ·min ⁻¹ %BF: 9.7 ± 7.6 Jump height: 25.1 ± 6.6 cm Anaerobic mean power: 6.2 ± 0.9 Watts kg ⁻¹
			No significant differences
Wyon et al. 2004 [54]	dance students (males and females) n = 40	Mean VO ₂ during class, performance and rehearsal	Females: Class mean VO ₂ : 17.4 ± 2.7 ml·kg ⁻¹ ·min ⁻¹ Rehearsal mean VO ₂ : 10.2 ± 6.6 ml·kg ⁻¹ ·min ⁻¹ Performance mean VO ₂ : 23.3 ± 3.8 ml·kg ⁻¹ ·min ⁻¹

Table 2 Continued.

			Males: Class mean VO_2 : $22.1 \pm 5.9 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ Rehearsal mean VO_2 : $17.2 \pm 3.3 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ Performance mean VO_2 : $24.9 \pm 5.8 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$
			Performance had a significantly greater physiological demand than rehearsal and class.
Wyon et al. 2005 [56]	professional dancers n = 17 company 1 n = 10	Company 1 Aerobic supplemental training no guidance provision and time PD = 8 weeks	Pre assessment company 1 Mean HR: $166 \pm 10.65 \text{ b}\cdot\text{min}^{-1}$ BL: $2.1 \pm 0.9 \text{ Mmol}\cdot\text{L}^{-1}$
			Post assessment Company 1: Mean HR: $155 \pm 12.9 \text{ b}\cdot\text{min}^{-1}$ BL: $1.5 \pm 0.8 \text{ Mmol}\cdot\text{L}^{-1}$
			Significant differences
	company 2 n = 7	Company 2 Dance training only	Pre assessment company 2: Mean HR: $189 \pm 4.19 \text{ b}\cdot\text{min}^{-1}$ BL: $3.4 \pm 1.1 \text{ Mmol}\cdot\text{L}^{-1}$
			Post assessment company 2: Mean HR: $179 \pm 4.8 \text{ b}\cdot\text{min}^{-1}$ BL: $2.8 \pm 1.1 \text{ Mmol}\cdot\text{L}^{-1}$
	intervention non RCT		No significant differences
Novak et al. 1978 [36]	female dance students n = 12	$\text{VO}_{2\text{max}}$ and %BF	Dance students: $\text{VO}_{2\text{max}}$: $41.5 \pm 6.7 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ %BF: 20.5 ± 4.6
	sedentary females n = 12		Controls: $\text{VO}_{2\text{max}}$: $36.8 \pm 5.5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ %BF: 26.5 ± 3.6
			Significant differences in $\text{VO}_{2\text{max}}$ and %BF
Chatfield et al. 1990 [12]	non dancers n = 8 beginner students n = 14 intermediate students n = 11 professional dancers n = 8	$\text{VO}_{2\text{max}}$ %BF, knee and ankle strength, knee and ankle power, WAT power	$\text{VO}_{2\text{max}}$: Non dancers: $36.4 \pm 4.8 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ Beginners: $40.4 \pm 4.9 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ Intermediate: $42.5 \pm 4.3 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ Professional: $43.6 \pm 2.3 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$
			Significant differences between non-dancers and intermediate and non- dancers and professionals
			%BF: Non dancers: 27.8 ± 4.4 Beginners: 23.7 ± 4.8 Intermediate: 20.9 ± 4.6 Professional: 18.1 ± 2.3
			Significant differences between non-dancers and intermediate, non-dancers and professionals, and professional and beginners
			No significant differences in knee and ankle strength and power between all groups
			WAT capacity: Non Dancers: $828.38 \pm 161.2 \text{ kgm}\cdot 30 \text{ sec}^{-1}$ Beginners: $922.50 \pm 195.4 \text{ kgm}\cdot 30 \text{ sec}^{-1}$ Intermediate: $917.73 \pm 120.1 \text{ kgm}\cdot 30 \text{ sec}^{-1}$ Professional: $907.50 \pm 140.7 \text{ kgm}\cdot 30 \text{ sec}^{-1}$
			No significant differences
Dahlstrom et al. 1996 [15]	dance students ballet + contemporary n = 10 contemporary + jazz n = 30 contemporary + character n = 9	$\text{VO}_{2\text{max}}$	Ballet + contemporary $\text{VO}_{2\text{max}}$: $51.2 \pm 11.4 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ Contemporary + jazz $\text{VO}_{2\text{max}}$: $45.8 \pm 8.7 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ Contemporary + character $\text{VO}_{2\text{max}}$: $46.6 \pm 12.2 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$
Chmelar et al. 1988 [13]	professional contemporary n = 9	$\text{VO}_{2\text{max}}$, BL, %BF, QPT/BW, HPT/BW	Contemporary professional: $\text{VO}_{2\text{max}}$: $49.1 \pm 5.9 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ BL: $9.7 \pm 1.4 \text{ mM}\cdot\text{L}^{-1}$ %BF: 12.2 ± 2.1 $60^\circ/\text{sec}$ QPT/BW: $75.7 \pm 13.1 \%$

Table 2 Continued.

			60°/sec HPT/BW: 43.2±5.9 % 180°/sec QPT/BW: 47.9±6.1 % 180°/sec HPT/BW: 36.4±4.1 %
	professional ballet n=9		Professional ballet: VO _{2max} : 42.2±2.9 ml·kg ⁻¹ ·min ⁻¹ * BL: 6.0±1.5 mM·L ⁻¹ * %BF: 14.1±1.9 60°/sec QPT/BW: 73.7±12.4 % 60°/sec HPT/BW: 50.5±6.7 % 180°/sec QPT/BW: 46.5±11.4 % 180°/sec HPT/BW: 42.3±9.9 %
	contemporary students n=11		Contemporary students: VO _{2max} : 47.5±3.1 ml·kg ⁻¹ ·min ⁻¹ BL: 9.0±2.4 mM·L ⁻¹ %BF: 14.7±3.4 60°/sec QPT/BW: 78.8±14.0 % 60°/sec HPT/BW: 45.1±6.6 % 180°/sec QPT/BW: 50.9±9.1 % 180°/sec HPT/BW: 37.4±5.1 %
	ballet students n=10		Ballet students: VO _{2max} : 47.0±2.1 ml·kg ⁻¹ ·min ⁻¹ BL: 9.5±0.9 mM·L ⁻¹ %BF: 14.2±3.2 60°/sec QPT/BW: 74.7±10.1 % 60°/sec HPT/BW: 46.2±5.5 % 180°/sec QPT/BW: 45.5±6.3 % 180°/sec HPT/BW: 35.5±5.0 %
			* = significant difference between ballet and contemporary professionals and dance students (ballet and contemporary)
O'Mailia et al. 2002 [37]	female dancers n=14	VO _{2max}	VO _{2max} : 45.0±3.9 ml·kg ⁻¹ ·min ⁻¹

RCT = randomised controlled trial; F = frequency; PD = programme duration; VO_{2max} = maximal oxygen uptake; mean VO₂ = mean volume of oxygen uptake; %BF = percentage body fat; FFM = fat-free mass; HR = heart rate

VO_{2max} = maximal oxygen uptake; %BF = percentage body fat; mean VO₂ = mean volume of oxygen uptake; RCT: randomized control trial; PD = programme duration; HR = heart rate; BL = blood lactate; WAT = Wingate anaerobic power test; QPT/BW = quadriceps peak torque/body weight; HPT/BW = hamstring peak torque/body weight

Body composition

An investigation into body composition of female dancers revealed that, using the skinfolds method, percentage body fat (%BF) was found to range from 13.0 to 26.9%. In the same sample of participants, using dual energy X ray absorptiometry (DXA), values for %BF ranged from 10.3 to 30.4%. The fat-free mass (FFM), as determined by DXA, was 42.6±3.3 kg (range 35.6–50.1) [59]. Regarding different level of dancers, it has been found that performing and recreational adolescent dance students do not significantly differ in %BF [38]. In all these aforementioned studies, the total number of dance students derived from both ballet and modern dance training. In other studies, however, which indeed separated the dance students into ballet and contemporary, no significant differences were found either in %BF or FFM between these two dance styles [13,50]. Significant lower %BF values were instead found in professional contemporary dancers compared to beginner dance students [12].

Female dance students and graduates were found to have a significantly lower %BF than age-matched non-active females [36]. In addition, significant differences were also found between advanced dancers and non-dancers, as well as intermediate dance students and non-dancers [12].

Results from one RCT and one non randomized intervention revealed that supplementary aerobic and/or strength training does not elicit significant changes in %BF of dance students [11,25]. **Table 4** depicts the evidence from all studies primarily investigating body composition characteristics of contemporary dancers.

Discussion

The aim of this systematic review was to investigate a) the aerobic/anaerobic fitness, strength levels and body composition characteristics of contemporary dancers and b) if supplementary training is effective in improving aspects of dance performance. To our knowledge, this is the first review systematically investigating all these fitness components in relation to contemporary dance. Unlike most ballet dancers, contemporary dancers may have a multidisciplinary background, which includes other sport activities such as gymnastics [26]. This is also the case in other sports such as football and water polo, where the players used to be runners and swimmers, respectively. This sample heterogeneity as well as the different training demands between contemporary and ballet dance, may result in different levels of fitness and strength. Moreover, it is important to highlight that contemporary choreographers require different artistic, technical and physical demands during auditions [52]. Hence, it seems reasonable to suggest that contemporary dancers with sporting background might be also advantaged during auditions. Other differences between ballet and contemporary dancers have been reported to be injury sites and rates as well as the biomechanical mechanisms that cause these injuries [29]. Moreover, results from separate studies investigating physiological demands of contemporary [54] and ballet [14] class and performance, suggest that the two dance styles may also differ in their cardiorespiratory demands. For these reasons it was decided not to report research evidence for dancers as a whole, but to focus on the contemporary style, and differenti-

Table 3 Studies primarily investigating muscle strength levels of contemporary dancers.

Author (reference)	Participants	Method	Results
Koutedakis et al. 1997 [27]	male ballet and contemporary professionals n=20	Knee extensors and flexor muscle peak torques, %BF, FFM	Males: Knee flexion at 1.04 (rad/sec): 121 ± 15 Nm Knee extension at 1.04 (rad/sec): 248 ± 24 Nm Sum: 5.8 ± 0.5 Nm/kg FFM
			Knee flexion at 4.19 (rad/sec): 81 ± 10 Nm Knee extension at 4.19 (rad/sec): 131 ± 12 Nm Sum: 3.3 ± 3.1 Nm/kg FFM
	female ballet and contemporary professionals n=22		Females: Knee flexion at 1.04 (rad/sec): 63 ± 11 Nm Knee extension at 1.04 (rad/sec): 151 ± 26 Nm Sum: 4.6 ± 0.4 Nm/kg FFM
			Knee flexion at 4.19 (rad/sec): 60 ± 8.4 Nm Knee extension at 4.19 (rad/sec): 83 ± 11 Nm Sum: 3.1 ± 0.2 Nm/kg FFM
			Significant differences between males and females in knee flexion, extension and sum at 1.04 (rad/sec), and in knee flexion and extension at 4.19 (rad/sec)
			Males: %BF: 14.1 ± 2.4 Females: %BF: 19.2 ± 5.8 Significant difference
Harley et al. 2002 [17]	female semi professional dancers n = 11 (semi professional)	Quads strength, jump height, %BF, FFM	Dancers had significantly greater peak and mean force output in the 5 sec maximal voluntary isometric leg extension tests (p < 0.01; values not available)
	age-matched active females n = 11		Jump height: Dancers: 37.6 ± 5.5 cm Controls: 35.9 ± 3.9 cm No significant difference
			%BF: Dancers: 21.4 ± 2.8 Controls: 25.6 ± 3.7 Significant difference
			FFM: Dancers: 42.2 ± 3.7 kg Controls: 42.2 ± 6.6 kg No significant difference
Thomas 2003 [44]	performing dance students	Heel – rises muscular endurance	Number of RPL: Contemporary: 26.4 ± 3.8 Ballet: 25.4 ± 3.7 Folk: 33.0 ± 3.64
	contemporary n=15 ballet n=15 folk n=19 other styles n=41		Number of RPKg: Contemporary: 19.1 ± 3.1 Ballet: 18.9 ± 3.05 Folk: 23.0 ± 3
Brown et al. 2007 [11]	18 dance students weight training n=6 plyometric training n=6 controls n=6 intervention non RCT	F = 1–1.30 h/wk Intensity- weight training = 80% of 1 repetition maximum 3 sets of 6–8 repetitions Intensity- plyometric = 3 sets of 8 repetitions of 4 exercises PD = 12 weeks	Plyometric training group pre intervention: Leg press strength: 183 ± 30.9 kg Vertical jump from standing 12.0 ± 1.2 in Aesthetic evaluation – jump height: 3.2 ± 0.4
			Plyometric training group post intervention: Leg press strength: 251.5 ± 39.4 kg * Vertical jump from standing 13.0 ± 1.0 in * Aesthetic evaluation – jump height: 3.6 ± 0.5 * = significant differences*
			Weight training group pre intervention: Leg press strength: 214 ± 61.0 kg Knee curl strength: 34.8 ± 4.5 kg Anaerobic mean power: 340.8 ± 53.5 Watts Aesthetic evaluation - feet point: 3.0 ± 1.2 Aesthetic evaluation - jump height: 2.8 ± 1.0

Table 3 Continued.

Weight training group post intervention:
 Leg press strength: 282.5 ± 48.0 kg *
 Knee curl strength: 42.8 ± 3.4 kg *
 Anaerobic mean power: 361.1 ± 62.6 Watts *
 Aesthetic evaluation – feet point: 3.6 ± 0.7 *
 Aesthetic evaluation - jump height: 3.5 ± 0.8 *
 * = significant differences

%BF = percentage body fat; FFM = fat-free mass; RPL = repetitions per leg; RPKg = repetitions per kilogram; RCT = randomised controlled trial; F = frequency; PD = programme duration

ate between their levels (student and professional), with respect to their fitness, strength and body composition characteristics.

An important aspect which has to be stressed herein, is the link between dance performance and fitness. It has been suggested that although the former has significant “aesthetic” elements, it is the overall fitness of the individual dancer that determines the final outcome [26]. For an optimal stage performance, the dancers aerobic and anaerobic capacities, strength power and endurance as well as their flexibility levels, must be at their peak on the day they are needed. Hence, it is peremptory that dancers, akin to all performing athletes, must adhere to the principles of periodisation and regular evaluation of their fitness levels (e.g. strength, flexibility) via validated laboratory procedures. However, unlike physical fitness and its well defined components [18], the description and quantification of dance performance is less clear, since there are no validated tools that assess full performance. To date research studies have only attempted to quantify and score aspects of dance performance such as overall proficiency, full body involvement, articulation and skills [30]. Therefore, future research in dance science should focus on the development of valid and reliable tools that will enable the accurate assessment and prediction of stage dance performance.

At a professional level, it appears that contemporary dancers demonstrate higher VO_{2max} and %BF than ballet. However, student contemporary dancers are equally fit compared to their ballet counterparts and their body composition is also very similar. Comparisons between contemporary, ballet and athletes of other sports are presented in **Table 1**. It is worth noting that **Table 1** depicts values only for VO_{2max} and body composition of female dancers; the lack of relevant data for professional and student male dancers (either contemporary or ballet), did not allow us to produce a similar table. In addition, the different techniques, equipment and muscular groups do not currently allow for a representative and thorough comparison in strength levels between contemporary dancers with athletes of other sports. Available data, however, showed that muscular strength and power among intermediate dance students, advanced dance students and sedentary individuals do not differ significantly [12] whereas contemporary dancers reported higher scores in muscular endurance compared to ballet dancers [44]. Anaerobic fitness was found to be the least studied component. However, investigating this fitness aspect is indeed important in dance given that actions requiring high power output rely predominantly on the ATP-CP and glycolytic system of energy [5], and dance is characterised by short explosive movements, such as jump series, interspersed between longer periods of rest [52]. Despite this, data from two studies revealed no significant differences in mean anaerobic power between performing and recreational dance students and between various levels of dancers compared to sedentary populations [12,38]. However, following

supplemental weight training, dancers improved their anaerobic power which also revealed a concomitant improvement in aesthetic evaluation of jump ability [11].

In summary, it appears that both contemporary and ballet dancers have aerobic fitness levels higher to that seen in sedentary individuals [36] and somewhat lower compared to other sports. In addition, muscular strength is higher in professional dancers compared to other athletes [17], however, at a student level no significant differences exist in this fitness component. The reason for this phenomenon is probably the fact that the dance training is not sufficient enough to overload the aerobic/anaerobic and musculoskeletal systems [12,26] and thus, to produce physiological adaptations that will enhance each individual fitness component. On the other hand, dance specialists and physiologists have to consider how these potential adaptations (gained through supplementary aerobic/strength training) will benefit dance performance since, at least professional dancers, may produce a high quality performance even if their VO_{2max} is lower compared to other sports.

The effectiveness of supplementary aerobic/strength training in order to improve dance performance has been very frequently discussed in published manuscripts (both in trials and reviews) but has only been recently investigated [11,25]. One well-methodologically designed study [25] suggests that in students, increases in fitness components result in concomitant beneficial effects in aspects of performance. Nevertheless, the limitations of this study – according to the CONSORT guidelines for RCTs – were the method of randomization, the lack of justification for the sample sizes used and finally the lack of presenting the participants' flow diagram. Although the results of this study are in line with the non-randomised study by Brown [11], these studies can only be interpreted as preliminary data and have to be confirmed in future prospective and well-designed studies.

Improvement in individual fitness components may be important for different reasons. In professional dancers, knee extensor and flexor low muscle strength levels have been associated with increased injury severity, expressed as the total time off dance training [27]. The injury recovery process may take longer in dancers with reduced muscular strength, because joints surrounded by weaker soft tissue are subject to more strain due to overexertion, and therefore take longer to recover from the cause of the injury [31,49]. Since dance training is not sufficient enough to overload the musculoskeletal systems [12,26], and considering the high injury rates found in dance [47], the implementation of strength training could therefore be recommended as a preventive measure, at least for less strong dancers [24]. In addition, improvements in aerobic/anaerobic capacities and muscular strength have been previously linked to better oxygen transport facilities [4] and enhanced neuromuscular function

Table 4 Studies primarily investigating body composition characteristics of contemporary dancers.

Author (reference)	Participants	Method	Results
Yannakoulia et al. 2004 [58]	female dance students n = 37 controls: age- and weight-matched reference population	BMD	Dancers BMD: 1.185 g/cm ² (9% higher than reference values)
Berlet et al. 2002 [9]	professional female dancers n = 9	BMD, total regional fat (%), TLM	Female dancers: BMD: 1.18 ± 0.1 g/cm ² Total regional fat: 13.6 ± 3.3 % TLM: 42.928 ± 3.4 g
	non-dancers n = 26		Female controls (weight-matched): BMD: 1.19 ± 0.1 g/cm ² Total regional fat: 9.7 ± 2.5 % TLM: 37.689 ± 3.4 g Significant differences in %BF and TLM
	professional male dancers n = 6		Male dancers: BMD: 1.35 ± 0.1 g/cm ² Total regional fat: 14.4 ± 4.8 % TLM: 60.132 ± 6.8 g
Yannakoulia et al. 2000 [59]	elite female dance students n = 42	Investigation of levels of BMD, FFM, % BF	BMD: 1.180 ± 0.1 g/cm ² FFM: 42.55 ± 3.3 kg %BF (Skinfold): 21.3 ± 3.2 %BF (DXA): 19.4 ± 4.3
	female students with experience in contemporary, ballet and rhythmic gymnastics n = 24		Sum-SF, calf circumference
Miletic et al. 2007 [33]	active female students with no previous experience in aesthetic disciplines n = 21		Non experienced students: Sum-SF: 23.47 ± 5.2 mm Calf circumference: 35.98 ± 2.26 cm Significant difference in Sum-SF

BMD = bone mineral density; TLM = Total lean mass; FFM = fat-free mass; %BF = percentage body fat; DXA = dual-x ray absorptiometry; Sum-SF = sum of skinfolds

[20], which in turn, affect qualitative elements of physical performance through reduced fatigue [39, 43] and injury rates [23]. In conclusion, fitness levels of dancers vary according to different styles and levels and thus future research should distinguish between not only levels of dancers but also styles. It appears that contemporary dancers demonstrate higher maximal oxygen uptake than ballet, while contemporary dance students are equally fit compared to their ballet counterparts and their body composition is also very similar. Similar values were detected in anaerobic fitness, muscular strength/power between various levels of dancers compared to the normal population, whereas contemporary dancers reported higher scores in muscular endurance than ballet counterparts. From the results of this systematic review it appears that the majority of research studies in dance have focused on the assessment of dancers' levels of fitness. In contrast, there is a lack of studies trying to identify an objective assessment of contemporary dance performance. In the two studies investigating the effects of an intervention on dance, two different dance-based tests were used [11, 25]; these were the most externally valid to 'dance performance'. However, both tests that were employed to assess aspects of aesthetic competence were not previously validated appropriately, which is a major limitation that should be addressed in similar studies in the future. The data of these preliminary research studies, however, suggest that aerobic and strength training improve overall aesthetic competence, dance technique and aesthetic jump performance of dance students. Further research is needed in order to confirm these preliminary data.

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Erratum

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An error has occurred in this article. The name of one of the authors should be “G. S. Metsios” instead of “G. Metsios”.