Performing arts as a health resource? An umbrella review of the health impacts of music and dance participation

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Performing arts participation as a prospective public health resource: A review

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Abstract

Importance: An increasing body of evidence notes robust health benefits of physical activity, yet participation rates have stagnated. Challenges related to exercise self-efficacy are at least partly responsible. Exercise self-efficacy is a consistent moderator of physical activity participation and highly resistant to change, but also activity-specific. Health-promoting non-exercise activities may thus substantially improve health outcomes by engaging inactive individuals. Performing arts are globally popular (up to 40% annual adult participation) and intrinsically physically exertive, presenting an intriguing alternative. This umbrella review aims to evaluate the public health utility of active performing arts participation by systematically reviewing and appraising evidence regarding its health effects in healthy adults, adolescents and children. PROSPERO ID #: CRD42020191991

Observations: Results of 33 systematic reviews (286 primary studies), 9 observational studies of performing arts participation and non-communicable disease risk, and 87 studies reporting mean heart rate during performing arts participation were synthesized and appraised according to the GRADE framework following a 3-component umbrella review. Positive health effects of performing arts participation were found in 17 of 18 investigated domains, including 9 domains supported by moderate-high quality evidence: auditory; body composition; cognitive; immune function/inflammation; mental health; physical fitness; physical function; self-reported health/wellbeing; social functioning. 9 of 13 domains associated with the health benefits of physical activity. Heart rate data indicate that both music and dance participation intrinsically elicit, while maintaining expressive rather than exertive aims, mean heart rate values corresponding to a range of intensities, including moderate and vigorous (≥*64% maximum*).

Conclusions and Relevance: Performing arts participation is health promoting activity and likely a valuable public health resource and exercise alternative/adjunct. The specific frequency,

timing, types and mechanisms of performing arts participation underpinning observed benefits are presently varied, justifying research aiming to facilitate specific performing arts prescriptions and public health recommendations.

1. Introduction

An increasing body of evidence demonstrates the robust health benefits of physical activity – primary and/or secondary prevention for at least 25 chronic medical conditions and a 9-39% reduction in mortality risk.[1-3] The converse, physical *in*activity, is conservatively estimated to cost global healthcare systems an annual $53.8 billion and global citizens 13.4 million disability-adjusted life years.[4] World Health Organization (WHO) guidelines broadly define physical activity as 'any bodily movement produced by skeletal muscles that requires energy expenditure', however the foci of physical activity research and recommendations are predominantly exercise modalities (i.e. aerobic activity, walking, cycling, sports).[5,6]

Substantial international resources and attention have been directed towards increasing physical activity, with policies operational in a majority (56%) of WHO member states.[7] Despite this investment, however, physical activity participation rates have not meaningfully increased over the past 20 years;[8] an estimated 27.5% of global adults and 81% of school-going adolescents are currently classified as 'insufficiently active' (not meeting WHO guidelines).[9]

Stagnant physical activity participation rates can be attributed at least in part to challenges related to exercise self-efficacy – an individual's belief in their ability to successfully perform and benefit from exercise.[10] Exercise self-efficacy has been shown to be a consistent correlate and determinant of initiating and maintaining regular physical activity in both adult and adolescent populations,[7,10] but is highly resistant to long-term change.[11,12] Self-efficacy is, however, also activity-specific,[13] highlighting an opportunity for health-promoting non-exercise activities to substantially improve outcomes in inactive individuals, and in particular those with low exercise self-efficacy.

Active performing arts participation presents an intriguing non-exercise activity in that it involves the enjoyment of music – "reliably ranked as one of life's greatest pleasures"[14] – while often intrinsically achieving levels of physical exertion associated with many health benefits.[15,16] *NB: music and dance participation are the two most popular modes of active performing arts engagement and the focus of this review;[17] 'performing arts participation' will be used to refer, jointly, to music and dance participation from this point forward.*

Unlike exercise, physical intensity during performing arts participation is achieved while maintaining a distinctly expressive, rather than exertive, focus. Further, the performing arts have substantial established interest and self-efficacy, with 40% of US residents and up to 35% of EU citizens estimated to actively participate in the performing arts every year.[17,18]

While the arts have been shown to be generally health promoting,[19] evidence regarding the health impact of performing arts participation has yet to be compiled and critically appraised using a common framework, limiting specific conclusions regarding its prospective public health utility. Accordingly, the aim of this umbrella review is to systematically review and appraise evidence regarding the health effects of performing arts participation in healthy adults, adolescents and children. A secondary aim of this review is to compile data regarding the physical intensity of performing arts participation to understand its demands and inform hypotheses related to relationships between physical intensity and observed effects.

2. Methods

2.1 Review Registration

This review was prospectively registered in the PROSPERO registry (ID: CRD42020191991).

2.2 Overview

Following informal literature searches, the authors made an a priori decision that an integrated, three component umbrella review would most effectively address study aims:

1) A systematic review of systematic reviews of the health benefits of performing arts participation;
2) A systematic review of observational studies investigating the impact of performing arts participation on mortality and non-communicable disease risk;
3) A systematic review of studies of heart rate responses to performing arts participation.

Search terms and inclusion/exclusion criteria for each component are described below. All components involved searches of MEDLINE (*all fields, English & human subjects limiter*), EMBASE (*all fields, English & human subjects limiter*), SPORTDiscus (*all fields, English limiter*), and Web of Science (*Arts & Humanities citation index; all fields; English limiter)* from inception – 15 June 2020. Abstracts of all database search results were screened, followed by full text review of potentially relevant articles. Hand searches of the reference lists of included articles were also conducted to locate additional relevant articles. The review procedure was conducted by the first author in consultation with the authorship team.

Across all components, 'music participation' was defined as singing or playing a musical instrument. 'Dance participation' was broadly defined as an activity involving "moving one's body rhythmically…to music,"[20] with an additional criterion that included articles must identify the investigated activity as 'dance.' To distinguish performing arts from exercise participation, articles investigating music and dance participation conducted with an exertive aim (i.e. target heart rate/rating of perceived exertion) were excluded.

2.3 Systematic review of systematic reviews of the health benefits of performing arts participation

2.3.1 Database search terms

Database searches were performed using the following search terms and a 'Reviews' limiter where available: ((music* OR danc* OR performing art* OR choir OR choral) AND (psycholog* OR biochem* OR immun* OR cognit* OR physical OR health)).

2.3.2 Inclusion/exclusion criteria

Inclusion criteria were systematic reviews examining the health effects of active performing arts participation in healthy adults, adolescents or children. A 'systematic review' was defined based on Cochrane definitions[21] as a review conducted using explicit, reproducible methodology and aiming to comprehensively synthesize all available relevant evidence. Exclusion criteria were assessed at the primary study level within relevant reviews: 1) studies with qualitative data only; 2) studies in which performing arts participation was conducted with a target exercise intensity or heart rate – these studies were judged to evaluate exercise, rather than performing arts participation; 3) studies of long-term dance or music interventions in experienced dancers or musicians; 4) single-group observational studies characterizing experienced dancers or musicians.

Systematic reviews including a mixture of primary studies meeting and not meeting inclusion/exclusion criteria were included if:

- The majority (>50%) of included studies examined active performing arts participation in healthy populations and met no exclusion criteria (*reviews containing quantitative synthesis/meta-analysis*)

  OR

- The results of primary studies of active participation in healthy populations meeting no exclusion criteria could be extracted and re-synthesized for the purposes of this review (*reviews containing narrative synthesis*).

2.3.3 Data extraction

Demographic and outcome data were extracted for all included reviews and their underlying primary studies meeting inclusion criteria and no exclusion criteria. For each outcome, the effect of performing arts participation was determined to be 'positive', 'negative', 'no effect', or 'unclear'.

2.3.4 GRADE Quality of evidence appraisal

The GRADE system was favored for this review because of its alignment with review aims and applicability to systematic reviews of systematic reviews;[21] GRADE is specifically "designed for reviews…that examine alternative management strategies."[22] The GRADE system results in an appraisal of the quality of evidence supporting conclusions related to each outcome of interest—very low; low; moderate; high. Specific criteria and appraisal methodology are detailed in the Supplementary Appendix.

2.3.5 Evidence synthesis

To minimize the biasing effects of overlapping reviews, all outcomes from primary studies included in multiple reviews were only considered once. One outcome (flexibility – sit & reach) from one primary study was included in multiple meta-analyses and thus considered twice.[23] Common outcomes were first combined and assigned a grouped health effect and GRADE appraisal at the review level. Outcomes and GRADE appraisals were then combined across reviews and assigned a health effect and GRADE appraisal at the umbrella review level. Where appropriate, outcome results were stratified by music/dance participation, sex, age, GRADE appraisal, or instrument/style. Outcomes were categorized by domain, based on similar domains associated with the health benefits of physical activity.[3] Specific outcomes contained within each category are detailed in Table S1.

2.4 Systematic review of observational studies investigating the impact of performing arts participation on mortality and non-communicable disease risk

Given an absence of known reviews of epidemiologic data regarding performing arts participation and the importance of these data in evaluating health effects, the authors made an a priori decision to conduct a separate systematic review.

2.4.1 Search terms

Databases were searched using the following terms: ((music* OR danc* OR performing art* OR choir OR choral) AND (mortality OR public health OR disease OR risk) AND epidemiology).

2.4.2 Inclusion/exclusion criteria

Inclusion criteria were observational studies investigating the relationship between performing arts participation and all-cause mortality or non-communicable disease risk and/or non-

communicable disease risk factors (i.e. metabolic syndrome) in adults, adolescents or children. No exclusion criteria were defined.

2.4.3 Evidence synthesis, GRADE appraisal and synthesis

Conducted using an adaptation of the procedure detailed in sections 2.3.3-2.3.5, with included primary studies appraised individually and then synthesized at the level of this systematic review.

2.5 Systematic review of studies of heart rate responses to performing arts participation.

2.5.1 Search Terms

Database searches were performed using the following search terms: ((music* OR danc* OR performing art* OR choir OR choral) AND (load OR intensity OR heart rate)).

2.5.2 Inclusion/exclusion criteria

Inclusion criteria were studies reporting average/mean heart rate data collected from at least 1 minute of a representative period of active music or dance participation in any setting. Studies reporting heart rate such that raw heart rate data (beats per minute) could not be extracted were excluded.

2.5.3 Data extraction and appraisal

Demographic and raw heart rate data were extracted from all included studies. Raw heart rate data were calculated where necessary (i.e. from data expressed as % maximum heart rate). Rigorous application of inclusion/exclusion criteria was used in lieu of a formal assessment of evidence quality.

2.5.4 Evidence synthesis

Raw heart rate data were converted to % heart rate maximum ($\%HR_{max}$) using common estimation methods:[24,25]

$\%HR_{max}$ = ((raw heart rate / (208 – (0.7*age))*100).

$\%HR_{max}$ values were then categorized by intensity according to American College of Sports Medicine definitions.[26]

2.6 *Role of Funding Source*

The funder of the study had no role in study design, data collection, data analysis, data interpretation or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

3. Results

3.1 Systematic Review Statistics (Figure 1)

This umbrella review includes 33 systematic reviews of the health effects of performing arts participation (15 dance; 18 music), encompassing the results of 286 unique primary studies (128 dance; 158 music) and 149 outcomes across 18 health domains. Additionally, 9 observational studies investigating the impact of performing arts participation on mortality and non-communicable disease risk (3 dance, 5 music, 1 dance & music) were included, as well as 87 studies investigating heart rate responses to active performing arts participation (71 dance, 16 music). Review articles and observational studies of mortality and non-communicable disease risk are directly referenced in this manuscript (Tables 1 & 2); the complete list of references, including studies investigating heart rate responses, is contained in the Supplementary Appendix.

3.2 Health effects of active performing arts participation

Positive effects of performing arts participation were reported in 17 of 18 investigated domains – only glucose/insulin outcomes were consistently reported to be unaffected by dance participation (no data related to music participation)(Table 1). Positive effects in 9 domains (45 individual outcomes – *auditory; body composition; cognitive; immune function; mental health; physical fitness; physical function; self-reported health/wellbeing; social wellbeing*) were supported by moderate to high quality evidence, although results in 4 of these 9 domains (*cognitive; mental health; physical fitness; self-reported health/wellbeing*) demonstrated a mixture of positive and neutral/no effects varying by specific outcome (Table 2). Positive effects of performing arts participation were found in 9 of 13 domains (7 of 13 supported by moderate-high quality evidence) associated with the mechanisms of physical activity benefits (Tables 1 & 2).[3,12] Raw data underpinning summary results and GRADE appraisals are detailed in the Supplementary Appendix.

3.3 Physical demands of active performing arts participation

Heart rate responses to performing arts participation widely varied by style and/or performance setting, with studies of both music and dance participation reporting heart rates classified as very light, light, moderate, and vigorous intensity physical activity (Tables 3 and 4). Heart rate also varied substantially within the same instrument/style of music/dance participation, with 16 instruments/styles (12 music; 4 dance) associated with heart rate responses at two intensity levels, 3 instruments/styles (1 music – trumpet; 2 dance – ballet, modern) associated with heart rate responses at three intensity levels, and active video game dancing associated with heart rate

responses at all four intensity levels. Raw heart rate data underpinning summary results are detailed in the Supplementary Appendix.

4. Discussion

Synthesizing and appraising the results of 286 primary studies contained within 33 systematic reviews and an additional 9 epidemiological studies, this umbrella review demonstrates that performing arts participation is broadly health promoting activity, with evidence demonstrating positive effects in 17 domains. Further, heart rate data from an additional 87 studies indicate that both music and dance participation intrinsically elicit, while maintaining expressive rather than exertive aims, mean heart rate values corresponding to a range of intensities, including moderate and vigorous.

Significant variability in the demands of performing arts participation, even within the same instrument/style, limit specific conclusions regarding the impact of intensity on reported benefits. However, evidence regarding the health impacts of performing arts participation and physical activity are broadly consistent, both suggesting that higher intensity activity is a necessary prerequisite to positive changes in some domains (i.e. body composition, physical fitness) more than others (i.e. physical function, cognitive).[12] Positive effects of dance participation on body composition and physical fitness outcomes were largely generated through dance styles associated with moderate-vigorous intensity heart rate responses (aerobic dance, ballroom, Zumba)(Tables 2 &3). Conversely, performing arts activities associated with a range of heart rate responses (i.e. aerobic dance, ballroom dance, instrumental music, tango) reported positive impacts on physical function and cognitive outcomes (Tables 2-4).

Studies of the impact of performing arts participation on mortality and non-communicable disease risk indicate a positive association supported by low quality evidence. However, the range of heart rate intensities elicited by performing arts activities (*very light – vigorous*) suggest at least modest benefits in these domains across styles/instruments; physical activity data demonstrate that mortality and disease benefits are conferred on a 'some is better than none, more is better than less' continuum with respect to the intensity and/or duration of weekly exercise.[1] Further high quality research with validated, sensitive instruments for quantifying performing arts participation is necessary to confirm these suggestive results.

In sum, the results of this review suggest that active performing arts participation may be a valuable public health resource as an alternative and/or adjunct to commonly promoted exercise-based physical activity modes.[5] The potential scope of health benefits is massive, with 27.5% of adults and 81% of adolescents insufficiently active worldwide.[9] However, the specific public health utility of performing arts participation hinges on confirmation of its ability to engage presently inactive individuals and, in particular, those with low exercise self-efficacy.

Enjoying music – central to both dance and music participation – is highly pleasurable and engages several reward-related brain areas, in particular the nucleus accumbens (NAc).[14] Further, this hedonic quality of performing arts participation is suggested to be foundational to motivations for both dance and music participation,[27,28] with a preliminary study also demonstrating distinct motivations for dance vs. exercise.[29] However, robust investigations are necessary to provide more detailed insights regarding differential motivations for exercise vs. performing arts participation and their implications for individual engagement and sustained participation. Such research would enable future studies of performing arts participation to be targeted towards clarifying health effects and participation specifics (i.e. frequency, duration,

type) in areas of greatest prospective public health impact – i.e. studies in inactive populations if performing arts participation is shown to engage these individuals.

While this review presents promising evidence, it should be noted that the evidence base is very much still in its infancy. Many reported benefits are supported by evidence from only one study and the overall quality of evidence is generally low (*26% (45/173) of reported outcomes backed by moderate-high quality evidence*). Additionally, this umbrella review was limited, excepting studies of non-communicable disease risk, to studies included in systematic reviews of the health effects of performing arts participation. It is thus possible that some primary studies were not considered; their exclusion could significantly impact individual outcome results given the aforementioned infancy of the evidence base. However, it is unlikely that these primary studies would change the broad conclusions of this umbrella review that performing arts participation is health promoting activity with potential public health utility.

This review is also potentially limited in specificity and precision by the conduct of literature searches, data extraction, and evidence appraisal by the first author alone, in consultation with the authorship team, due to resource constraints. Single author search, extraction and appraisal has been demonstrated to increase the incidence of errors,[30] yet these errors have been found to have a minimal impact on review results and conclusions.[31] Further, such unconscious errors would be particularly unlikely to substantially change review results given the general nature of data syntheses and umbrella review conclusions. To best meet study aims, the authors thus favored a broad, single author search, extraction and appraisal over a more constrained review conducted by multiple authors in duplicate. Additionally, the inclusion of a comprehensive and transparent supplementary appendix detailing all review data and subjective decision-making (i.e. article inclusions, GRADE appraisals) clarifies the basis for specific

conclusions and serves as a foundation for discussion and future research building upon specific outcome results.

Finally, while studies of participation-related performing arts injuries were beyond the scope of this review, it should be noted that, similar to exercise participation,[32] the health impact of performing arts activities is not exclusively positive and participation in performing arts does carry an injury risk, for example caused by overpractice.[15] These risks are considerably counterbalanced by the broad benefits of performing arts participation demonstrated in this review. However, on an individual level, participation risks must always be managed and weighed against potential benefits.

Conclusions

Performing arts participation is broadly health promoting activity and may be a valuable public health resource as an alternative and/or adjunct to exercise-based physical activity modes. The evidence base regarding the health impact of performing arts participation is, however, very much in its infancy, and further research is necessary to clarify specific health effects and participation characteristics (i.e. type, duration, frequency) underpinning observed benefits. Additionally, investigations of the ability of the performing arts to engage inactive individuals and those with low exercise-self efficacy will help determine the specific public health utility of performing arts participation. The broad yet rigorous approach of this umbrella review provides an excellent knowledge foundation for such future research.

Contributors

JMM designed the review protocol, conducted literature searches, extracted and appraised data, and drafted the final manuscript. ER contributed to data interpretation and critically revised the final manuscript. EA contributed to protocol design and data interpretation, and critically revised the final manuscript.

Declaration of interests

We declare no competing interests.

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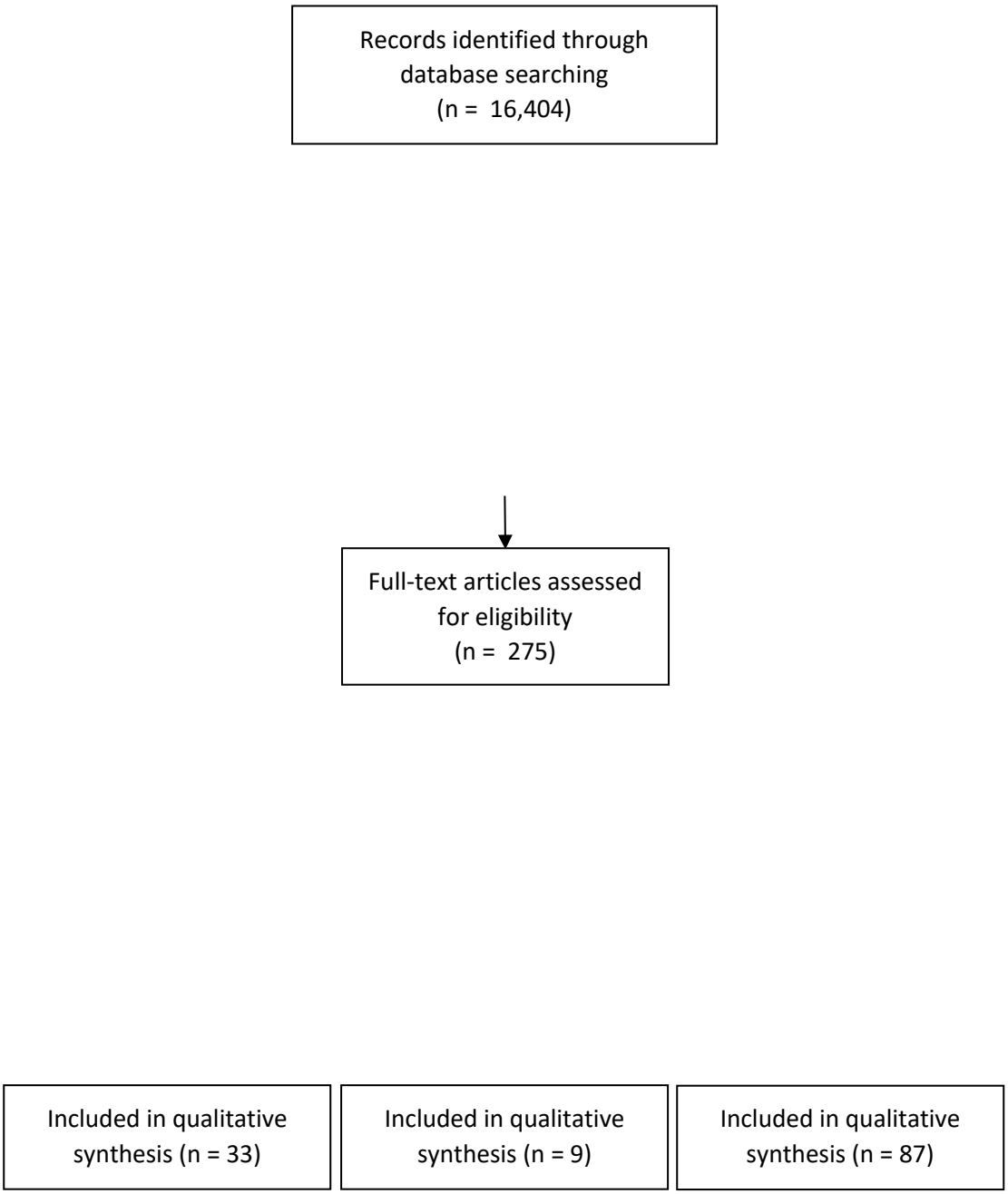

Figure 1. PRISMA diagram[33] detailing umbrella review results.

	MUSIC PARTICIPATION		DANCE PARTICIPATION	
Outcome Category	*Effects*	*GRADE quality of evidence*	*Effect*	*GRADE quality of evidence*
Auditory[34,35]	Positive, No effect, Negative	Very Low, Low, Moderate		
Autonomic Tone[36#]	Positive, No effect	Very Low		
Blood pressure[37-41#]	Positive, No effect	Very Low	Positive, No effect	Very Low
Body Composition[39-44#]			Positive, No effect	Very Low, Moderate
Bone Health[39,40,42,45]			Positive, No effect	Very Low, Low
Cognitive[34,36,37,42,46-50]	Positive, No effect	Very Low, Low, Moderate, High	Positive, No effect	Very Low, Low, Moderate, High
Developmental (physical)[40,43]			Positive, No effect, Negative	Very Low, Low
Educational[34,49,51-53]	Positive, No effect, Negative	Very Low		
Stress Response/Endothelial function[35,36,38,54#]	Positive, No effect	Very Low, Low		
Glucose/Insulin[39,41,42#]			No effect	High
Immune function/Inflammation[35-37,41,54#]	Positive, No effect	Very Low, Low, High	Unclear, No effect	Very Low, Low
Lipid lipoprotein profile[39,41,42,44#]			Positive, No effect	Very Low
Mental health[35-38,40,42,55-60#]	Positive, No effect	Very Low, Low	Positive, No effect	Low, Moderate, High
Non-communicable disease risk[61-69]	Positive, No effect, Negative	Very Low, Low	Positive, No effect	Very Low, Low
Physical fitness[39-44,46,54,70,71#]	Positive, No effect	Very Low	Positive, No effect	Very Low, Low, Moderate, High
Physical function[35,38-40,42-44,46,60,70-74#]	Positive, No effect	Very Low, Low	Positive, No effect	Very Low, Low, Moderate, High
Self-reported health/wellbeing[35-38,40,42,44,46,54,57-60,70,71,75]	Positive, No effect	Very Low, Low, High	Positive, No effect	Very Low, Low, Moderate, High
Social functioning[35-38,46,55,57-60]	Positive, No effect	Very Low, Low, High	Positive	Moderate

Table 1. Summary of effects of music and dance participation from included reviews and observational studies (non-communicable disease risk) on health parameters, grouped by domain. # - domain linked to mechanisms of the health benefits of physical activity (no performing arts data associated with 3 proposed domains/mechanisms –cardiac function; blood coagulation; coronary blood flow).[3,12] *'Positive' and 'no effect' results highlighted in green and black, respectively, are supported by moderate and/or high quality evidence.*

Domain	*Outcome*	*GRADE*	*Effect*	*# reviews*	*# studies/ outcomes*	*Sex*	*Age group*	*Music/ Dance?*	*Style/instrument*	*Participation Length*
Auditory	Auditory processing	Moderate	Positive	1[34]	13	Mixed	Adults	Music	Instrumental	Sustained
	Pitch discrimination	Moderate	Positive	1[34]	7	Mixed	Adults	Music	Instrumental, unspecified	Sustained
	Speech in noise	Moderate	Positive	1[34]	21	Mixed	Children, Adolescents, Adults	Music	Instrumental, vocal, unspecified	Sustained
***Autonomic Tone*[#]**										
***Blood pressure*[#]**										
***Body Composition*[#]**	Skinfold measurements	Moderate	Positive	1[39]	3	Female, Unspecified	Children, Adolescents, Adults	Dance	Aerobic dance	Sustained
	Total fat mass	Moderate	Positive	1[39]	4	Female	Children, Adolescents, Adults	Dance	Aerobic dance, Zumba	Sustained
Bone Health										
Cognitive	IQ	Moderate	Positive	2[34,49]	5	Mixed	Children, Adolescents, Adults	Music	Instrumental, Music education	Sustained
	Memory (long-/short-term, working)	Moderate	Positive	1[50]	42	Mixed	Adults	Music	Instrumental	Sustained
	Spatial ability/reasoning	High	Positive	1[48]	23	Mixed	Children, Adolescents	Music	Music education (general, Kodaly, Kindermusik, snare drum, piano, vocal)	Sustained
	Attention	Moderate	Positive	1[46]	2	Mixed	Older adults	Dance	Agilando, Multiple (line/jazz/ rock‘n‘roll/square)	Sustained
	BDNF	Moderate	Positive	1[46]	1	Mixed	Older adults	Dance	Multiple (line/jazz/rock‘n‘roll/ square)	Sustained
	Brain structure/plasticity	Moderate	Positive	1[46]	3	Mixed	Adults, Older adults	Dance	Multiple (line/jazz/rock‘n‘roll/ square), unspecified	Sustained
	Cognitive function/Global cognition	High	Positive	2[46,47]	10	Mixed	Older adults	Dance	Agilando, Ballroom, Jazz, Latin, Tango, Square dance	Sustained
	Executive function	High	No effect	3[42,46,47]	11	Mixed	Older adults	Dance	Ballroom, Contemporary, Folk, Latin, Social, Tango, Waltz	Sustained
	Perceptual speed	High	No effect	1[46]	2	Mixed	Adults, Older adults	Dance	Social, unspecified	Sustained
	Vocabulary	High	No effect	1[46]	1	Mixed	Older adults	Dance	Social	Sustained
Developmental										
Educational										

Stress Response / Endothelial function#										
Glucose/Insulin#	Glucose	High	No effect	3[39,41,42]	6	Mixed	Adults	Dance	Aerobic Dance, Ballroom, Bhangra, Zumba	Sustained
	Insulin	High	No effect	2[41,42]	2	Female	Adults	Dance	Bhangra, Zumba	Sustained
Immune function /Inflammation#	Immunological / inflammatory profile	High	Positive	2[36,37]	2	Mixed	Adults	Music	Drums	Acute
	Immunoglobulin A	High	Positive	3[35,36,54]	4	Mixed	Adults, Older adults	Music	Singing, Drums	Acute
Lipid lipoprotein profile#										
Mental health#	Depression	High	No effect	1[42]	1	Mixed	Older adults	Dance	Turkish folk dance, Jazz, Social	Sustained
	Mood	Moderate	Positive	1[40]	1	Mixed	Adults	Dance	Hip hop	Acute
	Self-perception	Moderate	Positive	1[40]	2	Female	Adolescents	Dance	Aerobic dance	Sustained
Non-communicable disease risk										
Physical fitness#	Abdominal strength/endurance (sit ups)	Moderate	Positive	2[39,40]	5	Female, Unspecified	Children, Adolescents, Adults	Dance	Aerobic dance	Sustained
	Cardiovascular capacity (VO_2 max)	High	Positive	3[39-41]	12	Mixed	Adolescents, Adults, Older Adults	Dance	Aerobic dance, Balinese, Dance Team, Greek folk/traditional dance, Waltz, Zumba	Sustained
	Endurance (6-minute walk test)	High	Positive	3[39,41,70]	6	Mixed	Adults, Older adults	Dance	Aerobic Dance, Ballroom, Thai, Turkish folk, Zumba	Sustained
	Power (muscular/aerobic)	High	No effect	2[42,43]	2	Mixed	Adults, Older adults	Dance	Ballet, Salsa	Sustained
	Peak ventilation	High	Positive	1[39]	4	Mixed	Adults, Older adults	Dance	Aerobic dance, Greek folk/traditional dance, Zumba	Sustained
	Respiratory exchange ratio	Moderate	No effect	1[39]	2	Mixed	Adults	Dance	Aerobic dance, Zumba	Sustained
	Strength	Moderate	Positive	3[39,40,42]	8	Mixed	Children, Adolescents, Adults, Older adults	Dance	Aerobic Dance, Dance Team, Social	Sustained
Physical function#	Balance	High	Positive	6[42,46,70, 72-74]	47	Mixed	Adolescents, Adults, Older adults	Dance	Aerobic Dance, Agilando, Ballet, Ballroom, Caribbean, Contemporary, Greek traditional, Latin, Lebed Method, Line dance, Modern, Multiple (line/jazz/rock‘n‘roll/ square), Opera, Salsa, Thai, Turkish folk, Zumba	Sustained

	Flexibility/range of motion	High	Positive	4[39,42,43,70]	19	Mixed	Children, Adolescents, Adults, Older Adults	Dance	Aerobic dance, Ballroom, Ballet, Folk/traditional dance, Social, Thai, Zumba	Sustained
	Mobility (timed up & go; sit to stand)	Moderate	Positive	2[42,70]	12	Mixed	Older adults	Dance	Aerobic dance, Argentine Tango, Ballroom, Folk, Lebed method, Turkish, Thai	Sustained
	Proprioception	High	Positive	1[74]	1	Mixed	Older adults	Dance	Creative Dance	Sustained
Self-reported health/wellbeing	Fatigue	High	Positive	2[38,39]	2	Mixed	Adults	Music	Drums	Acute
	Quality of life	High	Positive	2[38,57]	2	Mixed	Adults, Older Adults	Music	Singing	Sustained
	Alcohol Consumption	Moderate	No effect	1[42]	1	Mixed	Older adults	Dance	Caribbean	Sustained
	Balance confidence	High	Positive	1[42]	1	Mixed	Older adults	Dance	Argentine tango	Sustained
	Functional autonomy	High	Positive	1[42]	1	Unspecified	Older adults	Dance	Ballroom	Sustained
	Life satisfaction	High	Positive	1[42]	1	Mixed	Older adults	Dance	Creative Dance	Sustained
	Sexual activity	Moderate	Positive	1[42]	1	Mixed	Older adults	Dance	Caribbean	Sustained
	Sleep quality	Moderate	Positive	1[42]	1	Mixed	Older adults	Dance	Caribbean	Sustained
	Smoking	Moderate	No effect	1[42]	1	Mixed	Older adults	Dance	Caribbean	Sustained
	Stress	Moderate	Positive	1[46]	1	Mixed	Older adults	Dance	Social	Sustained
Social functioning	Anger	High	Positive	2[36,38]	2	Mixed	Adults, Older adults	Music	Drums	Acute
	Social Support (perceived)	Moderate	Positive	1[46]	1	Mixed	Older adults	Dance	Social	Sustained

Table 2. Details of specific outcomes with moderate – high certainty of evidence (GRADE). Age group classifications based on United Nations/World Health Organization definitions: 0-9 years – children; 10-19 years – adolescents; 20-59 – adults; 60+ – older adults. 'Acute' participation refers to a single session (up to 2.5 hours) of performing arts participation; 'sustained' participation refers to 4+ weeks of at least weekly performing arts participation. # - domain linked to mechanisms of the health benefits of physical activity (no performing arts data associated with 3 proposed domains/mechanisms –cardiac function; blood coagulation; coronary blood flow).[3,12]

	Instrument/style	*Participation Setting*
Very Light (<57% max)	Classical Indian Music	Performance
	Contemporary band*	Rehearsal
	Drum corps*	Rehearsal
	Flute/Singing*	Rehearsal
	Marching band*	Rehearsal
	Piano*	Rehearsal
	Strings*	Rehearsal, Practice
	Trumpet**	Practice
	Varied instruments in orchestra*	Rehearsal, Performance
	Winds*	Rehearsal
Light (57-63% max)	Clarinet*	Performance
	Contemporary band*	Performance
	Drum corps*	Rehearsal
	Percussion (classical)	Performance
	Singing (operetta)*	Performance
	Strings*	Performance
	Trumpet**	Laboratory
	Winds*	Performance
Moderate (64-76% max)	Bagpipes*	Laboratory
	Clarinet*	Performance
	Conductor (opera)	Performance
	Drum set*	Laboratory
	Flute/singing*	Performance
	Marching band*	Performance
	Singing (Opera)	Performance
	Piano*	Performance
	Trumpet**	Laboratory
	Varied instruments in orchestra*	Performance ('public session')
Vigorous (≥77% max)	Bagpipes*	Laboratory
	Drum set*	Performance
	Musical theater (singing + dance)	Laboratory
	Singing (operetta)*	Performance

*Table 3. Summary of heart rate responses to active music participation from included studies. * - instruments / styles with reported heart rate responses at 2 intensity levels. ** - instruments/styles with reported heart rate responses at 3 intensity levels. See Supplementary Appendix for source data and citations.*

	Dance style	*Participation setting*
Very Light (<57% max)	Active Video Game Dance***	Laboratory
	Modern**	Rehearsal/Class
Light (57-63% max)	Active Video Game Dance***	Laboratory
	Ballet**	Class
	Fox trot	Class
	Merengue	Class
	Mixed ('Dancing Classrooms')	Class
	Modern**	Class
	Rhumba	Class
	Salsa*	Class
	Tango	Class
	Waltz	Class
Moderate (64-76% max)	Active Video Game Dance***	Laboratory
	Aerobic Dance*	Laboratory, Class
	Ballet**	Class
	Dance Fitness Class	Laboratory
	Disco	Party
	Fijian	Laboratory
	'Fun Dance'	Class
	Hawaiian Hula*	Laboratory
	Latin	Laboratory
	Line dancing	Class
	Maori haka	Laboratory
	Maori poi balls	Laboratory
	Mixture (anti-aging focus)	Class
	Modern**	Class, Dress Rehearsal
	Pole Dancing	Class
	Salsa*	Class, nightclub
	Samoan sasa	Laboratory
	Swing	Class
	Tongan	Laboratory
	Zumba*	Class, Home, Laboratory
Vigorous (≥77% max)	Active Video Game Dance***	Laboratory
	Aerobic Dance*	Laboratory, Class
	Ballet**	Class, Rehearsal, Laboratory, Performance
	Ballroom	Laboratory
	Highland Dance	Rehearsal, Performance
	Hip-hop	Laboratory
	Hawaiian Hula*	Laboratory
	Musical Theater (dance only)	Laboratory
	Polish folk dancing	Laboratory
	Samoan slap	Laboratory
	Sardinian folk dance (ballu sardu)	Laboratory
	Sports Dancing	Laboratory
	Swedish folk dance (hambo)	Laboratory
	Tahitian	Laboratory
	Tap dance	Laboratory

Tinikling (traditional Filipino dance)	Laboratory
Zumba*	Class

*Table 4. Summary of heart rate responses to active dance participation from included studies. * - dance styles with reported heart rate responses at 2 intensity levels; ** - dance styles with reported heart rate responses at 3 intensity levels; *** - dance styles with reported heart rate responses at all 4 intensity levels. See Supplementary Appendix for source data and citations.*

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