The Effectiveness of Technology-Mediated Dance Interventions and Their Impact on Psychosocial Factors in Older Adults: A Systematic Review and Meta-Analysis

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The Effectiveness of Technology-Mediated Dance Interventions and Their Impact on Psychosocial Factors in Older Adults: A Systematic Review and Meta-Analysis

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Abstract

Background: Engaging in physical activity contributes to healthy aging; however, adherence to exercise programs is often low among older adults. Technology-mediated dance systems, which can be used at home, and dance as a way of keeping physically active have been receiving attention as a means of not only enabling physical activity among older people but may also address key psychosocial factors that are amenable to change.

Objectives: To assess the effectiveness of technology-mediated dance interventions and their impact on psychosocial factors in older adults (aged 65 or older).

Methods: A systematic review of randomized controlled trials from January 2000 to February 2017 using key search terms. Two independent reviewers screened articles using predetermined selection criteria. Risk of bias of selected articles was assessed in accordance with the Cochrane guidelines.

Results: From an overall 264 articles, six articles (five studies) were found, which assessed the impact technology-mediated dance interventions on psychosocial factors in older adults. Studies' quality ratin low, with exception of one study that was considered of moderate quality. None of the studies considered psychosocial factors as primary outcomes. Secondary outcomes assessed fear of falling, depression, and training enjoyment, but no study showed evidence of an effective impact on these variables. The meta-analysis revealed low quality evidence that there was little or no difference above that of the comparison groups for fear of falling (standardized mean difference [SMD] −0.02, 95% confidence interval [CI] −0.37 to 0.33; *P* = 0.91; five trials). Similarly, there was little or no difference on depression (SMD −0.06, 95% CI −0.59 to 0.47; *P* = 0.83; three trials).

Conclusion: Existing evidence to support the effectiveness of technology-mediated dance interventions and their impact on psychosocial factors in older adults is weak and with a high risk for bias. The findings of this review may inform future, more rigorous research in the area.

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Introduction

The world's population is aging. According to the Eurostat, an increase from 18.5% (or 93.9 million) to 28.7% (or 149.1 million) is projected for people aged 65+ between 2014 and 2080.[1] The United Nations[2] make similar projections for people aged 60+, forecasting a growth of 56% between 2015 and 2030, and more than doubling between 2015 and 2050, when the number of people older than 60 in the world should reach nearly 2.1 billion. With these projections, the welfare of older generations becomes increasingly important, both for the individual and the wider society.

Promoting and maintaining physical activity play a critical role in sustaining health, well-being, and quality of life; in an aging society, these attributes are especially important to maintain. The effects of engaging in physical activity have been extensively researched and evidence shows that the benefits range from physical to cognitive and psychosocial improvements.[3–11] It is thus of no surprise that organizations such as the WHO[12] and Age UK[13] stress the importance of a healthy active life style and exercising to maintain and improve health.

Despite the benefits in promoting health and quality of life associated with physical activity, adults are not regular exercisers[14] and adherence to exercise programs is problematic and often low (e.g., Refs.[15,16]). One of the possible reasons for this may be the fact that repetitive form of exercise may be perceived as monotonous and boring.[17] Having fun is one of the main reasons that older adults adhere to physical activity programs[18]; this puts dance, as well as entertainment technologies, in a privileged position to promote physical activity among older adults.

Dance, in this context, can be described as a physical, cognitive, and often social activity, comprising a sequence of movements usually performed to the sound of music or some sort of rhythm. Dance emerges as an alternative form of exercise that has the potential of being effective, appropriate, and attractive, which, irrespective of the style, improves muscular strength and endurance, balance, and other aspects of functional fitness in older adults.[19] Moreover, dance can positively impact the health and well-being of both healthy (e.g., Refs.[20,21]) older people and those with specific health conditions (e.g., Refs.[20,22–24]).

Specifically, the reported physical benefits of dance include improvements in aerobic power, balance, agility, gait, and muscle power.[25–30] Studies examining cognitive or psychosocial factors alone are scarcer. Nevertheless, cognitive benefits of dance have been reported, especially when choreographies and dual-task activities are present.[31] Likewise, benefits extend to psychosocial improvements, for example, in terms of perceptions of general health and pain,[32] depression,[33,34] mood, and quality of life.[35,36]

For example, a study with 35 healthy older adults by Kattenstroth et al.[21] investigated physical, cognitive, as well as psychosocial effects after a 6-month dance intervention and concluded that dance has benefits across the domains. There are, therefore, compelling reasons to encourage people to engage in dancing activi only to improve their physical but also their cognitive and psychosocial health, well-being, and quality o Given the evidence of sensory, motor, and cognitive improvements observed, Kattenstroth et al.[37](p31) argue that dance is "a prime candidate for the preservation of everyday life competence of elderly individuals," with benefits for the body and mind. Dhami et al.[38] further argue that dance offers a framework for rehabilitation and neurorehabilitation, given its potential in promoting physical and cognitive stimulation, being enjoyable, and likely to achieve high levels of adherence.

While some older adults may particularly enjoy dancing as a form of exercise, there is often a lack of specific opportunities to dance and difficulty of fitting classes or events into their schedules.[39] Technology-mediated interventions offer a viable alternative, which could be readily accessed at home for example. This is especially relevant as evidence from an earlier systematic review suggests that training at home increases adherence of older adults to physical activity in the long term[40]; this was the case for a group of sedentary older adults receiving cardiovascular treatment, where the home-based group had double the adherence of the center-based group over a period of 6 months.

Technology-mediated applications also have the potential to offer motivating alternatives for older adults to exercise regularly. A review by Shelton and Uz[41] highlights the positive impact of games, simulations, and robots on motivation and the reduction of barriers to exercise among the older population. This improvement may be explained by the fact that game elements in virtual reality applications may help to take attention away from any pain or discomfort, thus increasing motivation and participation.[42]

Technologies used in the context of physical activity for older adults can take many forms, from interactive television[43] to virtual reality[42] and Kinect-based applications,[15,44–46] both at home[47] and institutionalized settings (e.g., Ref.[17]). Exergames are a popular type of application, which, by adding an element of fun to exercise, can improve seniors' physical and mental health.[48] Both tailor-made (e.g., Ref.[49]) and commercial exergames (e.g., Ref.[50]), such as the ones available for the Nintendo Wii, have been extensively researched to assess its efficacy (for a review see Chao et al.,[51] including systematic reviews of randomized controlled trials, e.g., Ref.[52]).

Exergaming may be employed as an effective exercise behavior change strategy for adults[53] and appears to be appropriate, effective, and safe for older adults.[54] However, despite showing promising results in improving older adult's physical function, both in terms of safety and efficacy, studies on exergames so far have methodological weaknesses associated with risk of bias, limiting the ability to confirm and truly understand its benefits.[55] Similar concerns related to methodological reservations were reported in a number of systematic reviews.[52,56,57] However, a common positive aspect that emerges in studies using technology to improve older adults' physical functioning is enhanced motivation.[52]

There are a number of examples of exergames that incorporate dance games; some are designed for any age group (for e.g., Refs.[53,58,59]) and others are specifically developed for older adults or adapted to be inclusive of the older adult population. The latter include the following: DanceAlong,[39] DanceTown,[17] and Dance! Don't Fall.[60,61] Dance Dance Revolution (DDR) was begun as an arcade game and became the first commercially successful exergame around the time when consoles such as the Nintendo Wii gained popularity.[62] To use DDR, players stand on a pad with colored arrows and step on them according to the visual cues on a screen.

However, features such as its fast-paced music, frequent jumping, and overload of information on the screen may render the game inappropriate for the older adult population.[63] This led Smith et al.[16] to develop a modified version of DDR to specially accommodate for older adults' characteristics and to improve their motivation and adherence to rehabilitation activities. This modified version of the game was played on a dance pad sensor with about 1 m^2 with four to eight panels displayed as arrows. Instructions were displayed on a television or computer screen. In their study, Smith et al.[16] showed seniors were able to use the system, but their error rate grew as the step speed and rate increased. After this, a number of studies followed, disc and using iterated versions of the system to further contextualize[42] and understand its potential (e.g., Refs.[64,65]).

In 2011, Smith et al.[65] investigated the interaction and use of the modified DDR game by older adults, concluding that older adults could indeed use the modified game and stepping performance measures could be collected. In turn, De Bruin et al.[64] assessed feasibility and specific effects of the dance intervention over 12 weeks on walking and fear of falling, with results indicating positive changes on both. Schoene et al.[65] further assessed and confirmed the reliability of the dance mat to perform a Choice Stepping Reaction Time task, typically used to distinguish between fallers and nonfallers older adults. After this, a number of studies, including randomized controlled trials,[47,66–74] followed to verify the impact and efficacy of the modified game, which started to be referred to as StepMania at some point in 2012 (all of the previously cited except[70]).

To our knowledge, studies on dance interventions and technology-mediated dance interventions for older adults predominantly focus on physical factors and sometimes on cognitive, but those investigating psychosocial aspects are less common. This may be due to a lack of consistency surrounding the term quality of life.[75] Moreover, systematic reviews have examined the effectiveness of dance (e.g., Ref.[19]) and technology-mediated interventions (e.g., Ref.[56]) in improving older adults' quality of life and health, but to our knowledge, none has specifically reviewed technology-mediated *dance* interventions. Arguably, psychosocial aspects are equally important to maintaining the health and well-being of older adults, therefore these deserve to be further investigated, as previous studies have concluded that this type of effects are unclear.[57] Thus, this study concerns the intersection of dance, health, and technology with a focus on psychosocial factors and the broader area of quality of life.

Only randomized controlled trials are included because these are considered "the gold standard for assessing the effectiveness"[76] and "the evidence of efficacy"[77] of interventions. Specifically, this systematic review aims to address this question: What is the effectiveness of technology-mediated dance interventions in improving psychosocial variables in older adults (+65)?

Method

The guidelines from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement[78] were used to create this systematic review. The review was registered with PROSPERO (International Prospective Register of Systematic Reviews: registration number: CRD42016045180) before the start of the literature search.

Search strategy

The systematic search of an initial database (PubMed) was conducted between January and February 2017. The search was extended to six databases (Academic Search, etc.) as well as grey literature repositories (See Appendix A1 for Pubmed search strategy). The search was further extended to additional databases (ACM Digital Library, Academic Search Complete, IEEE, Scopus, Web of Science Core Collection, BASE, Open Grey, Core, NDLTD, DOAJ, Trip and Social Science Full) to maximize coverage. Searches were limited to English language only and published from 2000 onward, reflecting the development and use of the technology of interest.

We also screened reference lists of relevant articles and other systematic reviews to identify any additional eligible trials. All titles and abstracts of the identified references were screened for eligibility; those that were deemed immediately irrelevant were discarded. Two review authors (P.A.S. and A.C.) independently reviewed the full text of the remaining studies; disagreements were resolved by discussion and consensus.

Eligibility criteria

Trial design

Randomized controlled trials (RCTs), cluster randomized trials, and quasi-RCTs compared with a control group consisted of either (1) dance without technology; (2) wait-list; or (3) active intervention arms, such as other forms of physical activity.

Population

People aged 65 or older, including both healthy older adults and/or those with specific chronic conditions. We only included studies with younger populations if it was possible to disaggregate the data.

Intervention

For the purpose of this review, dance was defined as a physical, cognitive, and psychosocial activity, either done alone or in a group, which encompassed a sequence of movements usually performed to the sound of music or some sort of rhythm. The intervention could comprise any type of dance, alone, in pairs, or as a group, as long as it was mediated by a form of technology (e.g., serious games, exergames, virtual reality, online applications, public displays, consoles, virtual coaches, avatars, videos, mats, tiles, and platforms, i.e., technology is understood in a broad sense). We also considered studies that included dance as part of a multicomponent intervention. The intervention could take place in any location, including the home, community, or healthcare setting.

Outcomes

Trials were only included if they measured one or more psychosocial outcome, including the following:

- Quality of life using standardized measures (e.g., SF-36, EQ-5D, and CASP-19) or other tools designed specifically for the study.
- Falls efficacy, fear of falling, and number of falls.
- Measures reporting on overall satisfaction with life such as mood (e.g., depression and anxiety), self-efficacy, and fatigue.

Secondary outcomes were satisfaction with, acceptability, and adherence of the intervention. Adverse events were, for example, fall and or injuries sustained while dancing.

We included trials that reported outcomes for short- (e.g., 2–12 months) and long-term follow-up (e.g., 12 months or longer). Studies of cost-effectiveness were included as long as these were conducted alongside or subsequent to a trial that met the inclusion criteria.

Risk of bias assessment

The methodological risk of bias of included studies was assessed in accordance with the Cochrane guidelines.[79] The six main domains of the risk of bias tool and the following other potential sources of bias were assessed: (1) baseline comparability of groups; (2) compliance with intervention; and (3) use of co-interventions. Each item was judged separately as being at high, low, or unclear risk of bias.[79] Studies were assigned a low-quality rating (low risk of bias on four or less items); moderate quality (low risk of bias on 5–7 items); or high quality (low risk of bias on eight or more items). In all cases, two reviewers independent assessed the risk of bias of included studies; any disagreements were resolved by discussion and con

Data extraction and synthesis of results

Data were extracted independently by two reviewers to identify the following: Country; Settings (e.g., home/care facilities and dance activity done in group/alone); Participants (e.g., age, gender, health status, diagnosis); Technology used for dance; Dance intervention characteristics (including frequency, intensity, and duration); Comparison group intervention characteristics; Assessment timeframes; Outcomes; and Compliance (for details refer to Tables 2 and 3). Where necessary, methods described in the Cochrane Handbook were used to convert study results to the required format. Intention-to-treat analyses were used when available. In trials where there were multiple groups from the same study (e.g., two active nondance groups), we planned to follow the approaches outlined in the Cochrane Handbook to either combine groups or conduct pair-wise comparisons.

We conducted a meta-analysis where homogeneity was sufficient in terms of the main components of the intervention, outcome domains, and follow-up time point. We assessed the degree of heterogeneity by the visual inspection of forest plots and by examining the χ^2 test for heterogeneity. Heterogeneity was quantified using the I^2 statistic 81; an I^2 value of 50% or more was considered to represent substantial heterogeneity, and this was interpreted in view of size and direction of effects, and the strength of the heterogeneity based on the *P* value from the χ^2 test. If there was evidence of heterogeneity, we planned to discuss any possible reason, and if there had been sufficient trials, we would have conducted subgroup analyses accordingly; the issue of sample size and power in each study would be considered in the interpretation and reporting of results.

Continuous data (e.g., fear of falling) were analyzed based on the mean and standard deviation, and number of people assessed for both the intervention and comparison groups to calculate mean difference and 95% confidence intervals (CIs). Where continuous variables (e.g., depression) were measured using different scales across studies, we used standardized mean differences (SMDs) with 95% CIs and the random effects method to pool results. All analyses were calculated using Review Manager 5.3.[80]

Results

Figure 1 summarizes the screening and selection process. The initial search yielded 264 records, from which 129 duplicates were removed. The titles and abstracts of the remaining 133 articles plus 6 additional ones identified through targeted searches were then screened for eligibility to yield 76 full-text articles. From these, 71 records were excluded following examination of the full text. Articles were excluded mostly because they were narrative reviews, the participants were younger than 50, the intervention did not involve technology, the study did not report on quality-of life measures or any psychosocial outcomes, the studies were not RCTs, and the technology was meant to support dance teachers instead of participants. One particular record was excluded because despite stating collecting psychosocial measures, these are not reported.[81] Six records met our inclusion criteria. From these, two referred to the same cohort of participants and overall study, but results were reported in two different articles. For this reason, from now on, whenever appropriate, these two studies are grouped and referred to as one single study.

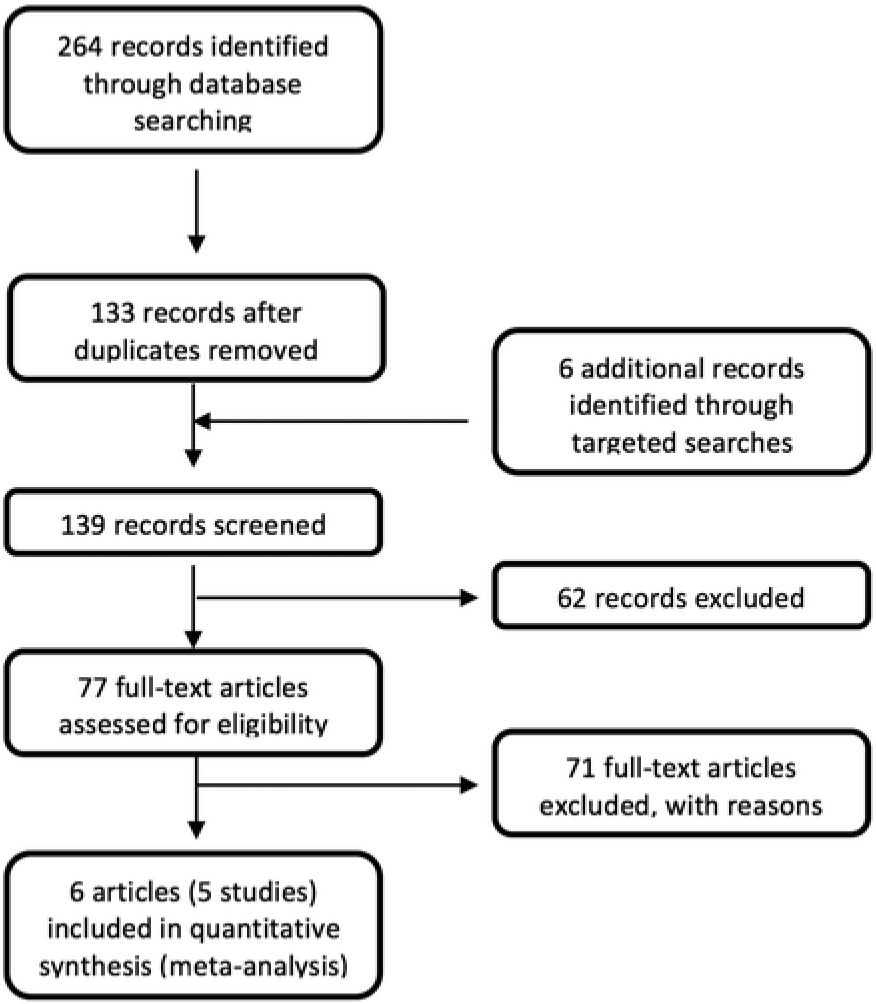

FIG. 1. Overview of screening and selection process.

Quality of the evidence

A high-risk bias was identified for the majority of studies using the Cochrane Collaboration Risk of Bias Tool (Table 1). Only one study[72] was considered to be of moderate quality with the remainder of low quality. There is also some concern over the precision of the findings due to the small sample sizes, compounded by the high attrition rates for all studies, except the study by Schoene D et al.[72]

Table 1. Risk of Bias

Trial	*Random sequence generation*	*Allocation concealment*	*Participants personnel blinding*	*Outcome assessors blinding*	*Incomplete outcome data (attrition)*	[illegible]
Eggenberger et al.[66,67,a]	Low	Low	High	High	High	[illegible]

Trial	Random sequence generation	Allocation concealment	Participants personnel blinding	Outcome assessors blinding	Incomplete outcome data (attrition)
Eggenberger et al.[68]	Low	Unclear	High	High	High
Pichierri et al.[69]	Low	Unclear	High	High	High
Schoene et al.[72]	Low	Low	High	Low	Low
Schoene et al.[73]	Low	Low	High	Low	High

[a]Two articles reporting on different parts of the same study.

Trial characteristics

The study characteristics for the trials included in this systematic review are summarized in Tables 2 and 3. Four studies were conducted in Switzerland[66–68,70] and two in Australia,[72,73] mainly within the same two research groups. None of the studies had the primary objectives to enhance psychosocial factors, but rather physical and cognitive factors. The main goal of four of the studies was related to fall risk, with one study focusing mainly on physical aspects,[72] another on cognitive functions,[16] and the remaining study on both physical and cognitive aspects.[67,70] The other two studies focused on cognition performance[66] and cognitive executive functions.[68] In terms of outcomes, all studies included a rich panoply of measures, with all studies except the study by Pichierri et al.,[70] which measured physical, physical and cognitive, cognitive, and psychosocial outcomes; Pichierri et al.[70] measured all types of outcomes, except cognitive. An overvie[w of] outcome measures of the studies included in this systematic review is displayed in Table 3. The length of the interventions was eight,[68,72] twelve,[70] sixteen,[73] and twenty-six[66,67] weeks.

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Table 2. Overview of Trials Characteris

Trial ID and country	Setting	Target population and number participants	Age and gender distribution of participants	Technology used for dance	Dance interventi (DI) grou

Trial ID and country	*Setting*	*Target population and number participants*	*Age and gender distribution of participants*	*Technology used for dance*	*Dance interventi (DI) grou*
Eggenberger et al.[66,67] Switzerland	Elderly care facilities instructed and eight sessions/4 weeks at home (with only strength and balance exercises) Groups of 5–6 Supervised	Aged 70+, independent living, able to walk 20 m without aid, rated 0, 1, or 2 in BESA,[a] no Alzheimer, no dementia, no head injury, 22+ in MMSE, stable health. I = 24; C1 = 22; C2 = 25	Mean age = 78.8 (I = 77.3 ± 6.3; C1 = 78.5 ± 5.1; C2 = 80.8 ± 4.7) Female = 65% (I = 58.3%; C1 = 72.7%; C2 = 64%)	Modified version of DDR game, StepMania + two impact dance platforms[b] + large screen projected on wall	Perform s patterns a sequence displayed cued on t screen. S styles of r were sele to add var and meet preferenc participan Participan could hol to ropes f security reasons. Difficulty adapted t participan abilities a progressi adjusted t ac m vigorous intensity through reported r perceived exertion, identified through th level Cate Ratio Sca (adapted scale)—va

Trial ID and country	*Setting*	*Target population and number participants*	*Age and gender distribution of participants*	*Technology used for dance*	*Dance interventi (DI) grou*
					for the thr condition
Eggenberger et al.[68] Switzerland	Clinic Groups of four Supervised	Aged 65+ living independently, rated 0, 1, or 2 in BESA,[a] no Alzheimer, no dementia, no head injury. I = 19; C = 14	Mean age = 75.3 (I = 72.8 ± 5.9; C = 77.8 ± 7.4) Female = 63.8% (I = 63.2%; C = 64.3%)	Modified version of DDR game, StepMania + two impact dance platforms[b] + large screen projected on wall	Stepping sequence cued with arrows appearing large scre Steps had performe exactly w an arrow reached a highlighte area on th screen to ac sc Participa could hol to ropes t maintain balance. Several le of difficul stepping patterns a frequency created a different

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Trial ID and country	Setting	Target population and number participants	Age and gender distribution of participants	Technology used for dance	Dance interventi (DI) grou
					of music chosen tc variety ar meet participar preferenc Training difficulty adapted t each individual coordinat ability an increased progressi
Pichierri et al.[70] Switzerland	Residential homes Groups of 3–4 Supervised	Aged 65 + 22+ in MMSE able to walk 8 m without aid, stable health condition, no vision impairment. I = 11; C = 11	Mean age = 86.3 (I = 86.9 ± 5.1; C = 85.6 ± 4.2) Female = 81.8% (I = 72.7%; C = 90.9%)	Modified version of DDR game, StepMania (version 3.9) + metal dance pads[c] + large screen projected on wall	Progressi resistanc training, postural balance training (on the rig ar vi Each sess lasted 50 (warm-up resistanc training 2 balance exercises and danc videogam 10–15 m) dance compone

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Trial ID and country	Setting	Target population and number participants	Age and gender distribution of participants	Technology used for dance	Dance interventi (DI) group
					participan executed cued on s in time wi different s (four song 2–3 m wit second br As levels increased additiona distractin visual cue example, bombs, w presented Occasion participan had to rer in one leg Progressi was contr through b p di Participar held on to ropes for security reasons.
Schoene et al.[72] Australia	Home Individual Unsupervised	Aged 65+, able to walk 20 m without aid, able to step in place unassisted, no	Mean age = 78 (I = 77.5 ± 4.5; C = 78.4 ± 4.5)	Modified version of DDR game, StepMania[d] + Step pads + TV set	Participar step as pe instructio presented the scree then retur

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Trial ID and country	Setting	Target population and number participants	Age and gender distribution of participants	Technology used for dance	Dance interventi (DI) group
		cognitive impairment, degenerative disorder, no joint inflammation problems, stable health. I = 15; C = 17	Female = not stated		to central stance pa panel. Feedback (perfect, miss) and points ac at the end each sequ Randomly "bomb" appeared inhibit ste response Failing to bomb led indication error and deduction Participa played ga with accompa m by Stepping sequence patterns synchroni with the r of the mu Game containe levels of difficulty medium, hard), eac

Trial ID and country	*Setting*	*Target population and number participants*	*Age and gender distribution of participants*	*Technology used for dance*	*Dance interventi (DI) group*
					with a sep range of musical t (3–4 m ea Progressi higher dif adjusted week bas CSRT and participa perceptio performa (performi well at th current le game lev sufficient challengi higher lev game lev too diffic return to lower lev
Schoene et al.[73] Australia	Home Individual Unsupervised	Aged 70+ independent living, able to walk and step unassisted, Mini-Cog <3, stable health, others. I = 47; C = 43	Mean age = 81.5 (I = 82 ± 7; C81 = ±7) Female = 66.5% (I = 66%; C = 67%)	Modified version of DDR game, StepMania[d] + Step pads + TV set	P… asked to perform w timed and directed s to achiev many poi possible w four step games. S was choic reaction t that train

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Trial ID and country	*Setting*	*Target population and number participants*	*Age and gender distribution of participants*	*Technology used for dance*	*Dance interventi (DI) grouj*
					processir speed an visual attention. Stepping trained vi attention set-shifti was a ste version o trail maki test. Tetri trained visuospat skills, pla and decis making. StepMani trained multidire and varia speed stepping, g re in simultane processir multiple stimuli. Objective to accura timely ste the pad following arrows or screen.

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Trial ID and country	*Setting*	*Target population and number participants*	*Age and gender distribution of participants*	*Technology used for dance*	*Dance interventi (DI) grou*
					Participa were aske return to stance pa after each Cognitive was manipula step resp not synchroni with musi rhythm ar round obj ("mines") drifting u screen in between arrows, u which participar had to inh step resp L di differed i terms of s and numb objects ar distractor (mines) o screen. Participar chose wh level to pl but were encourag

Trial ID and country	Setting	Target population and number participants	Age and gender distribution of participants	Technology used for dance	Dance interventi (DI) group
					start sess where the finished l and progr a higher l when they considere be perfor well at cu level or th game leve not suffic challengi Participa could also return to a lower leve they considere game leve too difficu

[a]BESA-levels, German abbreviation for: Bewohner-Einstufungs- und Abrechnungs-System, Swiss classification system for healthcare requirements.

[b]Positive Gaming BV, Haarlem, the Netherlands.

[c]TX 6000 Metal DDR Platinum Pro, Mayflash Limited, Baoan Shenzhen, China.

[d]Differed from the original version in that participants were asked to return to the center stance pads after each step.

DI, dance intervention group; C, comparison or control group; MMSE, Mini-Mental State Examination.

Table 3. Overview of Trials' Outcome Measures

	Outcomes

Trial ID	*Outcomes* *Physical*	*Physical and cognitive*	*Cognitive*	*Psychosocial*	*O*
Trial ID	*Physical*	*Physical and cognitive*	*Cognitive*	*Psychosocial*	*O*
Eggenberger et al.[66,67]	Eggenberger et al.[67] Gait performance, temporal and spatial, single task [PO] Short Physical Performance Battery (SPPB) Functional aerobic endurance Maximum walking distance (MWT)	Eggenberger et al.[67] Gait performance, temporal and spatial, dual task, at preferred and fast speed [PO]	Eggenberger et al.[67]	Eggenberger et al.[67] Fear of falling measured through FES-I Symptoms of depression recorded using GDS	Eg et Fa 6 be 6, m
	Eggenberger et al.[66]	Eggenberger et al.[66]	Eggenberger et al.[66] Executive	Eggenberger et al.[66] Training	Eg et

	Outcomes				
Trial ID	Physical	Physical and cognitive	Cognitive	Psychosocial	O
			function by TMT-B [PO] Working memory by ECT [PO] Long-term visual memory by PAL [PO] Long-term verbal memory by LM:WMS-R [PO] Short-term verbal memory by DFB:WMS-R [PO] Attention by ACT [PO] Information processing speed by TMT-A and DSS:WMS-R [PO]	enjoyment by German eight-item version of the Physical Activity Enjoyment Scale	

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	Outcomes				
Trial ID	Physical	Physical and cognitive	Cognitive	Psychosocial	O
Eggenberger et al.[68]	Short Physical Performance Battery	Prefrontal Cortex Activity during walking through Functional Near-Infrared Spectroscopy [PO]	Executive function: Shifting by TMT-B Executive function: Inhibition by SWCI Executive function: Working Memory by Executive Control task General cognitive ability by MOCA Information processing speed by TMT-A	Fear of falling measured through FES-I Symptoms of depression recorded by GDS Training enjoyment using the German eight-item version of the Physical Activity Enjoyment Scale	

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	Outcomes				
Trial ID	***Physical***	***Physical and cognitive***	***Cognitive***	***Psychosocial***	***O***

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	Outcomes				
Trial ID	*Physical*	*Physical and cognitive*	*Cognitive*	*Psychosocial*	*O*
Pichierri et al.[70]	Foot placement accuracy coupled with Gaze behavior through head-mounted eyetracking Gait performance, temporal and spatial, single task	Gait performance, temporal and spatial, dual task		Fear of falling measured by FES-I	
Schoene et al.[81]	Choice stepping reaction time (CSRT) [PO] Physiological fall risk using Physiological Profile Assessment General physical performance using the TUG test	Dual task performance through TUG coupled with verbal fluency task Impact of executive function on dynamic balance through stepping task with inhibition component	Cognitive function (scanning, visuomotor tracking, divided attention, and cognitive flexibility) was assessed using the TMT A and B	Fear of falling using the short version of the Icon-FES Enjoyment through single question in questionnaire	S p re in fe q A re c s lo

	Outcomes				
Trial ID	Physical	Physical and cognitive	Cognitive	Psychosocial	O

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	Outcomes				
Trial ID	***Physical***	***Physical and cognitive***	***Cognitive***	***Psychosocial***	***O***
Schoene et al.[73]	**Choice stepping reaction time**	**Combined stepping and attention/executive function using the Stroop Stepping Test [PO]**	**Processing speed** **Attention and Executive Function (set-shifting) by TMT** **Executive control by response inhibition by VS** **Divided attention by TUG with concurrent task** **Visuospatial performance**	**Depression symptoms through Patient Health Questionnaire (PHQ-9)** **Fear of falling using Icon-FES**	**A re co ar ca fi pa**

When findings of an outcome are not mentioned, one of the following happened: results were not reported, results were not significant.

INHIB, Inhibition; PO, primary outcome; TMT, trail making test; TUG, timed up and go test; GDS, Geriatric Depression Scale; FES-I, Falls Efficacy Scale International; SPPB, Short Physical Performance Battery; ECT, executive control task; WMS-R, Wechsler Memory Scale-Revised; WAIS-R, Wechsler Adult Intelligence Scale-Revised; PAL, paired-associates learning task; LM:WMS-R, logical memory subtest (Story Recall) from WMS-R; DFB:WMS-R, digit forward and backward tasks of (WMS-R); ACT, age concentration tests; DSS:WMS-R, digit symbol substitution task from WAIS-R; SWCI, Stroop Word-Color Interference task; MOCA, Montreal Cognitive Assessment; VS, Victoria Stroop task; Icon-FES, Iconographical Falls Efficacy Scale.

The studies conducted in Switzerland took place in both care facilities and at home, in residential homes, and in a clinic, while the studies conducted in Australia took place at home. The intervention was conducted in a group setting (3-6 participants) for four studies,[66–68,70] the remaining two studies[72,73] were conducted with individual participants. Participants were requested to play the dance game between 10 and 15 minutes to 30 minutes, with 20 minutes being the most frequently advised duration for the activity as reported for studies by Eggenberger P et al. and Schoene D et al.[66,67,72,73] (Table 2). Frequency varies between two and three times a week, with three trials inviting to two times a week frequency,[66,67,70] two inviting to three times a week,[68,73] and one[72] inviting participants to enroll in the activity 2–3 times a week.

Participants

Overall sample size ranged from 22 to 90 with a combined total of 223 participants. All participants were stable, healthy, and autonomous. The mean age was 80 years (range 75–86), and 69% were female for the studies that stated it (range 64%–82%[72]; did not state the percentage of females). Participants were either recruited from independent living facilities[70,72,73] or senior resident facilities, as well as newspaper articles, senior organizations, and the websites of sports- and health-related organizations.[66–68]

Technology-mediated dance intervention details

All studies used StepMania (https://stepmania.com), a modified version of DDR, as the technology-mediated dance component of the intervention. Pichierri et al.[70] reported using version 3.9 of StepMania; none of the other studies reported on the specific version used. To play the game, participants step as accurately as possible, in terms of direction and timing, on pads of about 1 m^2, while following the stepping sequences' instructions cued with arrows displayed on a screen, which means StepMania is used in combination with pressure-sensitive step pads and a display. Studies by Eggenberger P et al.[66–68] used two impact dance platforms (Positive Gaming BV, Haarlem, the Netherlands), study by Pichierri G et al.[70] used metal dance pads (TX 6000 Metal DDR Platinum Pro; Mayflash Limited, Baoan Shenzhen, China), and studies by Schoene D et al.[72,73] used step pads (specifications not reported). In practice, studies by Schoene D et al.[72,73] included 12 sensitive areas, two for each stepping direction, two central stances, and two for program control, while studies by Eggenberger P et al. and Pichierri G et al.[66–68,70] included four pressure-sensitive areas to detect steps forwards, backwards, to the left, and to the right. The two studies conducted at home[72,73] used the television set to display the game; the remaining studies used a large screen projected on the wall.

All studies included increasing levels of difficulty, which were manipulated by the step patterns and frequency. In addition, studies by Pichierri G et al. and Schoene D et al.[70,72,73] added distracting visual cues to increase cognitive load and in the presence of which participants had to inhibit their step response. The study by Pichierri G et al.[70] also included longer arrows that required the participants to remain longer in a speci location.

All interventions included music, with studies by Eggenberger P et al.[66–68] using different styles of music to specifically suit participants' preferences, while studies by Schoene D et al.[72,73] used music also to increase cognitive load of the task and by intentionally having the stepping sequences not synchronized with the rhythm of the music. Studies by Schoene D et al.[72,73] also required the participants to return to the central stance before initiating another sequence of steps.

Two studies[70,73] combined an additional nondance component with the use of StepMania (Table 2). The intervention of Schoene et al.[73] included three other games: Stepper, Trail-stepping, and Tetris. Pichierri et al.[70] combined StepMania with progressive resistance training and postural balance training.

Psychosocial outcomes measured and their impact

No trials had psychosocial measures as a primary outcome, and three were reported as secondary outcomes:

- Fear of falling[67,68,70,72,73] measured through the Falls Efficacy Scale International[67,68,70] and by the Icon-Falls Efficacy Scale.[72,73]
- Symptoms of depression[67,68,73] measured through the Geriatric Depression Scale[67,68] and by the nine-item Patient Health Questionnaire.[73]
- Training enjoyment[66,68,72] measured through the German eight-item version of the Physical Activity Enjoyment Scale[66,68] and by a single question in a questionnaire developed by the authors of the study.[72]

When looking into the reported results on fear of falling, Schoene et al.[73] report a significant reduction in fear of falling, and Eggenberger et al.[68] show a trend toward significance; the remaining three studies[67,70,72] report no changes regarding fear of falling. Despite showing a significant reduction in fear of falling, from 50.1 to 47.3 in the intervention group and from 51.1 to 53.4 in the control group ($P = 0.041$), the intervention employed by Schoene et al.[73] is multicomponent, including three other games in addition to the dance game. This means that the evidence is weak because improvements could be attributed to any of the three other components or the sum or any other combination of them. The dance intervention by Eggenberger et al.[68] is not multicomponent, but only a trend is observed, from 20.84 to 19.05 in the intervention group and from 18.57 to 18.21 in the control group ($P = 0.095$). The evidence is then weak to claim a beneficial effect of the technology-mediated dance interventions on fear of falling.

The results of the trials again show no evidence of any significant improvements toward depression for any of the studies assessing it. Schoene et al.[73] merely report an increase in depression in the control group of the study for those with low depressive symptoms at baseline.

Training enjoyment was assessed in three studies.[66,68,72] Training enjoyment was reported positive by all participants in the study by Schoene D et al.[72]; however, this measure was collected by a single question in a questionnaire developed by the authors of the study and thus lends it weak validity. The remaining studies[66,68] again indicated no difference between training types.

Meta-analysis

A meta-analysis was conducted for outcomes on fear of falling and on symptoms of depression. We were unable to conduct any meta-analysis on training enjoyment due to insufficient data reported in the articles. Fear of falling outcomes were available for five studies[66–68,70,72,73] at 2–4 months and the low-quality evide indicated that there was, as displayed in Figure 2, little or no difference above that of the comparison g (SMD −0.02, 95% CI −0.37 to 0.33; $P = 0.91$; $I^2 = 37\%$). Similarly, as displayed in Figure 3, there was little or no difference on depression[66–68,73] at 2–4 months (SMD −0.06, 95% CI −0.59 to 0.47; $P = 0.83$; $I^2 = 61\%$). One study reported on outcomes at a six month follow-up, with no differences in fear of falling or depression.[66,67]

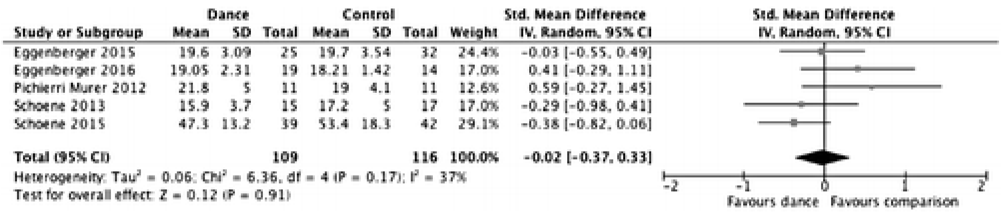

FIG. 2. Meta-analysis for fear of falling.

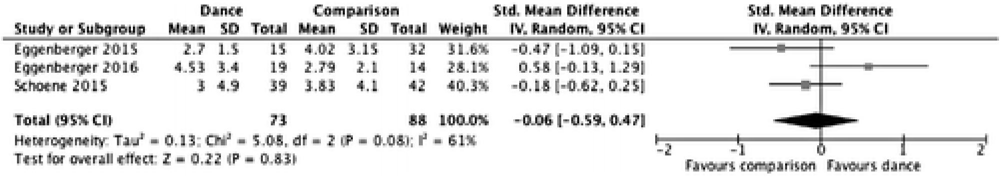

FIG. 3. Meta-analysis for depression.

Discussion and Future Work

Despite a thorough search of the existing evidence for the effectiveness of technology-mediated dance intervention on psychosocial outcomes for older adults, we identified only five trials that were eligible for inclusion in this review. In addition, we were unable to conduct any of the planned subgroup analyses due to insufficient studies. It is possible that our strict inclusion criteria may have led to us omitting some studies when searching, including those not published in English. We excluded all nonrandomized trials; it is possible that these may have provided a more extensive understanding of the effects of technology-mediated dance interventions, and greater variety in the type of technology employed. Future reviews could consider including additional research designs, although these may introduce some additional bias to the findings.

Most studies scored poorly regarding their quality (only one study[72] was considered of moderate quality), so the results presented are derived from relatively weak supporting evidence. This is not a unique result of this research as other authors (for e.g., Refs.[52,82]) have reported similar issues in the broader area of technology-mediated interventions for older adults with a view to improve their health. The inconclusive findings are also not unusual, as other systematic reviews in parallel areas report similar problems.[83] Well-designed comparative studies using standardized outcome measures are needed to identify optimal treatment programs,[35,36] including duration and frequency of exposure. Specifically, more well-designed studies are needed to clarify the effects of dance on nonmotor aspects to adequately inform prescription.[36] In other words, and for the specific area of this research, more studies are needed, which specifically look into quality-of-life measures.

Furthermore, future studies could consider the isolated effects of the dance game or other technology-mediated dance intervention alone rather than mixed with other components to fully understand its effect. The fact that all studies included in this review used a modified version of DDR, StepMania, introduced significant variability to the interventions. With an open-source platform such as StepMania, the dance systems can take many forms (e.g., speed, stimuli, and music). By focusing on precision and/or speed, adding cognitive load tasks, allowing participants to hold on to ropes, and by being combined with resistance and balance training the studies included in this review are highly multifaceted. Such diversity and heterogeneity may preclu accurate assessment of the effect of dance and make it harder to effectively understand the actual im the dance component itself. A study by Gschwind et al.[84] suggests that it is feasible for older people to conduct an unsupervised exercise program at home using exergames, still further refinement of the systems is required to improve adherence and maximize the benefits of exergames. An open-source platform, such as StepMania, may be particularly interesting to explore in this, as it allows for the necessary tweaking of the system, until more accurate assessments are achieved, which could inform prescription.

The samples' characteristics of the trials included in this review are similar, involving healthy independent older adults with average ages between 75 and 86, but samples sizes, while variable (11–47 participants), are generally small. The lack of eligible RCTs in this area and the small sample sizes in the included studies appears to reflect some of the challenges associated with recruiting and retaining potentially frail older people. For example, as observed in the 31.9% dropout rates reported by Schoene et al.,[73] this population may be lost to follow-up for a number of reasons, including deteriorating health and hospital admissions. The attrition rates, with already small samples, raise some concerns regarding the overall findings of the included studies. While compliance was generally good (75+%) for those who continued with the intervention, it is possible that the attrition rates reflect a lack of engagement among some of the participants. The design and focus of the included trials may have reduced any 'fun' element considered to be an important benefit of exergaming,[85] and thus reduced motivation and precluded any change in positive affect (enjoyment).

The duration of the interventions was relatively short—8 to 26 weeks—for the trials included in this review, and it has been suggested that motivation to exercise starts to decrease after 16 weeks.[86] This deserves further investigation with longer follow-up and reports on the uptake of the technology and/or other forms of dance after the intervention period. Three of the studies included in the review were supervised and this may have been necessary to capture some of the objective measures. The two other studies took place in the home setting and were therefore unsupervised. The relative efficacy of supervised versus unsupervised exercise-based interventions for older adults remains unclear, with variable findings.[87] Nevertheless, it seems likely that older adults, especially those with a history of falls or mobility difficulties, may prefer home-based programs[88]; some elements of supervision and/or reinforcement may be possible in the home using cost-effective technology-based solutions. With regard to the trials included in this review, if it is true that one of the home-based interventions shows lower adherence rates—68.1%[73]—this is also the longest study and the one involving the highest number of participants (more than double than any of the other trials); therefore, higher dropout rates would be expected, and it would be unreasonable to link dropouts to the home setting. All other studies, despite their particular settings, had more approximate adherence rates, spanning from 84% to 94%. In terms of efficacy, it is important to note that the only study reporting effective improvements, both in fear of falling and depression, is the same home-based trial.[73] None of the other studies showed significant results in any of the psychosocial measures observed. Despite significance of the results, all studies suggest feasibility, both at home or institutionalized settings.

StepMania was used by all studies included in this review. This lack of variety is striking, as is the fact that this dance game focuses on stepping performance and precision. While the focus on precision may be the goal in a competitive activity, this may remove other equally valuable components of dance and may be inappropriate for an activity that is expected to be an enabler for fun and self-expression. Designs and technologies that incorporate more fluid and expressive elements and the development of abilities over time could offer a better alternative to the more binary approaches used. In this way, the triad of "thinking-feeling-moving" could be included in the intervention and may positively influence health-related quality of life.[89]

Technology-based interventions, such as computer-mediated training, have demonstrated improvements in the well-being of older adults through a sense of mastery and self-efficacy.[90] Other studies looking into the effects of exergames in psychosocial well-being show conflicting results.[91,92] It is possible that technology-mediated dance interventions may act through similar processes. However, no evidence of effects of technology-mediated dance interventions in psychosocial outcomes was found in this review, but the reason for th
results remains unanswered. This warrants the need for further investigations on the topic.

None of the primary outcomes related to psychosocial variables, and perhaps surprisingly, none of the trials included a quality-of-life measure, such as the well-validated SF-36, EQ-5D, and CASP-19. It is possible that the technology employed for the dance interventions was appropriate for improving physical and cognitive outcomes, but, as mentioned earlier, was not designed to capture the essence and enjoyment of dance that may improve mood and, in turn, quality of life.

There remains a need for more studies of higher quality, a finding that is not unique to this review (see also Larsen et al.[82]). Despite the perceived potential, the relationship between technology-mediated dance interventions for older adults and psychosocial factors remains unclear with a considerable gap in the research literature.

Conclusions

Only five studies fulfilled the inclusion criteria for this systematic review. All included trials focused on healthy older adults and on physical and cognitive benefits of exercise (combined or not), but not on psychosocial benefits alone. Furthermore, none of the included studies considered psychosocial variables as a primary outcome, and none assessed the impact of their intervention on quality of life. All studies used the modified version of DDR, StepMania.

Studies included in this review were scored as methodologically low and reported results based on small sample sizes; this denotes their lack of quality. Moreover, there was low quality evidence that the dance interventions made little or no difference above that of the comparison groups on the psychosocial variables that were included (fear of falling, depression, and training enjoyment).

More and better-quality studies are needed to adequately understand and assess the effectiveness of technology-mediated dance interventions on psychosocial factors and the quality of life in older adults.

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Author Disclosure Statement

No competing financial interests exist.

Appendix A1

PubMed Search Strategy

The following filters were applied in PubMed: Publication date from 2000; Humans; English; middle aged + aged: 45+ years; Middle aged: 45–64 years; aged: 65+ years; 80 and over: 80+ years.

Two search strategies were used in PubMed. The first used Mesh Terms "dance therapy" "dancing" combined with the terms "technology," "software," "apps," "playware," "edutainment," "exergaming," "robot," "game," or "haptics" as search terms in all fields, returning 22 results.

A keyword search was also run, using a combination of keywords: "technology," "software" "apps" "playware" "edutainment," "exergaming," "AI games", "robot," "game," "haptics," all of which were combined with "da "dancing," "dance therapy" and also with the terms "older," "elderly," "frail elderly" "older-adults," "Old-Old "geriatric" and "senior." This returned 44 results.

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