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Review

The effect of dance on mental health and quality of life of people with Parkinson's disease: A systematic review and three-level meta-analysis

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HIGHLIGHTS

- Compared to passive control, dance improves mental health and quality of life in individuals with Parkinson's disease.
- Non-partnered dance is more effective in improving mental health than partnered dance.
- Higher total dosage of dance intervention negatively correlates with the effects on mental health.

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ABSTRACT

Objectives: Parkinson's disease (PD) is a neurodegenerative disease that affects millions of individuals worldwide. Dance has emerged as a comprehensive intervention for enhancing well-being in this population. This meta-analysis aimed to assess the effectiveness of dance on mental health and quality of life among individuals with PD.
Methods: Three databases were searched in December 2022. Research papers comparing the effects of dance with a non-dance control on the quality of life or mental health of individuals with PD were included. Two authors independently screened the studies, extracted data, and assessed methodological quality of eligible studies. To address the interdependence of effect sizes within studies, the three-level meta-analysis approach was employed to analyze the data.
Results: Thirteen trials involving a total of 496 participants were included, with 11 being subjected to statistical analysis. The results indicated that dance had a positive impact on mental health ($g = 0.43$, 95 % $CI = [0.11, 0.75]$) and quality of life ($g = 0.46$, 95 % $CI = [-0.04, 0.95]$) when compared to passive control groups. Moderator analyses revealed that non-partnered dance and dance interventions with lower total dosages were particularly beneficial for mental health.
Conclusion: Dance interventions are an effective lifestyle activity for enhancing mental health and quality of life in individuals with PD. A theoretical framework is proposed to explain the impact of dance on well-being from neurological, social, physical, and psychological perspectives.

1. Introduction

According to the World Health Organization (2022), the prevalence of Parkinson's disease (PD) has doubled in the past 25 years, affecting over 8.5 million people globally in 2019. PD leads to both motor symptoms such as slow movement and stiffness, as well as non-motor symptoms like cognitive decline and sleep disturbances. These symptoms deteriorate over time and can significantly impact one's psychological well-being (Barak & Achiron, 2009; Nicoletti et al., 2017; World Health Organization, 2022). Indeed, compared to healthy controls, individuals with PD experience poorer quality of life and greater psychological mental health problems such as anxiety and depression (Vescovelli, Sarti & Ruini, 2019).

Current treatments for PD primarily focus on motor symptoms, while treatments addressing well-being are often overlooked (Baig et al., 2015; Clarke, 2007). Exercise has emerged as a beneficial complementary

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therapy, as it not only engages the motor system but enhances well-being (Hadley, Eastwood-Gray, Kiddier, Rose & Ponzo, 2020). Among various exercise modalities, dance stands out as a pleasurable and multidimensional activity that encompasses music perception, motor learning, body awareness, emotional perception, memory, and synchronization of body movements with musical rhythm. Dance may be especially attractive to individuals who dislike repetitive exercise routines, lack self-confidence, and want to increase mobility (Houston & McGill, 2013). Music, an inherent stimulus in dance, stimulates spontaneous physical movement and provides a steady external cue for synchronization, making the dancing experience more immersive and engaging (Brancatisano, Baird & Thompson, 2020). Additionally, music can trigger emotional states and reward systems and facilitate the release of dopamine, which may address dopaminergic deterioration in people with PD and hence enhance well-being (Batt-Rawden & Tellnes, 2011; Rios Romenets, Anang, Fereshtehnejad, Pelletier & Postuma, 2015).

Dance also encourages social interaction (Boster et al., 2021; Rocha, Slade, McClelland & Morris, 2017). Social interaction and coordination are common features across various dance types (Shanahan, Morris, Bhriain, Saunders & Clifford, 2015). Dance types such as ballroom dancing (e.g., waltz, tango, foxtrot) and Latin American dancing (e.g., salsa and rumba) are forms of partnered dancing that involve coordinated dancing movements between a pair of individuals. Partnered dancing has been shown to improve mobility functions such as balance and postural stability in people with PD (de Dreu, van der Wilk, Poppe, Kwakkel & van Wegen, 2012; Hackney & Earhart, 2009a; Jeka, 1997). Hackney and Earhart (2010) reported that participants who engaged in partnered dance classes expressed more enjoyment and a desire to continue than those in non-partnered dance classes. However, there is limited research comparing the benefits of partnered versus non-partnered dance for well-being.

Dance interventions have been shown to improve well-being in people with PD (e.g., Hashimoto, Takabatake, Miyaguchi, Nakanishi & Naitou, 2015; Heiberger et al., 2011; Koch et al., 2016; Lee et al., 2018). However, non-significant improvements have also been reported (e.g., Dahmen-Zimmer & Jansen, 2017; Poier, Rodrigues Recchia, Ostermann & Büssing, 2019). Given the lack of consistent findings, the current study aimed to synthesize existing empirical studies on the effects of dance interventions for well-being in people with PD. Two well-being indicators were considered: quality of life and mental health. Quality of life reflects the extent of satisfaction that individuals obtain from life (American Psychological Association, 2023; The World Health Organization Quality of Life Group, 1995). Mental health refers to a mental state marked by emotional health, positive behavioral adaptation, and the absence of anxiety and disabling symptoms (American Psychological Association, 2023). Despite inconsistent outcomes in the literature, it was expected that dance should improve quality of life and mental health in patients with PD, given its engaging combination of music and coordinated movement triggering the release of neurotransmitters associated with well-being, such as dopamine, serotonin, and endorphins. Dance also helps to refine skills of coordinated movement (e.g., Lötzke, Ostermann & Büssing, 2015), enhancing confidence and augmenting feelings of well-being.

Although a small number of reviews and meta-analyses have already considered the benefits of dance for individuals with PD, they have yielded inconsistent outcomes (Carapellotti, Stevenson & Doumas, 2020; dos Santos Delabary, Komeroski, Monteiro, Costa & Haas, 2018; Koch, Kunz, Lykou & Cruz, 2014; Kwok, Choi & Chan, 2016; Lötzke et al., 2015; Sharp & Hewitt, 2014; Zhang, Hu, Wei, Jia & Jin, 2019; Zhou, Zhou, Wei, Luan & Li, 2021). For example, Sharp and Hewitt (2014) reported significant improvements in quality of life, whereas dos Santos Delabary et al. (2018) reported insignificant effects. Carapellotti et al. (2020) suggested that the characteristics of control groups should be considered, noting that quality of life improved significantly compared to no intervention controls but not compared to active controls. Moreover, the lack of consideration for potential effects of partnership or dosage in dance interventions may contribute to inconsistent results.

To address the recommendations posed by Carapellotti et al. (2020) and expand upon existing evidence, the current meta-analysis aimed to investigate the benefits of dance interventions on quality of life and mental health in individuals with PD, focused on three questions that are currently not well understood. First, do dance interventions offer benefits to individuals with PD relative to both passive and active control groups? Second, do partnered and non-partnered dance interventions offer the same level of benefits? Third, what are the benefits associated with different dosages of dance interventions for individuals with PD?

2. Methods

This meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guideline (Page et al., 2021). Appendix A shows the specific location where each item in the PRISMA checklist was addressed.

2.1. Search strategy

The database search was performed on PubMed, the Cochrane Library, and EMBASE in December 2022. An example of the search strings used in our search was: 'dance' OR 'dancing' AND 'Parkinson's Disease' AND 'well-being' OR 'quality of life' NOT ('review' OR 'meta-analysis'). The reference lists of eligible studies were also reviewed to identify any other relevant studies. The search was limited to papers published in English, without specifying a particular time frame.

2.2. Study selection

Two reviewers independently screened the studies using Rayyan (Ouzzani, Hammady, Fedorowicz & Elmagarmid, 2016) to determine the inclusion or exclusion of studies. Any disagreements between the two reviewers were resolved through discussion. The studies were screened based on pre-determined inclusion criteria, including: (a) participants should self-report or be medically diagnosed with PD, and should be over 55 years of age, (b) the intervention should include dance, (c) the comparator should be a non-dance control group, (d) the outcome should include measures of quality of life or mental health, (e) the outcome should be measured both before and after the intervention, and (f) the paper should be published in a peer-reviewed academic journal. The exclusion criteria were: (a) studies that include participants with chronic pain, cardiovascular or respiratory problems, neurological disorder, brain disease, cognitive impairments, motor deficits, or psychological disorders unrelated to PD, to isolate the effects specifically on PD and not be confounded by other health issues; (b) studies that include people diagnosed with atypical PD (age onset <55) as participants, since atypical PD has different underlying pathologies; and (c) studies that were systematic reviews or meta-analyses.

2.3. Data extraction and quality assessment

Data extraction was performed by two reviewers independently. Data related to the study design, methods and settings, participant demographics, descriptions of the intervention and comparator, and outcomes were extracted into an Excel spreadsheet. The control conditions were categorized into active control (i.e., activities that did not involve dance) and passive control (e.g., waitlist control and usual care). Partnership of the dance intervention was coded as partnered or non-partnered dance, depending on the nature of the dance intervention (e.g., ballroom dances such as waltz and tango are types of partnered dance, whereas modern dance is a non-partnered dance) or based on references to a "partner" in the intervention descriptions within the papers. The categorization was validated by a dance teacher. Dosages of the dance interventions were calculated by multiplying the number of sessions by the duration of each session.

The Effective Public Health Practice Project (EPHPP) quality assessment tool (Thomas, Ciliska, Dobbins & Micucci, 2004) was used to assess the methodological quality of each included paper by two independent reviewers. This tool was selected due to its higher inter-rater agreement than the Cochrane Collaboration Risk of Bias Tool, and because it is applicable to a variety of study designs beyond randomized controlled trials (Armijo-Olivo, Stiles, Hagen, Biondo & Cummings, 2012). The assessment categorized each paper as having strong, moderate, or weak quality based on ratings on six domains: selection bias, study design, confounders, blinding, data collection methods, and withdrawals and dropouts.

2.4. Statistical analyses methodology

Meta-analyses were conducted to compare the effectiveness of dance interventions against active or passive control on mental health and quality of life in individuals with PD. Both outcomes are continuous variables. Hedges' *g* was calculated from the number of participants, means, and standard deviations (*SD*) of change in outcome scores between pre-tests and post-tests. The change scores were recoded to ensure that a positive score indicates improvement. Effect sizes less than 0.2 were considered small effect, .5 moderate, and 0.8 large (Cohen, 1988). In cases where the SDs for the change scores were not reported, it was imputed from pre-test SD, post-test SD, and correlation between pre-test and post-test SDs (Higgins et al., 2022). The correlation coefficient was set at 0.39, calculated from included studies with completed data (i.e., Dahmen-Zimmer & Jansen, 2017; Kalyani et al., 2019; Lee et al., 2018; Rawson et al., 2019; Ventura et al., 2016). Formulae for calculating change score for SD, correlation coefficient, and combining interventions are listed in Appendix B, following the Cochrane Handbook (Higgins et al., 2022). A significance level of $\alpha < 0.05$ was used.

Given that most studies used multiple measurements within the same study, traditional meta-analysis of all measurements would violate the statistical independence assumption of meta-analysis. However, using one effect size per study or averaging the dependent effect sizes within studies into a single effect size could result in statistical power loss and bias (Assink & Wibbelink, 2016). Therefore, we employed a three-level meta-analytical method to account for the interdependency among effect sizes. This approach considers three nested levels contributing to the variability: sampling variance of the effect sizes at level 1, variance between effect sizes within the same study at level 2, and variance between different studies at level 3 (Assink & Wibbelink, 2016). It allows for examination of differences within (level 2) and between (level 3) studies, while a traditional meta-analysis does not account for within-study variance.

To determine significant within-study and between-study heterogeneities, the complete model was compared to a two-level model where the variance at level 2 was set to zero, and another two-level model where the variance at level 3 was set to zero, respectively. We followed the analysis procedure described by Assink and Wibbelink (2016). In cases where significant within- or between-studies differences were observed or when the sampling variance was less than 75 %, moderator analyses were conducted to explain the heterogeneity. Specifically, this study considered two moderators: partnership (partnered dance vs. non-partnered dance) as a categorical variable and the total dosage of dance interventions as a continuous variable.

To assess publication bias, we employed the extended Egger's test by including the sampling error as a moderator. This approach was used in previous studies (Habeck & Schultz, 2015; Zhang & Liu, 2022). Traditional funnel plot and Egger's test were not used because they do not account for potential correlations within studies and are not compatible with the three-level structure (for detailed explanations, see Zhang & Liu, 2022). Publication bias was considered to exist if the test's intercept was significant. It was conducted only when the number of included effect sizes exceeded 10. Sensitivity analyses were conducted by 1) excluding influential outliers, as outliers can potentially lead to skewed results; 2) including RCTs only, given that RCTs are rigorous study designs that reduce bias through randomization; 3) excluding studies with weak methodological quality that are likely to provide unreliable results; 4) employing different coefficient correlation values (0.5 and 0.8) to calculate the SD of change score, to assess the stability of the current results under different assumptions of variability. Influential outliers were defined based on criteria: 1) hat values exceeding two times the average hat value, 2) standardized residual values exceeding 3, or 3) Cook's distance exceeding 0.45 (Habeck & Schultz, 2015; Zhang & Liu, 2022).

Quantitative analyses were performed using the *metafor* package in R (R Core Team, 2020). Necessary missing data, such as means and SDs of pre- and post-intervention outcome scores, were requested from the authors. If the authors did not reply to the request or were unable to provide missing data after two requests, the paper with unreported data was excluded from further quantitative analysis but included in the qualitative synthesis.

3. Results

3.1. Literature selection

Fig. 1 illustrates the PRISMA diagram outlining the process of identifying eligible studies. Following the removal of duplicates, a total of 77 studies were identified in the literature search. Among these, 64 studies were excluded due to the absence of control groups, inappropriate publication type (e.g., review, protocol, wrong study design, wrong outcome measures, wrong population, or wrong intervention. Two studies that met the inclusion criteria but did not provide complete data were included in the qualitative synthesis but were not analyzed quantitatively. Eleven studies were included in the three-level meta-analysis.

3.2. Summary of study characteristics

Appendix C provides a tabular summary of the 13 included studies. These studies were conducted in nine countries: Australia, Brazil, Canada, Germany, Ireland, Italy, Japan, Korea, and the United States, and were published between 2009 and 2019. The sample sizes ranged from 15 to 96 participants, totaling 496 individuals with PD. Among them, 228 were in the dance intervention groups, and 268 were in the control groups. The mean age of participants ranged from 61.6 to 72.33 years, with 54.6 % being males. Of the dance intervention, eight involved partnered dance such as Argentine tango, Brazilian samba dance, Irish set dance, and waltz, while five were non-partnered dance such as choreographed dance movement, modern dance, and Turo. Two partnered dance studies did not specify the identity of partners, while the remaining six studies included spouses, family members, friends, or volunteers as partners. Regarding comparators, three studies had both active and passive control groups (Dahmen-Zimmer & Jansen, 2017; Hackney & Earhart, 2009b; Hashimoto et al., 2015); one study had two active control conditions (Rawson et al., 2019); two studies had one active control condition (Poier et al., 2019; Volpe et al., 2013); and the remaining seven studies had a passive control condition (such as "usual care"). Types of active controls included karate, tai chi, exercise, treadmill and stretching, and physiotherapy. Types of passive controls included waiting control, usual care, or no intervention. Mental health was assessed using various measurements, with the Apathy Scale, Beck Depression Inventory, and Hospital Anxiety and Depression Scale being relatively frequently employed. Quality of life was commonly assessed using the Parkinson's Disease Questionnaire – 39 (PDQ-39), used in nine of 13 studies, while other measures included Brief Multidimensional Life Satisfaction Scale and Parkinson's Disease Quality of Life Questionnaire.

A methodological quality assessment was conducted for the 11

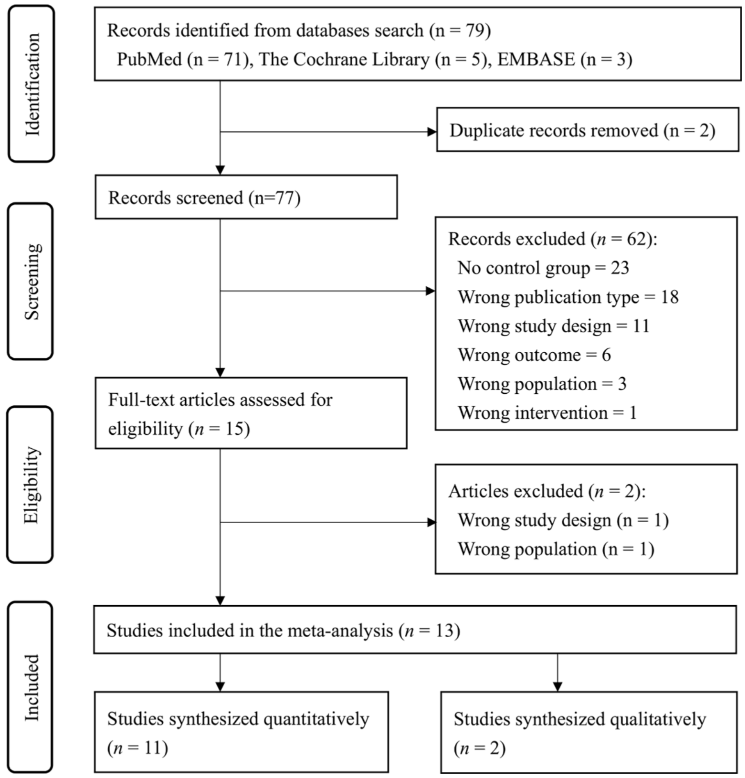

Fig. 1. PRISMA Diagram of the Process for Identifying Relevant Articles for Review.

studies that were included in the quantitative synthesis. Six studies were rated as strong, two as moderate, and three as weak (Appendix D). Seven studies were RCTs. None of the studies were double-blinded due to the nature of the interventions. All the included studies had relatively small sample sizes, with the number of participants per study arm ranging from seven to 39. Eight studies reported eligibility criteria, and six presented a flow diagram illustrating the process of participant recruitment, group allocation, and tracking over the course of the study.

3.3. Quantitative syntheses

The analyses were conducted separately for each combination of control groups and outcome domains, resulting in four results: mental health and passive control, mental health and active control, quality of life and passive control, and quality of life and active control.

3.3.1. Mental health

Seven studies examined the effect of dance on mental health (AS in two studies; BDI in three studies; HADS-anxiety in two studies; HADS-depression in two studies; CESD in one study; GDS in one study; SDS in one study; Starkstein Apathy Scale in one study). Dahmen-Zimmer and Jansen (2017) and Hashimoto et al. (2015) included both passive and active control groups. Among the seven studies, we obtained 15 effect sizes from seven studies for passive control and six effect sizes from two studies for active control. Based on the three-level meta-analysis, dance intervention had a significant and moderate effect in improving mental health compared to passive control ($g = 0.43$, $SE = 0.8$, $p = .01$, 95 % $CI = [0.11, 0.75]$), but it did not have significant difference compared to active control ($g = 0.12$, $SE = 0.15$, $p = .8$, 95 % $CI = [-1, 1.23]$).

Heterogeneity across samples was insignificant in both control conditions (passive control: $Q(14) = 13.07$, $p = .52$; active control: $Q(5) = 7.74$, $p = .17$). In studies with passive control, 31.2 % of the variance was attributed to between-study heterogeneity, while within-study heterogeneity was 0 %. This means that most of the variance (68.8 %) resulted from sampling error. Both two-level models did not significantly differ from the three-level model. In studies with an active control, the between-study heterogeneity (66.8 %) is also larger than the within-study heterogeneity (0 %), with the remaining 33.2 % attributed to sampling variance. The comparison with the original model showed significant between-study heterogeneity ($p = .035$).

Moderator analyses were performed because the sampling variances in both control conditions were less than 75 % (Assink & Wibbelink, 2016). For studies with a passive control, the effect of dance intervention on mental health was influenced by partnership, with F (1, 13) = 6.66 and $p = .02$. Non-partnered dance significantly improved mental health ($g = 0.61$, $SE = 0.13$, $p = .0005$, 95 % $CI = [0.32, 0.89]$, while partnered dance did not ($g = 0.06$, $SE = 0.16$, $p = .7$, 95 % $CI = [-0.29, 0.42]$). Total dosage did not significantly moderate mental health when dance was compared to passive controls ($b = 0.01$, $SE = 0.02$, $p = .57$, 95 % $CI = [-0.03, 0.06]$). In the two studies with an active control, both partnership and total dosage marginally moderated the effects, with the same outcome of F (1, 4) = 6.72 and $p = .06$. Non-partnered dance ($g = 0.56$, $SE = 0.26$, $p = .1$, 95 % $CI = [-0.16, 1.28]$) had a larger effect size over partnered dance ($g = -0.31$, $SE = 0.21$, $p = .22$, 95 % $CI = [-0.9, 0.28]$), but neither significantly improved mental health. Total dosage was marginally correlated with effect sizes ($b = -0.05$, $SE = 0.02$, $p = .06$, 95 % $CI = [-0.1, 0.003]$), suggesting that positive effects on mental health decreased with increasing total dosage.

The extended Egger's test was conducted to assess publication bias in studies with passive controls, because there were more than ten effect sizes. No evidence of publication bias was detected, with the test's intercept p-value at 0.7. Sensitivity analyses for mental health are shown in Appendix E. No influential outliers were identified. Overall, the main results remained consistent, showing significance compared to passive control and non-significance compared to passive control. However, the effect became insignificant when only including RCTs in the analysis for passive control ($g = 0.5$, $p = .11$, 95 % $CI = [-0.14, 1.13]$). Excluding low-quality studies or including RCTs both increased the effect sizes from 0.12 to 0.56, in studies with passive control.

3.3.2. Quality of life

Eight studies examined the effect of dance on quality of life using various measurements, including PDQ-39 in six studies, BMLSS in one study, and PDQL in one study. Across these studies, five effect sizes from five studies with a passive control and four effect sizes from three studies with an active control were obtained. The three-level meta-analysis revealed that dance interventions had a marginal significance in improving quality of life compared to a passive control (g = 0.46, SE = 0.18, p = .06, 95 % CI = [−0.04, 0.95]). However, the effect did not reach significance when compared to an active control (g = −0.08, SE = 0.15, p = .65, 95 % CI = [−0.56, 0.41])

Heterogeneity was not significant in either passive ($Q(4)$ = 4.51, p = .34) or active control ($Q(3)$ = 1.13, p = .77) conditions. In studies with passive and active controls, 97.16 % and 100 % of the variance was attributed to sampling error. Moderator analysis was thus not performed for quality of life in both conditions. Publication bias was also not assessed due to the low number of effect sizes in both conditions.

The sensitivity analyses for quality of life are shown in Appendix E. The main findings generally remained stable, showing a marginal significance compared to passive control and no significance compared to passive control. However, in studies with passive control, the effect size became lower when only including RCTs (g = 0.31, p = .54, 95 % CI = [−4.07, 4.69]). The exclusion of influential outliers did not influence the overall results, but Hedge's g increased from −0.08 to 0.03 for active control and from 0.46 to 0.62 for passive control.

3.4. Qualitative synthesis

Two studies were included in the qualitative synthesis due to insufficient data. Both studies investigated the effects of dance on quality of life, using the PDQ-39 as the assessment tool. Hackney and Earhart (2009b) reported that participating in a one-hour Argentine Tango dance intervention for 20 sessions significantly improved quality of life of individuals with PD. Specifically, improvements were observed in the PDQ-39 summary index ($p < .01$), mobility (p = .03), and social support (p = .05). No significant improvement was shown in the combined Waltz and Foxtrot, Tai Chi, and no intervention group, despite the former two groups having the same dosage as in Tango. In contrast, Shanahan et al. (2017) reported a 4.9-point reduction on the PDQ-39 summary index after attending a 10-week 1.5-hour Irish set dance intervention, but this improvement was not statistically significant (p = .88).

4. Discussion

The purpose of this meta-analysis was to investigate the effect of dance on well-being of individuals with PD, specifically focusing on their mental health and quality of life and addressing existing gaps in the literature. Although other meta-analyses have examined the impact of dance for individuals with PD (e.g., dos Santos Delabary et al., 2018; Zhang et al., 2019), none has compared the benefits of dance against different types of non-dance activities (i.e., passive and active), nor have they compared the effects of partnered and non-partnered dance interventions or considered the effects of different dosages of dance interventions. The current meta-analysis is the first to consider all three of these factors, providing a more comprehensive investigation into the efficacy and benefits of dance for people with PD.

Thirteen studies were included in the analysis, with eleven undergoing quantitative synthesis through a three-level meta-analysis approach to account for outcome interdependence within studies. Results revealed significant mental health improvements and marginal quality of life enhancements from dance compared to passive controls, both with moderate effects. Consistent results from the sensitivity analysis, by excluding low-quality studies, indicated the robustness and stability of the findings, ensuring that they were not reliant on potentially biased or less reliable studies. The marginal quality of life improvements may be attributed to the use of the PDQ-39, which is the most used measure in these included studies. This measure may primarily target more severe disease symptoms and might not be an ideal measure for all participants, particularly those with milder symptoms (Hackney & Earhart, 2009b). Nevertheless, the substantial effect size of 0.46 observed for quality of life suggests real-world relevance for dance in improving quality of life.

The effects of dance on mental health and quality of life were not significant when compared to an active control intervention. Two factors may account for these insignificant effects. Firstly, a limited number of studies with active control groups was included in the meta-analysis. Only two studies with active controls examined the effects of dance on mental health, and only three studies with active controls examined the effects of dance on quality of life. Secondly, the dance interventions in these studies may not have been intensive enough to yield significantly benefits over and above other active controls such as tai chi, exercise, treadmill, and physiotherapy (Carapellotti et al., 2020; Solla et al., 2019). These physical exercises share several features and mechanisms of dance in enhancing dopamine release, reducing stress, and improving motor functions.

4.1. Theoretical framework of dance on well-being

The mechanisms of dance on the well-being of individuals with PD remain a topic of ongoing discussion and investigation. Fig. 2 outlines a multi-faceted theoretical framework to account for the various benefits of dance. The figure illustrates that dance can directly enhance well-being through its neurological, social, and psychological benefits, while the physical benefits indirectly influence well-being. The improvement in well-being establishes a positive feedback loop that encourages continued participation in dance.

4.1.1. Neurological benefits

PD impairs the ability to select appropriate motor commands and affects the internal cueing systems, making rhythmic motor tasks (e.g., walking) difficult (Drui et al., 2014; Krotinger & Loui, 2021). Dance, especially with rhythmic music, fosters brain activity related to movement (Sharp & Hewitt, 2014). Using music as a pleasurable rhythmical auditory cue can potentially bypass the impaired basal ganglia loop (Krotinger & Loui, 2021) and foster the natural synchronization between auditory and motor systems (Heiberger et al., 2011). In this way, music-based movement can improve motor functions by promoting synchronization of movement to the music, facilitating coordinated actions such as walking (Zhou et al., 2021). This strategy of internalizing auditory cues for movement can be applied in daily activities, helping individuals synchronize their walking to mentally-generated musical rhythm (Holmes & Hackney, 2017).

Additionally, the degeneration of dopaminergic neurons leads to severe motor function problems (Lee et al., 2018; Ronken & Scharrenburg, 2002; Schapira & Jenner, 2011) and also correlates with impaired emotional identification and depressive-like behavior in PD (Dujardin et al., 2004; Tadaiesky et al., 2008). Dance, as a form of aerobic exercise, can regulate dopaminergic and glutamatergic neurotransmission (Reynolds, Otto, Ellis & Cronin-Golomb, 2016) and improve mood (Bognar et al., 2017; Lewis et al., 2016). Music accompaniment, in turn, may play a vital role in facilitating the release of neurotransmitters such as dopamine, serotonin, endorphins, and endocannabinoids (Boso, Politi, Barale & Emanuele, 2006; Kalyani et al., 2019; Rios Romenets et al., 2015; Shanahan et al., 2017; Zhou et al., 2021) that improve mood, reduce stress, and alleviate depressive and anxiety symptoms. To summarize the neurological implications, dance and accompanying music combine to enhance auditory-motor synchronization and release mood-enhancing neurotransmitters, ultimately forming a positive loop that encourages continuous engagement and improves well-being (Hackney & Earhart, 2009b).

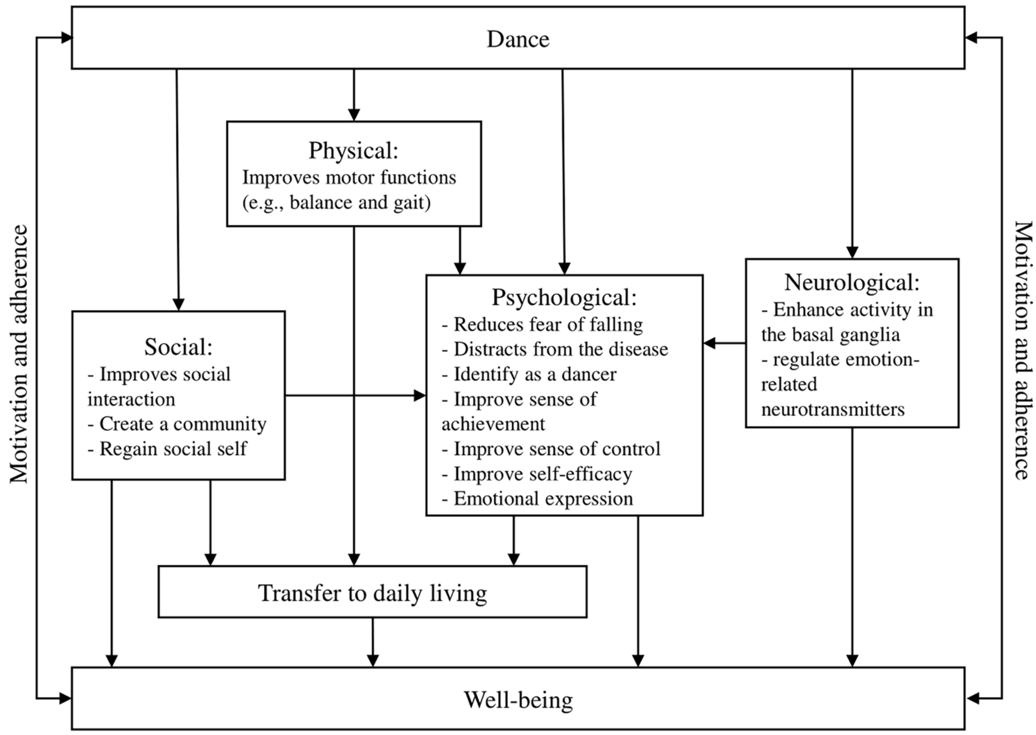

Fig. 2. Theoretical framework of dance on well-being.

4.1.2. Social benefits

After a PD diagnosis, individuals often experience shame regarding their symptoms, leading to their withdrawals from social activities and reducing social interactions (Carroll, Dale & Bail, 2022). This process can result in depression and social anxiety, affecting quality of life (Bognar et al., 2017). Dance interventions, like support groups, provide a safe and non-judgmental space to connect with others facing the same challenges (Hashimoto et al., 2015). These programs help participants feel accepted, share experience, and gain new perspectives about the disease (Carroll et al., 2022; Hashimoto et al., 2015; Heiberger et al., 2011; Holmes & Hackney, 2017). They can discuss their symptoms openly instead of hiding them. Additionally, the music in dance provides a non-verbal way of communication and self-expression, which is particularly beneficial for those with speech or expression challenges (Bognar et al., 2017).

In short, dance offers a supportive space for connection, acceptance, and non-verbal expression, and those who participate often regain a sense of their social self and confidence in communicating with others. These benefits, in turn, help to reduce social withdrawal and increase participation in other activities (Bognar et al., 2017; Kalyani et al., 2019; Rios Romenets et al., 2015). The sense of belonging that dance interventions confer of people with PD boosts their motivation to continue, reinforces a beneficial cycle of increased participation and enhanced well-being (Heiberger et al., 2011; Ventura et al., 2016).

4.1.3. Psychological benefits

Dance has been shown to alleviate motor symptoms in PD (e.g., Dahmen-Zimmer et al., 2017; Lötzke et al., 2015; Michels, Dubaz, Hornthal & Bega, 2018; Sharp & Hewitt et al., 2014). Many functional movements and sequences resembling strategies can be practiced through dance, which address symptoms that individuals with PD might find challenging (Earhart, 2009). These improvements on physical abilities, and more importantly, the awareness of the improvements or even the psychological placebo effect (i.e., the belief that dance can enhance motor skills and well-being), may indirectly boost confidence and emotion, ultimately enhancing well-being (Bognar et al., 2017; Carroll et al., 2022; Tillmann et al., 2020).

Individuals with PD often fear falling and are self-conscious about their symptoms, increasing their anxiety. Dance teaches safe movement transition strategies, which reduces the risk and fear of falling (Holmes & Hackney, 2017; Ventura et al., 2016). A participant from the study of Holmes and Hackney (2017) expressed this benefit "what it really did for me was to say that I didn't have to be scared of every little thing" (p.264). Dance also redirects their attention away from the symptoms and disease to focus consciously on movements (Earhart, 2009; Heiberger et al., 2011; Ventura et al., 2016). Instead of identifying themselves as a patient with PD, participating in dance programs helps them form a new identity –a dancer (Carroll et al., 2022; Kalyani et al., 2019).

Moreover, the sense of control is often lost after a PD diagnosis. Dance helps them regain this control through boosting their sense of achievement. Their attitudes shift from seeking external outcomes to embracing internal locus of control (Bognar et al., 2017). They become more focused on what they can do, what they are doing, and what they plan to do. As one participant mentioned, "Instead of letting the Parkinson's manage me, I'm more managing my situation" (Holmes & Hackney, 2017; p.266). Dance restores their sense of autonomy and enhances self-efficacy in managing the disease (Bognar et al., 2017; Carroll et al., 2022; Houston & McGill, 2013). This benefit transfers to daily life, encouraging them to engage in both familiar and new activities. In summary, from a psychological perspective, dance reinforces belief in motor improvements, reduces fear of falling, diverts attention from the disease, and helps individuals regain a sense of control, which undoubtedly improve their well-being (Bognar et al., 2017; Carroll et al., 2022; Foster, Golden, Duncan & Earhart, 2013; Holmes & Hackney, 2017; Houston & McGill, 2013).

4.2. Partnered dance

In both studies with passive and active control, non-partnered dance showed higher effect sizes in improving mental health compared to partnered dance. This result was counterintuitive, because dancing with a partner is typically assumed to foster stronger interpersonal connections, increase enjoyment, and lead to a greater sense of self-efficacy and motivation (Foster et al., 2013; Hackney & Earhart, 2010; Kunkel et al., 2018; Lötzke et al., 2015). We assume that the benefits of partnered dance might depend on compatibility with the partner and the partner's dance ability. Indeed, a qualitative study by Kunkel et al. (2018) suggested that the dance experience is influenced by the relationship with the partner. Many of the included studies on partnered dance featured a diverse range of partners, including spouses, family members, friends, and volunteers. Dancing with a spouse provides emotional support and positive reinforcement, enhancing overall well-being. In contrast, dancing with a friend, relative, or healthy volunteer yielded a more varied experience, depending on the partner's dance ability, attitude, and motivation for engaging in the program. If the partner was judgmental, lacked respect, or even offered discouragement, it undoubtedly dampened enjoyment and the dance experience, particularly because individuals with PD tend to place a high value on the attitudes and shared understanding of others. Moreover, it is likely more stressful to dance with an inexperienced partner, as opposed to dance alone.

On the contrary, non-partnered dance may be more effective in improving the well-being of people with PD when they are not partnered with their spouse or an experienced dancer. Psychologically, the absence of social stress related to physical proximity with an unfamiliar dance partner allows individuals with PD to focus on their own enjoyment. Physically, they could concentrate solely on their own movements without needing to synchronize with a partner's actions. Non-partnered dance also has a wider range of dance forms and movements, challenging both motor and cognitive functions. Socially, even though non-partnered dance does not involve close interaction with a single individual, the dance program still provides a safe environment for individuals to develop social bonding with others. Nonetheless, further research is needed to confirm these assumptions, as there was only one study (Hackney & Earhart, 2010) comparing partnered and non-partnered dance in individuals with PD to the best of our knowledge.

4.3. Dosage of dance

A marginal and negative correlation was observed between the total dosage of dance interventions and their effects on mental health when compared to active controls. This unexpected finding aligns with two reviews about exercise dosage (Earhart et al., 2009; Kwok et al., 2016). It might be true that higher dosages of dance interventions become a burden for individuals with PD as they require excessive physical strength and stamina, which might gradually diminish as motor symptoms progress (Kwok et al., 2016). Furthermore, the fear of failure and the lack of confidence could also hinder their commitment to and adherence to a high-dosage program. In contrast, lower dosages of dance intervention may be more effective at providing both pleasure and benefits in addressing the motor and non-motor symptoms of PD. This finding suggests that dance programs for individuals with PD should carefully consider the balance between sufficient engagement and overexertion. A moderate-dosage, such as a 60-minute session as found effective by Earhart (2009), might be more beneficial, being challenging yet manageable. High dosage, like a 90-minute session, should be avoided to prevent fatigue and ensure adherence.

4.4. Limitations and future directions

This meta-analysis is the first to employ the three-level analysis approach to investigate the effects of dance interventions on well-being in individuals with PD, to account for the dependency between effect sizes within studies. Nevertheless, limitations of the current meta-analysis should be considered before drawing definitive conclusions. Firstly, various scales were employed to measure mental health and quality of life. Although this inconsistency was addressed by using standardized mean difference scores for statistical analysis, the heterogeneity in scales may still introduce some degree of uncertainty into the accuracy of the pooled estimates. Secondly, only 11 studies were included. A potential reason for the limited number of eligible studies may be the relatively new emergence of dance intervention for this population. Additionally, researchers primarily focused on motor symptoms, given that a decline in motor function is a primary symptom of PD (Earhart, 2009). Thirdly, the categorization of partnership was determined by the description of the dance intervention. However, it is crucial to consider that different dance styles, such as tango and modern dance, may have inherently different effects on well-being, and this variation may not be solely due to the partnership aspect. It is therefore advisable to conduct studies that directly compare the effects of partnered and non-partnered dance on well-being for the same dance style.

Limitations of the included studies should also be taken into consideration. Sensitivity analyses indicated that the significant effect of dance on mental health and quality of life became insignificant when only RTCs were included. The exclusion of studies with weak methodological quality also affected the effect sizes. These findings suggest the need for more high-quality and rigorous RCTs to enhance the quality and reliability of studies in this field. Moreover, the limited number of studies comparing dance with active controls highlights the need to conduct three-arm RCTs that compare dance, active control such as aerobic exercise, and usual care. Such studies would provide more direct evidence for understanding the relative merits of these interventions in a controlled and systematic manner. Lastly, the theoretical framework proposed in this review requires further investigation and evaluation to elucidate the mechanisms by which dance can benefit well-being in individuals with PD. A better understanding of these mechanisms, in turn, may help practitioners to develop more tailored and effective dance-based interventions.

4.5. Conclusion

This three-level meta-analysis reveals that dance interventions are more effective in improving mental health ($g = 0.43$, 95 % $CI = [0.11, 0.75]$) and quality of life ($g = 0.46$, 95 % $CI = [-0.04, 0.95]$) for individuals with PD, compared to passive controls such as usual care. We propose a theoretical framework to explain the observed positive effects, attributing improvements to the neurological, physical, social, and psychological benefits of dance on well-being, which likely enhances motivation and adherence to the dance program. Our findings reinforce the potential of dance as a valuable complementary therapy for preserving and enhancing well-being of patients with PD. Healthcare practitioners and caregivers are encouraged to support individuals with PD in actively participating in dance programs to maintain their well-being throughout the long journey of living with PD.

Notably, our moderator analyses suggested greater effectiveness of non-partnered dance and lower dosage in improving mental health. Non-partnered dance may offer less social stress and more autonomy, allowing individuals to engage at their own pace. Lower dosages of dance provide enjoyment and avoid overexertion as motor symptoms progress. However, a definite conclusion cannot be drawn due to the limited direct comparisons between partnered and non-partnered dance. The optimal 'magic number' for dosage also remains undetermined and should be further investigated to inform practical recommendations for future dance programs.

Registration and protocol

This review was registered at Bond University (Ethics Application Number 20,221,012). Different from the protocol, this review synthesized the data using the three-level meta-analysis approach instead of a traditional meta-analysis, because of the interdependence between effect sizes within studies.

Data availability statement

The data that support the findings of this meta-analysis are available from the corresponding author upon reasonable request.

CRediT authorship contribution statement

Wei-Hsin Cheng: Writing – original draft, Data curation, Visualization, Project administration, Methodology, Investigation, Conceptualization. **Yixue Quan:** Writing – original draft, Writing – review & editing, Funding acquisition, Formal analysis, Visualization, Methodology. **William Forde Thompson:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare none.

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Appendix A. PRISMA checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	2–4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	4
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	6
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	5
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	5
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	6
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	6
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	7
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	7
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	7
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	7
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	10
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	8
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	10
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	8
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	8–9
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	9
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	9
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	/
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	10
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	/
Study characteristics	17	Cite each included study and present its characteristics.	35–37
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	38
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	/
Results of syntheses	20a	For each synthesis, briefly summarize the characteristics and risk of bias among contributing studies.	11
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	12–13
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	13, 15
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	14–15

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(*continued*)

Section and Topic	Item #	Checklist item	Location where item is reported
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	/
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	/
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	16–17
	23b	Discuss any limitations of the evidence included in the review.	26
	23c	Discuss any limitations of the review processes used.	25
	23d	Discuss implications of the results for practice, policy, and future research.	26
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	27
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	27
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	/
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	28
Competing interests	26	Declare any competing interests of review authors.	28
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	28

Appendix B. Calculation formulas

1. **Calculating SD for change score from 95 % confidence intervals:**

Steps:

(1) Input "=tinv(1–0.95, N_1+N_2–2) in a Microsoft Excel spreadsheet to calculate the *t-statistics*

(2) $SE = \frac{upper\ limit - lower\ limit}{2t}$

(3) $SD = \frac{SE}{\sqrt{\frac{1}{N1}+\frac{1}{N2}}}$

4. **Calculating correlation coefficient between baseline and post-intervention measurements across participants:**

$$Corr = \frac{\text{SDbaseline}^2 + \text{SDend}^2 - \text{SDchange}^2}{2 \times S\text{Dbaseline} \times \text{SDend}}$$

5. **Calculating the change-from-baseline SD using the correlation coefficient:**

$$SD\ change = \sqrt{SD^2_{pre-test} + SD^2_{post-test} - \left(2 \times r \times SD_{pre-test} \times SD_{post-test}\right)}$$

6. **Combining summary statistics Across Groups**

$$N = N_1 + N_2$$

$$\text{Mean} = \frac{N_1M_1 + N_2M_2}{N_1 + N_2}$$

$$\text{SD} = \sqrt{\frac{(N_1 - 1)SD_1^2 + (N_2 - 1)SD_2^2 + \frac{N_1N_2}{N_1+N_2}\left(M_1^2 + M_2^2 - 2M_1M_2\right)}{N_1 + N_2 - 1}}$$

Applied to Rawson et al. (2019), to combine the statistics of treadmill and stretching interventions.

Appendix C. Summary of study characteristics

Study (Year), country	Number of participants (male/female)	Mean age (SD)	Intervention frequency(sessions/week) *duration*number of sessions, intervention length	Total dosage (hours)	Control group	Outcome measures
Dahmen-Zimmer and Jansen (2017) Germany	T = 37 (27/10) I = 9 (6/3) C1 = 16 (13/3) C2 = 12 (8/4)	I = 72.33 (6.69) C1 = 68.87	Partnered dance: standard dance forms such as rumba and waltz 1 × 60mins*30, 30 weeks Partners: not specified	30	C1: Deutscher Karate; C2: Waiting control	**MH**: CESD, HADS -Depression, HADS

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(*continued*)

Study (Year), country	Number of participants (male/female)	Mean age (SD)	Intervention frequency(sessions/week) *duration*number of sessions, intervention length	Total dosage (hours)	Control group	Outcome measures
		(7.24) C2 = 70.42 (10.07)				-Anxiety, MDBF, SF-12,
Hackney and Earhart (2009b) U.S.	*T* = 61 (45/16) I1 = 17 (11/6) I2 =14 (11/3) C1 = 13 (11/2) C2 = 17 (12/5)	I1 = 66.8 (2.4) I2 =68.2 (1.4) C1 = 64.9 (2.3) C2 = 66.5 (2.8)	Partnered dance: T1: Argentine tango; T2: Waltz/Foxtrot 2 × 60mins*20, 13 weeks Partners: spouses, family members, friends, or healthy young volunteers	20	C1: Tai Chi; C2: No intervention	**QoL**: PDQ-39
Hashimoto et al. (2015) Japan	*T* = 46 (12/34) *I* = 15 (3/12) C1 = 17 (2/15) C2 = 14 (7/7)	*I* = 67.9 (7.0) C1 = 62.7 (14.9) C2 = 69.7 (4.0)	Non-partnered dance: Modern Dance (combination of aerobic, jazz, tango, and classical ballet) 1 × 60mins*12, 12 weeks	12	C1: Exercise; C2: Normal life	**MH**: AS, SDS
Kalyani et al. (2019) Australia	*T* = 33 (13/20) *I* = 17 (3/14) C = 16 (10/6)	*I* = 65.24 (11.88) C = 66.50 (7.70)	Non-partnered dance: Dance for PD program (include aspects of ballet, modern dance, choreographic repertory, jazz, tap, Flamenco, Scottish Dance) 2 × 60mins*24, 12 weeks	24	No intervention	**MH**: HADS -Depression, HADS -Anxiety, MDS-UPDRS **QoL**: PDQ-39
Lee et al. (2018) Korea	*T* = 41 (17/24) *I* = 25 (10/15) C = 16 (7/9)	*I* = 65.8 (7.2) C = 65.7 (6.4)	Non-partnered dance: Turo (Qi Dance) 2 × 60mins*16, 8 weeks	16	No intervention	**MH**: BDI **QoL**: PDQL
Poier et al. (2019) Germany	*T* = 29 (12/17) *I* = 14 (9/5) C = 15 (3/12)	*I* = 68.50 (8.07) C = 68.87 (10.96)	Partnered dance: Argentine tango 1 × 60mins*10, 10 weeks Partners: spouses or family members	10	Tai Chi	**QoL**: BMLSS, PDQ-39
Rawson et al. (2019) U.S.	*T* = 96 (56/40) *I* = 39 (25/14) C1 = 31 (17/14) C2 = 26 (14/12)	*I* = 66.73 (9.52) C1 = 68.52 (9.54) C2 = 66.18 (7.30)	Partnered dance: Argentine tango 2 × 60mins*24, 12 weeks Partners: spouses, caregivers, volunteers, or laboratory staff	24	C1: Treadmill; C2: Stretching	**QoL**: PDQ-39
Rios Romenets et al. (2015) Canada	*T* = 33 (19/14) *I* = 18 (12/6) C = 15 (7/8)	*I* = 63.2 (9.9) C = 64.3 (8.1)	Partnered dance: Argentine tango 2 × 60mins*24, 12 weeks Partners: spouses or friends	24	Waiting control	**MH**: AS, BDI **QoL**: PDQ-39
Shanahan et al. (2017) Ireland	*T* = 41 (26/15) *I* = 20 (13/7) C = 21 (13/8)	*I* = 69 (10) C = 69 (8)	Partnered dance: Irish set dance 1 × 90mins*10, 10 weeks Partners: family or caregivers	15	Usual care	**QoL**: PDQ-39
Solla et al. (2019) Italy	*T* = 20 (13/7) *I* = 10 (6/4) C = 10 (7/3)	*I* = 67.8 (5.9) C = 67.1 (6.3)	Non-partnered dance: Sardinian folk dance 2 × 90mins*24, 12 weeks	36	Usual care	**MH**: BDI, SAS
Tillmann et al. (2020) Brazil	*T* = 20 (16/4) *I* = 10 (8/2) C = 10 (8/2)	*I* = 65.3 (10.5) C = 67.6 (10.9)	Partnered dance: Brazilian samba dance 2 × 60mins*24, 12 weeks Partners: not specified	24	Usual care	**QoL**: PDQ-39
Ventura et al. (2016) U.S.	*T* = 15 (2/13) *I* = 8 (0/8) C = 7 (2/5)	*I* = 71.8 (3.6) C = 70.4 (5.5)	Non-partnered dance: Choreographed dance movement and improvisational movement 1 × 75mins*10, 4.5 months	12.5	Usual activities	**MH**: GDS **QoL**: PDQ-39
Volpe (2013) Italy	*T* = 24 (13/11) *I* = 12 (7/5) C = 12 (6/6)	*I* = 61.6 (4.5) C = 65.0 (5.3)	Partnered dance: Irish set dance 1 × 90mins*24, 6 months Partners: family members or members of the Irish set dancing school	36	Physiotherapy	**QoL**: PDQ-39

Note. N, Number; *SD*, Standard Deviation; T, Total; I, Intervention Group, C, Control Group; AS, Apathy scale; BDI, Beck Depression Inventory; BMLSS, Brief Multi-dimensional Life Satisfaction Scale; CESD, Center for Epidemiologic Studies Depression Scale; GDS, Geriatric Depression Scale; HADS, Hospital Anxiety and Depression Scale; HY, Hoehn and Yahr Scale; MDBF, Multidimensional Mood Questionnaire; MDS-UPDRS, Movement Disorders Society Unified Parkinson's Disease Rating Scale; PDQ-39, Parkinson's Disease Questionnaire; PDQL, Parkinson's Disease Quality of Life Questionnaire; SAS, Starkstein Apathy Scale; SDS, Self-rating Depression Scale; SF-12, 12-item Short-Form Health Survey; UPDRS, Unified Parkinson's Disease Rating Scale.

Appendix D. Summary of methodological quality assessment for included studies

Study (Year)	Selection bias	Study design	Confounder	Blinding	Data collection method	Withdraws and drop-outs	Global rating	Experimental design
Dahmen-Zimmer and Jansen (2017)	Weak	Strong	Weak	Moderate	Strong	Moderate	Weak	Non-RCT
Hashimoto et al. (2015)	Moderate	Strong	Strong	Moderate	Strong	Moderate	Strong	Cluster RCT
Kalyani et al. (2019)	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong	Parallel non-RCT
Lee et al. (2018)	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong	Cross-over RCT
Poier et al. (2019)	Weak	Strong	Weak	Moderate	Strong	Moderate	Weak	Parallel RCT
Rawson et al. (2019)	Moderate	Strong	Strong	Moderate	Strong	Moderate	Strong	Parallel RCT
Rios Romenets et al. (2015)	Moderate	Strong	Weak	Moderate	Strong	Moderate	Moderate	Parallel RCT
Solla et al. (2019)	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong	Parallel RCT
Tillmann et al. (2020)	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong	Non-RCT
Ventura et al. (2016)	Moderate	Strong	Weak	Moderate	Strong	Weak	Weak	Non-RCT
Volpe et al., 2013	Moderate	Strong	Strong	Moderate	Strong	Weak	Moderate	Parallel RCT

Appendix E. Sensitivity analyses

	Active control *N* ES (Study)	*b*	*SE*	*p*	95 %CI	Heterogeneity test	Passive control *N* ES (Study)	*b*	*SE*	*p*	95 %CI	Heterogeneity test
Mental health												
Original result	6 (2)	0.12	0.43	0.8	[−1, 1.23]	$Q(5)=7.74$, $p=.17$	15 (7)	0.43	0.15	0.01	[0.11, 0.75]	$Q(14)=13.07$, $p=.52$
$r = 0.5$[a]	6 (2)	0.14	0.46	0.77	[−1.04, 1.33]	$Q(5)=8.66$, $p=.12$	15 (7)	0.46	0.16	0.01	[0.11, 0.8]	$Q(14)=14.82$, $p=.39$
$r = 0.8$[a]	6 (2)	0.32	0.64	0.64	[−1.32, 1.95]	$Q(5)=15.12$, $p=.01$	15 (7)	0.6	0.25	0.03	[0.07, 1.13]	$Q(14)=26$, $p=.03$
Exclude low quality	2 (1)	0.56	0.26	0.27	[−2.69, 3.81]	$Q(1)=0.09$, $p=.77$	10 (5)	0.5	0.19	0.03	[0.07, 0.92]	$Q(9)=10.43$, $p=.32$
RCT only	2 (1)	0.56	0.26	0.27	[−2.69, 3.81]	$Q(1)=0.09$, $p=.77$	7 (4)	0.5	0.26	0.11	[−0.14, 1.13]	$Q(6)=9.57$, $p=.14$
Exclude outliers	No apparent outliers						No apparent outliers					
Quality of life												
Original result	4 (3)	−0.08	0.15	0.65	[−0.56, 0.41]	$Q(3)=1.13$, $p=.77$	5 (5)	0.46	0.18	0.06	[−0.04, 0.95]	$Q(4)=4.51$, $p=.34$
$r = 0.5$[a]	4 (3)	−0.08	0.15	0.65	[−0.56, 0.41]	$Q(3)=1.29$, $p=.73$	5 (5)	0.46	0.18	0.06	[−0.04, 0.96]	$Q(4)=4.63$, $p=.33$
$r = 0.8$[a]	4 (3)	−0.07	0.15	0.68	[−0.55, 0.41]	$Q(3)=2.55$, $p=.47$	5 (5)	0.53	0.21	0.07	[−0.06, 1.12]	$Q(4)=5.95$, $p=.2$
Exclude low quality	2 (2)	−0.06	0.2	0.83	[−2.66, 2.54]	$Q(1)=1.11$, $p=.29$	4 (4)	0.37	0.18	0.13	[−0.21, 0.95]	$Q(3)=2.31$, $p=.51$
RCT only	4 (3)	−0.08	0.15	0.65	[−0.56, 0.41]	$Q(3)=1.13$, $p=.77$	2 (2)	0.31	0.34	0.54	[−4.07, 4.69]	$Q(1)=2.07$, $p=.15$
Exclude outliers	3 (2)[b]	0.03	0.22	0.91	[−0.93, 0.98]	$Q(2)=0.72$, $p=.7$	4 (4)[c]	0.62	0.2	0.05	[−0.02, 1.25]	$Q(3)=1.78$, $p=.62$

a The correlation coefficient to calculate the SD of change score.
b Excluded Rawson et al. (2019).
c Excluded Romenets et al. (2015).

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