Effect of Square Dance Exercise on Middle-aged and Older Women With Persistent Postural-Perceptual Dizziness (PPPD)

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Research Article

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Abstract

Background: Persistent postural-perceptual dizziness (PPPD) is a disorder of vestibular dysfunction in which chronic dizziness leads to limitations in daily life. Although pharmacology, vestibular rehabilitation, and cognitive behavioral therapy have been suggested to have some efficacy, they have certain limitations. Some patients with PPPD report that square dance can effectively relieve the symptoms of dizziness and instability, and their mood also improves. However, to date, there has been no research about the effect of square dance Exercise on people of PPPD not to mention the middle-aged and older women who are more interested in square dance.

Objective: To evaluate the effects of square dance on the subjective sensations of dizziness, balance enhancement, anxiety, and depressive symptom regulation in middle-aged and older women with PPPD.

Materials and Methods: In this trial, a total of 124 patients diagnosed with PPPD were enrolled, among whom 64 were randomly assigned to square dance training as the experimental group (EG), and the other 60 cases were the control group (CG) without square dance training. To evaluate the effect of square dancing on middle-aged and elderly women with PPPD, data from the Dizziness Handicap Inventory (DHI), Hospital Anxiety and Depression Scale (HADS), Active-specific Balance Confidence Scale (ABC), and Vestibular Disorder Activities of Daily Living Scale (VADL) were collected and compared at the beginning and at three and six months of the trial.

Results: Before the trial, there were no significant differences between the EG and CG. Compared with baseline measures, DHI, HADS, ABC, and VADL scores improved as the experiment progressed, and the improvements were more pronounced in the EG.

Conclusion: Square dance has a positive impact on the subjective sensation of dizziness, balance enhancement, anxiety, and depressive symptom regulation in middle-aged and older women with PPPD.

Introduction

Persistent postural-perceptual dizziness (PPPD) is a vestibular dysfunction disorder characterized by persistent dizziness (≥ 3 months), nonrotational vertigo, and/or instability. Symptoms can worsen while standing up, exercising, and in complex visual environments\cite{1,2}. It has been estimated that PPPD accounts for 15–20% of all patients presenting to the hospital for dizziness and unsteady walking, making it the most common diagnosis of vestibular disease in young and middle-aged adults and the second most common diagnosis of dizziness in all adults, trailing only benign paroxysmal positional vertigo\cite{3}. Persons living with PPPD were found to have degraded efficiency (more overall elevated sway) and poorer performance, which is consistent with the theoretical constructs of high-risk postural control strategies and multimodal spatial integration issues compared with controls\cite{4}. Wuehr et al.\cite{5} found increased co-contractions of the lower extremity musculature during static standing in patients with phobic postural vertigo compared with healthy controls, and normalization of body sway and muscle contraction with the addition of a cognitive task. In addition, patients with PPPD often experience anxiety
and depression, and most of their personality characteristics tend to be neurotic and introverted\textsuperscript{[6]}. Because PPPD is a chronic dysfunction of the nervous system, manifested as chronic dizziness or imbalance due to the inability to receive effective treatment and often accompanied by psychological disorders, a multidisciplinary approach for treatment should be considered\textsuperscript{[7]}.

Although several treatments, including pharmacology, vestibular rehabilitation, and cognitive behavioral therapy have been shown to be effective, gold-standard guidelines for PPPD treatment are lacking\textsuperscript{[7, 8]}. In terms of drug therapy, selective serotonin reuptake inhibitors (SSRIs) or serotonin norepinephrine reuptake inhibitors (SNRIs) are currently preferred. It has been reported that SSRIs may indirectly interfere with dizziness symptoms by reducing anxiety and depressive symptoms, which are often observed in patients with PPPD\textsuperscript{[7]}. Moreover, SSRIs may directly affect the vestibular nucleus, which is closely related to motor-sensitive neural pathways\textsuperscript{[9]}. Nonetheless, among patients who properly received SSRI treatment, more than 30% of them reported no significant benefits\textsuperscript{[10, 11]}. Therefore, developing an alternative treatment option is a priority.

Square dance, also known as Dama square dance, is a unique phenomenon in China and is gaining popularity among middle-aged and older women due to increased awareness of the benefits of health and exercise\textsuperscript{[12]}. It is a special aerobic exercise that integrates body movement, balance and coordination, music experience, social interaction, and other factors. Square dance can not only improve behavioral cognitive function\textsuperscript{[13]}, but also plays an anti-anxiolytic and anti-depressant role\textsuperscript{[14]}. In addition, it can play a neuroprotective role by regulating the release of dopamine, increasing the level of brain-derived neurotrophic factor in the hippocampus, and affecting the secretion of specific steroid hormones\textsuperscript{[15]}. Moreover, square dance with high social interaction can improve the quality of life of participants and harvest pleasant mood allowing the participants suffering from dizziness and other discomfort reduce excessive attention to their own health conditions, so as to achieve the purpose of diversion and improve their sense of dizziness and instability \cite{5}. In addition to the walking, running, jumping, and basic dance movements of square dance, participants experience the cheerful music rhythm and practice single foot support. Moreover, participants must actively adjust their body posture to maintain balance, and eventually they effectively increase muscle strength, body flexibility, and coordination, and improve their dynamic balance in addition, square dance participants need to rotate their bodies constantly during activities, and their visual field also changes accordingly, which can strengthen the body’s ability to deal with vestibular sensation, vision, and proprioception to a certain extent and promote the dynamic recovery ability of vestibular function. According to the above speculation, it is possible that square dancing may improve the clinical symptoms of dizziness, instability, anxiety, and depression in middle-aged and elderly women with PPPD. However, to the best of our knowledge, no study has comparatively evaluated the effects of square dancing in patients with PPPD. Research on the effects of square dance may offer positive guidance to people with PPPD in selecting an appropriate exercise program.

This study aimed to assess the effects of square dance exercises on patients with PPPD. To evaluate the effect of square dance, pre-treatment and post-treatment Dizziness Handicap Inventory (DHI) scores (a
standard questionnaire that quantitatively evaluates the degree of handicap in the daily lives of patients with vestibular disorders)\(^{[16]}\), Hospital Anxiety and Depression Scale (HADS) scores (to evaluate the severity of depressive or anxiety symptoms), Activities-specific Balance Confidence scale (ABC) scores (to assess the confidence of performing sixteen daily activities without falling) and Vestibular Disorders Activities of Daily Living scale (VADL) scores were assessed and compared. We hypothesize that square dance can improve behavioral cognition, promote vestibular function rehabilitation, relieve anxiety and depression, and alleviate the symptoms of PPPD in middle-aged and elderly women.

**Materials And Methods**

**Study Design and Participants**

This study was a randomized controlled trial conducted in the First Hospital of Changsha, Hunan Province, China. Subjects were randomly divided into experimental group (EG) and control group (CG). Initially, we collected 130 patients who were randomly divided into EG and CG, with 65 patients in each group. Ultimately, six patients were excluded for the following reasons: one patient in EG was incapacitated by an accidental fracture, and five in CG failed to complete square dance.

Middle-aged and elderly women with PPPD between the ages of 45 and 75 years were recruited from the neurology outpatient clinic and hospital ward in the First Hospital of Changsha between June 2020 and May 2022. PPPD was diagnosed by a licensed neurologist (SN) according to the diagnostic criteria of PPPD established by the Classification Committee of the Bárány Society\(^{[17]}\). To minimize the possible confounds of side effects, patients were recommended to start and continue maintenance treatment with SSRIs for at least three weeks prior to and during the study period. The exclusion criteria were neurological disorders other than PPPD, psychiatric disorders (e.g., generalized anxiety disorder or major depressive disorder), history of head trauma with loss of consciousness, and pregnancy. The study protocol was approved by the Ethics Committee of the First Hospital of Changsha, Hunan, China.

**Intervention**

Square dance was used in the experimental group exercises. It is a popular form of aerobic exercise for middle-aged and elderly women. Square dance has a simple, easy-to-learn structure that is suitable for older individuals to use as a form of exercise. We chose dance music with simple melodies and low movement activity, and the main movement structures were hand clapping, high fiving, chest expansion, arm extension, and leg kicking.

Refer to previous literature\(^{[18]}\), Square dance workouts were performed outdoors three times a week for 30 min each session, starting at 7 pm on Mondays, Wednesdays, and Fridays (during periods of inclement weather, sessions were held indoors). The square dance exercise was led by two people who were proficient in square dance movements and volunteered to lead the dance, with 5 min of warm-up activities (finger joint activities, etc.) before the training, 30 min of dancing, and 5 min of relaxation exercises (i.e., deep breathing and stretching) at the end. During the square dance exercise, participants
agreed to wear a sports watch to monitor their heart rate. Exercise intensity was assessed by targeting the heart rate to 100–140 beats/min. The control group did not participate in organized physical activity and led a liberal daily lifestyle.

**Outcome Measures**

The DHI is a 25-item questionnaire that measures the patient's self-perceived handicap related to dizziness and self-perceived impact on the patient's quality of life in three domains: physical, functional, and emotional. The questionnaire provides a total score of 100; the greater the score, the higher the perceived impact of the patient's symptoms on their quality of life. This questionnaire was chosen because it has been validated\(^{[16]}\), has high test-retest reliability, and is widely used in clinics and research to measure the improvement in symptoms associated with square dance. The minimally clinically important change is 18 points between pre- and post-treatment (95% confidence interval [CI]) to indicate a significant change in self-perceived handicap\(^{[16]}\).

The HADS\(^{[19]}\) is a self-report questionnaire consisting of 14 questions, each rated on a 4-point scale. The anxiety and depression scales include seven items. This psychometric instrument was chosen because all items exclude physical symptoms and refer to only emotional state.

The ABC Scale\(^{[20]}\) comprehensively assesses the patient's confidence in not falling while performing 16 daily activities. A score of 0 indicates that the patient consistently falls while performing the exercise and fears losing his balance, whereas a score of 100 indicates that he is 100% confident that he will not fall.

The VADL was developed by Cohen et al.\(^{[21]}\). The scale has three subscales: functional, ambulation, and instrumental subscales. The scale has 28 items, each scored from 1 to 10, giving a total of 280 points. Means were calculated for the sub-scores and total scores. It is a reliable scale for the evaluation of adult patients with vertigo and dizziness\(^{[21, 22]}\).

**Statistical Analysis**

Statistical analyses were performed using SPSS 23.0. Kolmogorov-Smirnov test or Shapiro-Wilk test were used to test the normal distribution of the continuous variables, with P > 0.05 considered to obey the normal distribution. Normally distributed with mean ± standard deviation x ± s, according to comparison between groups using independent sample t-test. If the distribution was non-normal, the Median and Inter Quartile Range (IQR) were used to describe the distribution, and the Mann-Whitney non-parametric rank sum test was used for comparison between groups. Independent t-tests were used to compare baseline demographics and outcome variables between the experimental and control groups. Repeated measure ANOVA was used to compare scale scores at different time points. Statistical significance was set at p < 0.05. Data analyses were performed according to the principle of completing all experiments, and missing data were not included in the results.

**Results**
Baseline Participant Characteristics

A total of 124 participants (EG = 64, CG = 60) completed all the experimental tests. Table 1 presents the participants’ basic characteristics. There were no significant differences between the experimental and control groups in terms of baseline characteristics such as age, subjects on central nervous system medication, disease duration, DHI, HADS, ABC, and VADL scores (p > 0.05).

<table>
<thead>
<tr>
<th></th>
<th>EG (n = 64)</th>
<th>CG (n = 60)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>60.6 ± 9.3</td>
<td>60.3 ± 10.7</td>
<td>0.87</td>
</tr>
<tr>
<td>Subjects on CNS medication</td>
<td>56.3%</td>
<td>53.3%</td>
<td>*</td>
</tr>
<tr>
<td>Disease duration (months)</td>
<td>16.5 ± 8.3</td>
<td>15.9 ± 9.1</td>
<td>0.74</td>
</tr>
<tr>
<td>DHI</td>
<td>50.2 ± 16.3</td>
<td>49.8 ± 14.8</td>
<td>0.89</td>
</tr>
<tr>
<td>HADS-A</td>
<td>10.13 ± 3.43</td>
<td>9.68 ± 3.70</td>
<td>0.49</td>
</tr>
<tr>
<td>HADS-D</td>
<td>10.16 ± 2.84</td>
<td>10.68 ± 3.15</td>
<td>0.33</td>
</tr>
<tr>
<td>ABC</td>
<td>76.1 ± 21.1</td>
<td>75.7 ± 20.8</td>
<td>0.90</td>
</tr>
<tr>
<td>VADL</td>
<td>99.3 ± 24.9</td>
<td>98.8 ± 22.9</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Continuous variables are presented as mean ± standard deviation. DHI, Dizziness Handicap Inventory; HADS, Hospital Anxiety and Depression Scale; ABC, Activities-specific Balance Confidence scale; VADL, Vestibular Disorders Activities of Daily Living scale.

Experimental Outcome Comparisons

A series of subjective self-report measures were taken at baseline, three months, and six months to document the efficacy of square dance in the experimental group. Table 2 presents the comparison of the results of the CG and EG over time.
Table 2
Comparison of the results of the baseline, the experimental and control groups over time.

<table>
<thead>
<tr>
<th>Variables</th>
<th>time</th>
<th>CG(n = 60)</th>
<th>EG(n = 64)</th>
<th>Linear mixed-effects model (F)</th>
<th>Inter-group comparisons (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>group</td>
<td>time</td>
<td>group*time</td>
<td></td>
</tr>
<tr>
<td>DHI</td>
<td>baseline</td>
<td>50.2 ± 15.9</td>
<td>47.1 ± 17.8</td>
<td>17.03*</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>3months</td>
<td>42.4 ± 14.8</td>
<td>33.7 ± 9.7</td>
<td>116.72**</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>6months</td>
<td>32.6 ± 11.1</td>
<td>22.0 ± 7.7</td>
<td>7.77**</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>HADS-A</td>
<td>baseline</td>
<td>9.68 ± 3.70</td>
<td>10.13 ± 3.43</td>
<td>5.18*</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>3months</td>
<td>8.25 ± 2.07</td>
<td>7.39 ± 2.13</td>
<td>72.93**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6months</td>
<td>6.97 ± 2.67</td>
<td>5.19 ± 1.94</td>
<td>6.06**</td>
<td></td>
</tr>
<tr>
<td>HADS-D</td>
<td>baseline</td>
<td>10.68 ± 3.15</td>
<td>10.16 ± 2.84</td>
<td>26.28**</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>3months</td>
<td>9.12 ± 2.64</td>
<td>7.56 ± 3.08</td>
<td>66.04**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6months</td>
<td>7.98 ± 2.45</td>
<td>5.19 ± 1.94</td>
<td>5.78**</td>
<td></td>
</tr>
<tr>
<td>ABC</td>
<td>baseline</td>
<td>75.7 ± 20.8</td>
<td>76.1 ± 21.1</td>
<td>15.79**</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>3months</td>
<td>85.3 ± 18.1</td>
<td>102.7 ± 22.1</td>
<td>107.58**</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>6months</td>
<td>98.1 ± 23.1</td>
<td>116.3 ± 24.6</td>
<td>0.87**</td>
<td></td>
</tr>
<tr>
<td>VADL</td>
<td>baseline</td>
<td>98.8 ± 22.9</td>
<td>99.3 ± 24.9</td>
<td>12.29**</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>3months</td>
<td>76.8 ± 20.9</td>
<td>65.3 ± 16.9</td>
<td>130.74**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6months</td>
<td>60.7 ± 23.7</td>
<td>50.2 ± 12.4</td>
<td>2.45*</td>
<td></td>
</tr>
</tbody>
</table>

*P < 0.05, **P < 0.001
The DHI, HADS-A, HADS-D, ABC, and VADL scores of the two groups at different time points were compared by Mauchly spherical test, P < 0.01, and the data did not conform to spherical data, suggesting that there was a correlation between the results of multiple measurements. Finally, repeated measures ANOVA was used. The results showed that the total scores of DHI, HADS-A, HADS-D, and VADL in the CG and EG decreased over time, while the score of ABC increased, and the differences were very significant (P < 0.001). The interaction effect of group and time was very significant for DHI, HADS-A, HADS-D, and ABC (P < 0.001), and was significant for VADL (P < 0.05), with significant differences among different interventions (P < 0.001).

Independent sample t test was used to compare the scores of each scale between the CG and EG. The results showed that the DHI scores (EG: 33.7 ± 9.7; CG: 42.4 ± 14.8; p < 0.001), HADS-A scores (EG: 7.39 ± 2.13; CG: 8.25 ± 2.07; p = 0.02), HADS-D scores (EG: 7.56 ± 3.08; CG: 9.12 ± 2.64; p = 0.003), ABC scores (EG: 102.7 ± 22.1; CG: 85.3 ± 18.1; p < 0.001) and VADL scores (EG: 65.3 ± 16.9; CG: 76.8 ± 20.9; p = 0.001) were significantly different between the EG and CG at three months. In addition, like month 3, at month 6, the DHI scores (EG: 22.0 ± 7.7; CG: 32.6 ± 11.1; p < 0.001), HADS-A scores (EG: 5.19 ± 1.94; CG: 6.97 ± 2.67; p < 0.001), HADS-D scores (EG: 5.19 ± 2.43; CG: 7.98 ± 2.45; p < 0.001), ABC scores (EG: 116.3 ± 24.6; CG: 98.1 ± 23.1; p < 0.001) and VADL scores (EG: 50.2 ± 12.4; CG: 60.7 ± 23.7; p = 0.002) remained significantly different between the two groups.

Statistical analysis showed that the composite score was significantly affected by time and group. Figures 1–5 show the composite score for each group over time, where an improvement in score is observed, and the degree of change is significantly different between the groups. There was no difference in the starting point of the composite score between the CG and the EG. For the scores of each specific observation at different points in time, there was a significant group effect. With an obvious significant overall time effect observed, there was a trend for both groups to improve over time. The degree of improvement of EG was more obvious than that of CG.

**Discussion**

As a newly defined syndrome, PPPD encompasses the main characteristics of the lesions, including PPV (fear postural vertigo), CSD (chronic subjective dizziness), and related disorders [17], which is more comprehensive and specific than previous definitions. Although the exact pathophysiological mechanism
of PPPD has not been clarified in academic circles, three key mechanisms for the occurrence and development of PPPD are: excessively rigid posture when walking or standing, excessive dependence on visual information rather than vestibular input information when processing spatial orientation information, and failure of the higher cortex in regulating the first two processes\cite{4,23}. The cognitive behavioral response to this state is often followed by psychological and functional disorders such as fear of falling, anxiety or depression disorders, and postural gait abnormalities\cite{24,25}. Based on the above mechanisms, treatment of comorbid diseases including vestibular disorders, adjustment of sensory posture, and increasing tolerance to sensory stimuli through desensitization are currently commonly used therapeutic strategies for PPPD.

This randomized controlled study verified the application value of square dance in middle-aged and elderly women with PPPD, which can be used to relieve patient symptoms and promote their recovery. We found that DHI, HADS, ABC, and VADL scores of PPPD patients who partook in square dancing were significantly decreased compared with the control group who did not partake in square dancing, suggesting that the degree of vertigo disability was reduced, mood was improved, and quality of life was significantly improved. The difference remained at six months. To our knowledge, this is the first study in China to examine the effect of square dance on individuals with PPPD. We chose square dance because it is easy to learn, does not require specialized equipment or venues, and is easily accessible, which is particularly beneficial for older participants with PPPD. Good attendance and no adverse events supported the feasibility of the intervention trial.

This study showed that after three months of square dance training, the negative emotional indicators such as anxiety and depression decreased significantly, and with the extension of training time, the improvement effect was more obvious at six months. The reason may be that square dance exercise belongs to aerobic exercise. Many previous studies have confirmed that aerobic exercise improves mood by increasing positive emotions and reducing negative emotions such as anxiety and depression\cite{26–30}, which is confirmed in this study. The mechanism may be based on the fact that aerobic exercise can activate the dopaminergic system, stimulate the increase of brain-derived neurotrophic factor, reduce the secretion of 5-hydroxytryptamine in the central nervous system of menopausal women, and delay the occurrence of central fatigue\cite{29}. It can also increase the production of norepinephrine and increase the ability of the brain to resist stress\cite{31}. In addition, aerobic exercise causes the body to produce more beta-endorphins, which not only improve mood, but can improve memory. In addition, compared with the control group, participants who partake in square dance can share life experiences, relieve their helplessness and anxiety, reduce their ideological pressure, relax their mood, and obtain valuable experience of daily health care, thereby eliminating loneliness and improving their mood\cite{32}.

For DHI and VADL scores, our study revealed a significant main effect over time. The gradual decrease in dizziness symptoms over time in both groups could be due to the effects of SSRIs, as the efficacy of serotonergic medication in PPPD has been proven in previous studies\cite{10,33,34}. 
The majority of PPPD patients are secondary to organic vestibular disease with unilateral or bilateral vestibular dysfunction. Because of recurrent episodes of dizziness in people with PPPD, there are often mandatory restrictions on head movement to minimize feelings of imbalance and nausea\cite{35}. Eventually, limited head movement limits vestibular compensation, causing discomfort such as dizziness and instability to persist. Therefore, the improvement of vestibular compensatory function becomes a key step in the treatment of these patients, and vestibular improvement is primarily the regulation of vestibulo-ocular reflex (VOR). The VOR physically stabilizes the visual target in the fovea and involves eye displacement at the exact opposite amplitude and speed of head movement. After vestibular damage occurs, VOR gain decreases and oscillations occur, while repeated head rotations can drive active gaze recovery and thus VOR recovery, significantly improving postural stability\cite{36}. In addition, to some extent, gaze stability exercises can improve the subjective and behavioral performance of patients with unilateral vestibulopathy, despite an absence of change in VOR gain from the semicircular canals\cite{37}. The remaining otolith function\cite{37} and improvement in dynamic visual acuity\cite{38} have been suggested as possible mechanisms. Likewise, repetitive head and neck movements, including gaze stability exercises, are regarded as effective methods to decrease sensitivity to one's own movements (adaptation) and substitute other sensory systems for dynamic visual acuity without restoring vestibular loss in PPPD\cite{7,39}. Therefore, any exercise involving repeated head rotation can effectively improve the symptoms of dizziness and instability in PPPD patients. In this study, the DHI and VADL scores of PPPD patients were statistically significantly reduced after three to six months of square dance exercise, suggesting that square dancing can improve the dizziness and instability symptoms of patients. The beneficial effect of square dancing might come from the head rotation movement, which ultimately improved the subjective and objective symptoms of PPPD patients.

Overall, square dance is a promising nonpharmacological intervention strategy for middle-aged and older adults with PPPD. A six-month daily exercise intervention can improve overall dizziness, depressive or anxiety symptoms, balance, and quality of life in middle-aged and older women with PPPD. Square dance, an affordable form of exercise, is suitable for communities and other areas where middle-aged and older women are concentrated. Exercising in such an environment improves mood and is equally beneficial for improving cognition. Our recommendation is to practice once a day for about 30 minutes, three times a week, preferably for six months. Of course, due to the dizziness and instability symptoms of PPPD patients, primary hospitals or communities should evaluate the physical conditions of patients when organizing square dancing exercises, provide necessary guidance, supervise these exercises, and prevent patients from falling and other adverse events.

This study demonstrated the feasibility of square dance, the importance of which is being acknowledged, especially in this pandemic era. This study had several limitations. First, the participants were recruited from a single center, and future multicenter studies are needed to confirm our findings. Second, the assessment instrument used only scale measures. Future studies including the vestibular function examination and functional magnetic resonance imaging might provide more information about the
effect of square dance in PPPD patients. Third, this study only discussed PPPD in middle-aged and older women, and its applicability in men remains to be further explored.

**Conclusion**

This study investigated the effect of square dance exercise interventions in middle-aged and older women with PPPD. This study supports the positive effects of square dance in improving dizziness, depression or anxiety, balance, and quality of life in middle-aged and older women with PPPD.

**Declarations**

**DATA AVAILABILITY STATEMENT**

The original data supporting the conclusions of this study will be provided by the authors without reservations.

**ETHICS STATEMENT**

The studies involving human participants were reviewed and approved by the Scientific and Ethics Committee of the First Hospital of Changsha. The patients provided written informed consent to participate in the study.

**AUTHOR CONTRIBUTIONS**

Xiaojun Yu and Bo Tang conceived of and designed the study. Xiaojun Yu obtained the funding. Wei Jiang, Chuang Zhang, and Hong Tan supervised this study. Bo Tang, Yuqing He, Minghua Luo, and Chuang Zhang collected the data. Xiaojun Yu independently performed randomization. Bo Tang and Xiaojun Yu performed data analysis and wrote the first draft of the manuscript. All authors contributed to manuscript revisions and read and approved the final version of the manuscript for submission.

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Figures
Figure 1

Changes in the Dizziness Handicap Inventory (DHI) total score.
Figure 2

Changes in the Hospital Anxiety and Depression Scale for anxiety (HADS-A) total score.
Figure 3

Changes in the Hospital Anxiety and Depression Scale for depression (HADS-D) total score.
Figure 4

Changes in the Activities-specific Balance Confidence Scale (ABC) total score.
Figure 5

Changes in the Vestibular Disorders Activities of Daily Living Scale (VADL) total score.