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**Research article**

# The effect of Chinese Yuanji-Dance on dynamic balance and the associated attentional demands in elderly adults

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## Abstract

Walking performance changes with age. This has implications for the problem of falls in older adults. The aim of this study was to investigate the effects of Yuanji-Dance practice on walking balance and the associated attention demand in healthy elderly. Fifteen community-dwelling elderly (comparison group, no regular exercise habit) and fifteen Yuanji-Dance elderly (exercise group, dancing experience: 5.40 ± 1.95 years), aged 60-70 years, were included in this study. The subjects in exercise group participated in a 90-minute Yuanji-Dance practice at least three times per week and the comparison group continued their normal daily physical activity. Walking balance measures (including walking velocity, step length, step width, and percentage of time spent in double limb support, COM velocity and COM-COP inclination angles) and attentional demand tests (button reaction time and accuracy) were conducted under different conditions. Our results showed that stride lengths, walking velocities, peak A/P velocities (AP V) of the COM, medial COM-COP inclination (M angle) angles, reaction time, and accuracy decrease significantly as the dual-task (walking plus hand button pressing tasks) applied for either the comparison or exercise groups. These results demonstrated that walking performance is attenuated in our elderly participants as the cognitive tasks applied. Analysis also identified a significantly faster RT for our exercise group both in standing and walking conditions. This may indicate that physical exercise (Yuanji-Dance) may have facilitating effects on general cognitive and perceptual-motor functions. This implies that Chinese Yuanji-Dance practice for elderly adults may improve their personal safety when walking especially under the condition of multiple task demand.

**Key words:** Yuanji-Dance, exercise, balance, attention.

## Introduction

Yuanji-Dance (Chinese Aerobics) is derived from Yuan-Ji Gong which was a kind of dance combining Chi-Gung, Tai-Chi, medicine, martial arts, and also Yuanji music. In recent years, Yuanji-Dance has become one of the most popular exercises in the Chinese community. The majority of participants in Yuanji-Dance are senior citizens and most of them are women. It has the same attraction as traditional Chinese massage, where physical exercise is combined with entertainment, bodybuilding, and health care (Shah et al., 1999).

Chinese Yuanji-Dance is a low-middle intensity dance exercise (Chung et al., 2005). It provides interdisciplinary methods for health promotion (Jane et al., 2004; Chao et al., 2008). Through general observation, experienced Yuanji-Dance professionals report that the practice of Yuanji-Dance has improved their static and dynamic balance (Jane et al., 2004), strength (Wu, 2006), flexibility and coordination. It has also increased their focus, concentration, and memory. Until now, however, scientific studies on Yuanji-Dance have not been well established. In 2007, researchers in our department initiated a full-scale scientific study on Yuanji-Dance. Dr. Guo has done in-depth studies on important topics such as the effect of Yuanji-Dance on brain activity modulation (Tsai et al., 2007), heart rate variability (Tsai et al., 2007), and observed changes of spectrum distribution of the laser doppler perfusion signal in human skin after Yuanji-Dance (Leong et al., 2007). The results showed that practice of Yuanji-Dance has the significant post-exercise effect of up to 30 minutes on increasing heart rate and promoting peripheral circulation as compared to the resting state that were similar with that found out from general aerobic exercise which was, however, slightly different from other traditional Chinese exercise, such as Tai-Chi or Wai-Tan Kung. It implies that the Yuanji-Dance may also have positive effect on promoting aerobic fitness. On the other hand, electroencephalography study showed that no immediate changes were found on mood and attention status after Yuanji-Dance practice. The major limitation of above-mentioned studies were that there were no age-matched normal subjects served as the comparison group. These studies can only compare the physiological effects before and immediately after exercise.

Age-related impairment in gait, balance, cognition, hearing, and vision results in a large proportion of falls in older people that occur when walking is combined with attentional demand of concurrent verbal tasks or auditory-response tasks. Health care clinicians often recommend exercise for the elderly in helping to prevent falls by improving strength, coordination, and balance. Moreover, a growing body of evidence also suggests that physical exercise may have facilitating effects on general cognitive and perceptual-motor functions (Chodzko-Zajko et al., 1994; Clary et al., 2006; Hatta et al., 2005; Kramer et al., 2005; Yamauchi et al., 2005). Some literature results showed that performance on cognitive tasks is attenuated in participants with low physical fitness (Dustman et al., 1984; Özkaya et al., 2005). Despite the implications of the

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finding that exercise can facilitate fast sensory processing and contribute to cognitive capability (Özkaya et al., 2005; Tinetti et al., 1994), it is unclear whether Chinese traditional exercise (Yuanji-Dance) might contribute to the maintenance of cognitive capability or perceptual-motor functions, and to our knowledge, the effects of Yuanji-Dance practice on the walking performance and the associated attentional demands have not been studied using combined methods of biomechanics techniques and neurophysiology technique. Therefore, in this study, we hope to investigate the effects of Yuanji-Dance practice on walking balance and the associated attention demand in the healthy elderly.

## Methods

### Participants

Fifteen community-dwelling female elderly (no regular exercise habits, comparison group) and fifteen Yuanji-Dancing female elderly (exercise group, dancing experience: 5.40±1.95 years) were included in this study. The mean age of women in the exercise group was 68.67±2.80 and the comparison group was 68.33±3.06. To be included, participants had to have no related neurological or musculoskeletal problems. In addition, the subjects in the exercise group must participate in 90-minute Yuanji-Dance practice at least three times per week within 3 years. A Yuanji-Dance teacher offered help to recruit those who have similar skill levels to our study. Subjects may require to satisfy the following criteria: dance should be executed with fluent transitions and the required number of steps. On average, the subjects in exercise group had 5.40±1.95 years of dancing experience. The characteristics of the subjects are shown in Table 1. There was no significant difference in age, height or body weight between the two groups. All subjects signed an informed consent form before testing.

**Table 1. The characteristics of the subjects. Data are means (±SD).**

| | Exercise group | Comparison group |
|---|---|---|
| Age (yrs) | 68.7 (2.8) | 68.3 (3.1) |
| Height (m) | 1.55 (.07) | 1.59 (.02) |
| Body weight (kg) | 56.2 (10.3) | 61.7 (4.9) |
| Dancing Experience (yrs) | 5.40 (1.95) | |

### Dancing protocol

Typically a Yuanji-Dance class will start with a warm-up exercise, followed by the Yuanji-Dance number 1 and number 2 for a total of 45 minutes. After a ten-minute break, the class will then dance some of the other Yuanji-Dances for a total of 35 minutes. The principle footwork of Yuanji-Dance is "Lotus Steps" which consists of 'back left and front right, fore and back bow-steps. All these dance actions with body weight either applied to the left, right, back or fore are in fact represent the interaction of the Ying (when body weight is very lightly on the step) and Yang (when the body weight is heavily on the step). While dancing these Ying and Yang steps, the dancer's body is at the centre of this footwork. Therefore, in total the 90-minute class that mainly emphasizes practice on the "Lotus step" has very real effect on dynamic balance.

### Experimental apparatus

The sound operating system (STIM2 Acquisition Software, Compumedics Neuroscan, USA) was used to provide a stimulus tone to the subject. Two in-series force platforms (Kistler Instruments, Inc, Winterthur, Switzerland) embedded in the center of a 12-m walkway were used to record ground reaction forces with a sampling frequency of 1000 Hz. A six-camera motion analysis system (Qualisys Motion capture Systems, Qualisys AB, Sweden) was used in this study to collect the motion data of the whole body with a sampling frequency of 100 Hz. During the reaction time (RT) test, a radio telemetry handheld trigger was used to signal a response. Ground reaction force and motion data were recorded simultaneously on a desktop computer. The stimulus tone and reaction signals were recorded simultaneously on a notebook computer.

### Experimental protocol

For kinematic analysis, 31 anatomical reflective markers (Figure 1, spherical markers with a diameter of 18 mm) were placed on the anterior superior iliac spine, the iliac crest, the sacrum, the greater trochanter, the medial and lateral femoral condyles, the medial and lateral malleolus, the heel, the head of the first and fifth metatarsals, the top of the acromion, the medial and lateral epicondyle of the humerus and the styloid processes of radius and ulna. The 4 tracking markers (diameter: 13 mm) consisted of rigid plates secured to the thigh and the shank, the upper arm and the forearm. The markers in medial side were removed during walking.

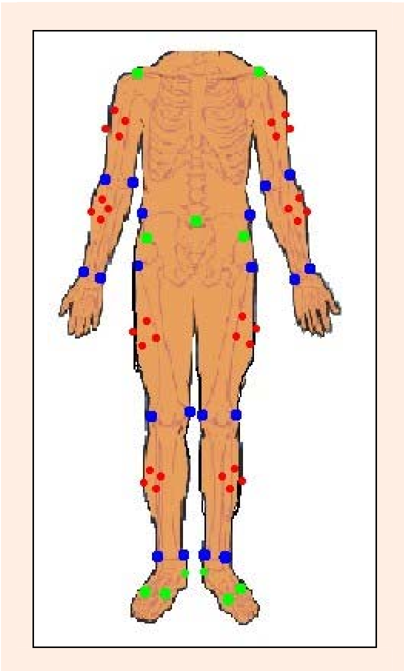

**Figure 1. Surface marker locations (The red markers are used for tracking only. The green markers are used for both the segment definition and for tracking. The blue markers are used only for the segment definitions).**

In order to determine the differences in walking performances and the associated attentional demands between the comparison group and the exercise group, three different conditions: single-primary task (walking alone), single-secondary task (hand button pressing alone), and dual-task (walking plus hand button pressing tasks) were tested for each participant. The participants were familiarized with the two different tones (2 kHz target tones and 1 kHz non-target tones) before testing and were instructed and practiced walking at their self-selected comfortable speeds and pressed the button with the dominant hand when hearing a "high frequency" tone signal.

In the single-primary task condition, each subject was first asked to stand in the starting point of the walkway with a symmetric stance. Subjects were then asked to walk barefoot for a total of almost 10 steps to the end of the walkway at a comfortable self-selected pace for each trial. Each subject performed a total of 3 trials of walking when hearing an audio signal of "go" from our examiner.

In the single-secondary task condition, subject performed the quick hand button press tasks during quiet standing after hearing a "high frequency (2 KHz)" tone signal. The stimulus signal was programmed to trigger every 1.5 seconds, 200 ms in duration. Of all auditory stimuli, 20% were "high frequency" tone targets stimuli, and the rest were randomly occurring "low frequency (1 KHz)" tone non-target stimuli. In total the sound operating system generated 150 test signals (30 high frequency and 120 low frequency signals) in random order, with the only constraint being that two targets could not appear consecutively. Thirty seconds resting time was arranged between every 50 test signals. All the above-mentioned strategies are commonly prescribed to study attention.

In the dual-task condition, subjects must simultaneously perform 30 trials of hand button pressing with the dominant hand and walking tasks. Initially, each subject was standing in the starting point of the walkway with a symmetric stance and was instructed to walk at a comfortable speed. Subjects heard an audible stimulus signal every 1.5 seconds and was asked to respond after hearing a "high frequency (2 KHz)" tone signal by pressing a button on the handheld trigger. Subjects were given instructions to react as soon as possible. Low frequency tone stimuli were randomly dispersed throughout the testing session. Approximately 80% of the audible stimulus signals are low frequency tone so that subjects are unaware of when a high frequency tone signal would occur. Prior to testing, the subjects were allowed to hear the audible stimulus tone to be familiar with them. Each walking trial lasted approximately 10 s. Therefore, subjects always need to press the button once or twice in each dual-task trial because the probability of occurrence of "high frequency" stimulus signal was 20%. The subject then returned to the starting position and waited several seconds for the next trial to begin. In total, each subject performed approximately 30 trials in this part of the experiment and the first 3 "successful" trials in which the subject got a clean force plate strike were averaged to calculate COP, COM, and temporal-distance data. Trials that were not "successful" were due to subjects not being able to get a successful foot strike on both force platforms every time. However, reaction times were measured 30 times and all trials were averaged.

On overall arrangement for the 3 testing conditions (single-primary task, single- secondary task, and dual-task), subjects were allowed a rest period of ten minutes during each transition to a new testing condition. All subjects were tested under three conditions in random order.

## Data analysis

The signals from the stimulus tone and the radio telemetry receiver were collected at 1000 Hz for 10 s. Reaction time (RT) was calculated from the time difference between the stimulus tone signal onset and the trigger signal onset.

Qualisys Track Manager software (Qualisys Motion capture Systems, Qualisys AB, Sweden) was used to track the markers in space for 10 s at 100 Hz. All marker data were low-pass filtered using a Butterworth filter with a cut-off frequency of 6 Hz, and interpolated with a maximum gap fill of 10 frames using a 3rd polynomial. Further analysis including walking velocity, step length, step width, and percentage of time spent in double limb support was calculated by Visual3D software (C-Motion Inc, USA.). Double limb support phase means that, at that time, both limbs are in contact with the ground simultaneously. This parameter is often used to analyze gait changes with aging (Shkuratova et al. 2004; Chamberlin et al. 2005). Aging will increase the duration of the double limb stance due to difficulty in moving the body over an unstable limb. An 11-segment, full-body model (forearms, upper arms, head + trunk, thighs, shanks, feet) was implemented in Visual3D, and the instantaneous location of the full-body center-of-mass (COM) and the first time derivate of position data of COM (COM velocity) were calculated within Visual3D. COM data was truncated to one walking stride from toe-off of one foot to the other foot heel-strike in order to analyze the difficulty of single limb support while walking.(Lee et al. 2007) Finally, the COM peak velocities in the A/P (AP V) and M/L directions (ML V) were analyzed.

GRF data was filtered with a low-pass forth order Butterworth filter at 20 Hz forward and backward in time. The filtered data was used in the subsequent COP analysis. COP data was calculated during one walking stride from the signals from the first and second force plates. Self developed MatLab programs were used to complete the processing of the data. Finally, the COP data was synchronized with the COM data to find the peak anterior (A angle), posterior (P angle), and medial COM-COP inclination (M angle) angles. The sagittal and frontal COM-COP inclination angles were defined as the angle formed by the interaction of the line connecting the COM and COP with a vertical line through the COP (Lee et al. 2007).

## Statistical analyses

A two-way repeated measures ANOVA was applied for statistical analysis of the data in which there are two independent variables: groups and tasks. Among it, each subject would receive repeated measures: tasks. Post-hoc analyses were performed with the Newman-Keuls test. Throughout the analysis, differences $p < 0.05$ were considered to be statistically significant. Spatio-temporal

**Table 2. Gait temporal-distance measurements for both groups during the walking stride. Data are means (±SD).**

| | Exercise group | | Comparison group | |
|---|---|---|---|---|
| | No stimulation | Stimulation | No stimulation | Stimulation |
| Stride Length (m) | 1.11 (.14) * | 1.00 (.10) | 1.12 (.07) * | 1.07 (.04) |
| Walking Velocity ($m \cdot s^{-1}$) | 1.12 (.12) * | .89 (.09) | 1.03 (.06) * | .95 (.02) |
| Step Width (m) | .19 (.05) | .18 (.04) | .20 (.07) | .20 (.06) |
| Percentage of Time spent in Double Limb Support | 26.26 (1.15) | 28.82 (1.67) | 25.79 (1.32) | 26.14 (.32) |

* denotes $p < 0.05$ compared to the sound stimulation effect in the same group.

parameters (walking velocity, stride length, step width, and percentage of time spent in double limb support) and COM parameters (AP V, and ML V), COM-COP parameters (A angle, P angle, and M angle) were compared between two experimental conditions: single-primary task (walking alone) and dual-task (walking plus hand button pressing tasks). Reaction time (RT) and accuracy in the tone discrimination were compared between two experimental conditions: single-secondary task (hand button pressing alone) and dual-task (walking plus hand button pressing tasks).

## Results

The gait temporal-distance measurements during walking for exercise group and comparison group are shown in Table 2. In total, there were significant task differences (no sound stimulation vs. sound stimulation) in stride length (p = 0.003 for exercise group; p = 0.043 for comparison group) and walking velocity (p = 0.009 for exercise group; p = 0.024 for comparison group). Stride length and walking velocities decrease significantly as the dual-task (walking plus hand button pressing tasks) were applied for both the comparison and exercise groups. No significant difference between the two groups was observed in both task conditions.

Significant decreases in peak velocities of the COM (Table 3) in the A/P (AP V) direction were detected both in the exercise (p = 0.005) and comparison groups (p = 0.037) during dual task when compared to single-primary task (walking alone). However, no stimulation effects were detected in M/L direction (ML V) both in the exercise and comparison groups. The results showed no significant difference between groups in peak velocities of the COM.

The instantaneous COM-COP inclination angles are illustrated in Figure 2. The overall pattern of angular changes in comparison group is similar to that observed in exercise group. However, a narrower medio-lateral angular excursion is observed in both groups during performing dual task (Figure 2). Table 4 shows that the medial COM-COP inclination (M angle) angles are significantly smaller as the dual-task applied for both the comparison (p = 0.034) and exercise groups (p = 0.041).

However, no group differences were detected for peak anterior (A angle), posterior (P angle), and medial COM-COP inclination angles. In addition, no significant stimulation effects were detected for peak anterior (A angle) and posterior (P angle) inclination angles during stride cycle in either group.

The RT was significantly faster for all participants in the single-secondary task condition (hand button pressing alone, stance) than for the dual-task (walking plus hand button pressing tasks, walking) condition (p = 0.006 for the exercise group; p = 0.022 for the comparison group). Task differences in reaction time were almost 56 msec for exercise group and 19 msec for comparison group (Table 5). Analysis also identified a significant group effect on reaction time measurement in the single-secondary task (hand button pressing alone, p = 0.009) and dual-task (walking plus hand button pressing tasks) conditions (p = 0.033).

There was an accuracy of 0.99 ± 0.01 for the exercise group and 0.98 ± 0.03 for the comparison group during performance of the single-secondary task. During the dual-task (walking plus hand button pressing tasks), the accuracy decreased to 0.95 ± 0.03 and 0.95 ± 0.03 for the exercise and comparison groups, respectively. The accuracy in the tone discrimination task was significantly higher for both exercise (p = 0.042) and comparison (p = 0.039) participants in the single-secondary task (hand button pressing alone, stance) condition than for the dual-task (walking plus hand button pressing tasks, walking) condition (Table 5). Overall, no significant group differences were found in accuracy measurement in the single-secondary task (hand button pressing alone, p = 0.392) and in the dual-task (walking plus hand button pressing tasks, walking, p = 0.571) conditions.

## Discussion

The findings showed that both the exercise and comparison groups had a smaller COM-COP inclination angle (M angle) during the dual task condition. This means that these individuals adopt a more conservative gait strategy to maintain stability during dual-task conditions. They keep their line of gravity as close as possible to the base of supporting foot to maintain stability during dual-task conditions.

We also found that our experimental design did not obviously affect gait measures between exercise and comparison groups, only exhibiting some differences in reaction time measurement. This means that our subjects were able to adopt similar gait strategy to maintain

**Table 3. Mean (±SD) of the peak velocities in the A/P (AP V) and M/L directions (ML V) for both groups during each task.**

| | Exercise group | | Comparison group | |
|---|---|---|---|---|
| | No stimulation | Stimulation | No stimulation | Stimulation |
| **AP V ($m \cdot s^{-1}$)** | 1.01 (.03) * | .84 (.16) | .95 (.13) * | .90 (.25) |
| **ML V ($m \cdot s^{-1}$)** | .17 (.01) | .18 (.01) | .17 (.05) | .20 (.07) |

* denotes $p < 0.05$ compared to the sound stimulation effect in the same group.

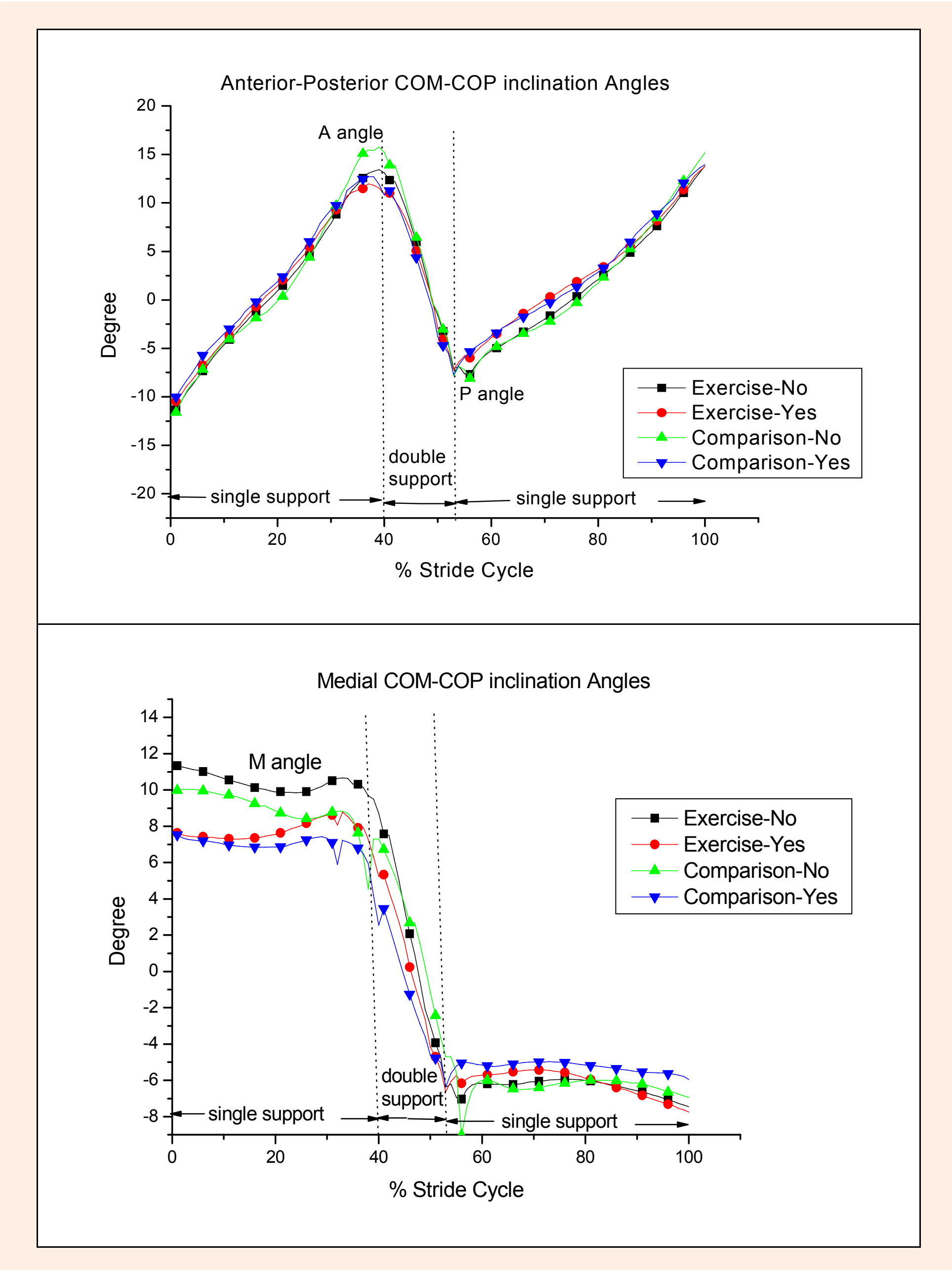


**Figure 2. Mean anterior-posterior and medial COM-COP inclination angles from comparison group and exercise group while walking (Yes: represents walk combined with sound stimulation; No: represents only walking).**

stability during single-primary task or dual-task work. Minor differences were only exhibited in information processing speed. Subjects in comparison group processed all information more slowly and gave most of their attention to the walking task The assumption behind this inference is that the person has a fixed capacity for attention, (Yardley et al., 2001) such that when attention is divided between two tasks, performance will be worse than when each task is performed alone (Weerdesteyn et al., 2003). Therefore, if failure at the secondary task presents no danger, locomotion will naturally receive first priority (Buford, 2005).

The secondary task chosen for the present study was a simple button pressing work. Besides, an additional possibility is that our dual-task design was not difficult enough to affect both gait and reaction time measurements. More challenging tests are recommended for future design of a testing protocol.

In addition, muscle strength of lower extremity is an important factor to affect walking performance (Kim et al.,

**Table 4. Mean (±SD) of the peak inclination angles in the A, P, and M directions during the walking stride.**

| | Exercise group | | Comparison group | |
|---|---|---|---|---|
| | No stimulation | Stimulation | No stimulation | Stimulation |
| **A angle** | 13.43 (5.03) | 11.98 (1.87) | 15.40 (5.65) | 12.71 (.27) |
| **P angle** | 7.66 (1.28) | 6.00 (3.56) | 8.10 (1.25) | 7.71 (.48) |
| **M angle** | 9.86 (0.95) * | 7.45 (1.95) | 8.52 (3.35) * | 6.86 (.54) |

* denotes $p < 0.05$ compared to the sound stimulation effect in the same group.

**Table 5. Reaction time (RT) and accuracy measurements for both groups during the walking stride (walking) and quite stance (stance) with hand button press alone. Data are means (±SD).**

| | Exercise group | | Comparison group | |
|---|---|---|---|---|
| | Stance | Walking | Stance | Walking |
| **Reaction time (ms)** | 490.20 (125.40) *† | 546.07 (56.89) | 544.28 (239.93) *† | 563.15 (143.23) |
| **Accuracy** | .99 (.01) * | .95 (.03) | .98 (.03) *† | .95 (.03) |

* denotes $p < 0.05$ compared to the sound walking effect in the same group. † denotes $p < 0.05$ compared to comparison group.

2004), and it may be why there were no differences between groups. Chinese Yuanji-Dance practice for elderly adults seems can't offer the predicted benefits in improving muscle strength. Maybe it can only offer the similar cardiovascular benefits as aerobic exercises do.

In this manuscript, there seems to be a possibility to infer the correlation between Yuanji-Dance practice and cognitive information processing speed (faster reaction time). Previous research using animal models showed that aerobic training increases cortical capillary supplies, the number of synaptic connections (Lu et al., 1999), and the development of new neurons (van Praag et al., 1999). The end result is a brain that is more efficient, which translates into better performance in aging animals (van Praag et al., 1999). Most recently, from human study, it also suggested that cardiovascular fitness should positively affect cortical function in aging humans (Colcombe et al., 2004). Older adults who were more aerobically fit tended to lose less tissue in the frontal, parietal and temporal cortices as a function of age. Thus, we infer that exercise participation leading to improved aerobic fitness may improve the functional integrity of the older adult brain and cognition.

The central pattern generator (CPG) is a system within the central nervous system that responds to rhythmic and simple motor activities (Kuo, 2002), such as walking. While the sensory receptors, including vision, vestibular apparatus, and somatosensory, play an important role in smoothing the performance. Aging is significantly associated with diminished sensory feedback function. Therefore, aging is frequently accompanied by a deterioration in postural control (Lin et al., 2004). Under dual-tasking, the elderly 's attention is more likely to be interfered (Anand et al., 2003; Yogev et al., 2005) so that the performance of locomotion would be influenced. This information agrees with what we found in our study. From single to dual task conditions, the stride length was shorten and the velocity in body motion decreased which resulting in a slower gait pattern. It suggests that, for elder people, not only the CPG system, but also the cortical are highly involved in maintaining proper posture while walking.

In our experiments, subjects can be nearly 100% correct in button press work (ranged from 95 to 99% correct decisions), and, therefore, RT become the variable of importance. If the stimulation signal is a bit more complex, no matter how long subjects take in responding, we infer that they cannot be 100% correct. It may be worth for future study.

In summary, we demonstrated clinically relevant effects in general cognitive and perceptual-motor functions after long-term Chinese Yuanji-Dance practice. Even though practical considerations interfere with the perfect experimental design, our matched comparison group design can partly overcome the problems caused by limited resources for experimentation. Our two groups are, as far as possible, matched for reducing other influences. Only one "Yuanji-Dance" is given the treatment and therefore, differences can be attributed to the treatment. In addition, because matched comparison group designs do not require that the evaluator controls who does, and does not, get the intervention, they are often a very pragmatic design choice when dealing with real-world evaluations. To sum up, our study really showed observed difference between our intervention and comparison group. Yuanji-Dance really has facilitating effects on general cognitive and perceptual-motor functions.

## Conclusion

Our study verified that Yuanji-Dance practice can benefit the general cognitive and perceptual-motor functions of elderly people and not influence the dynamic walking balance. Reduction of response time would be effective in preventing a fall after a trip because response time is an important factor in affecting success of recovery after the trip. This implies that Chinese Yuanji-Dance practice for elderly adults may improve their personal safety when walking especially under the condition of multiple task demand.

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## Key points

- The purpose of this study was to investigate the training effects of a Chinese traditional exercise, Yuanji-Dance, on walking balance and the associated attention demand in the healthy elderly.
- Walking performance is attenuated in elderly participants as the cognitive tasks applied.
- A significantly faster reaction time for our exercise group both in standing and walking conditions.
- Yuanji-Dance exercise training can improve the information processing speed of elderly people and has no influence of the dynamic walking balance.

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