The Effects of Low-Impact Dance on Knee Torque and Lower Extremity Mobility in Middle-Aged and Older Women

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Introduction

Aging, characterized by muscle atrophy, is typified by a decline of bone mineral density (BMD) and changes in body composition, that is, increasing fat related to other component body materials (Finkelstein et al., 2008; Kuk, Saunders, Davidson, & Ross, 2009; Raguso et al., 2006). Growing aging populations are a worldwide trend. Negative influences in the physiological and psychological dimensions with respect to aging can be attenuated throughout regular physical activity and exercise (American College of Sports Medicine [ACSM], 1998; Steffen, Hacker, & Mollinger, 2002). The ACSM and American Heart Association jointly recommended for older adults under 65 years old a minimum of 30 minutes of moderate-intensity aerobic physical activity for 5 days a week or a minimum of 20 minutes of vigorous-intensity aerobic activity for 3 days a week to promote and maintain their health (Haskell et al., 2007).

Although many physical activities and exercises are appropriate for healthy adults, greater attention should be paid to aging women because of the effects of menopause. Declines in muscular strength and bone mass in the lower extremities of menopausal women occur faster and more perceptibly in comparison with that of premenopausal women (Ahlborg, Johnell, Turner, Rannevik, & Karlsson 2003; Greeves, Cable, Reilly, & Kingsland, 1999). These phenomena are likely associated with reduced estrogen levels (Samson et al., 2000; Taaffe et al., 2005). Research has indicated that hormone replacement therapy can improve weak muscular strength (Carville, Rutherford, & Newham, 2006; Gothenström et al., 2010). In addition to medicine, physical activity and exercise interventions can help mitigate the decay of muscular strength in the lower extremities (Bocalini,
Serra, dos Santos, Murad, & Levy, 2009; Shigematsu, Okura, Sakai, & Rantanen, 2008). Weak muscular strength in the lower limbs is a risk factor in falls. Studies have reported that individuals who engage in a regular physical activity or exercise had fewer fall incidents than those who did not (Kemmler, von Stengel, Engelke, Haberle, & Kalender, 2010; Shigematsu et al., 2002). Reasons for this difference are probably because of improvements in muscular strength, BMD, and balance in regular exercisers. Aerobic dance is one of numerous recommended physical activities and is widely enjoyed by female adults. Generally speaking, high-impact aerobic dance differs from low-impact aerobic dance in that the former has both feet leaving the ground simultaneously whereas the latter keeps one foot in contact with the ground at all times (Ricard & Veatch, 1990). Although high-impact aerobic dance can improve cardiorespiratory fitness, maximal oxygen capability, and submaximal aerobic power, in older adults (Dowdy, Cureton, DuVal, & Ouzts, 1985), the literature reports that peak impact force, mean loading rate, and mean impact impulse during the first 50 milliseconds of impact are significantly higher in high-impact aerobic dance compared with low-impact aerobic dance (Ricard & Veatch, 1990). High-impact dance poses greater risks to lower extremity strength, joints, and soft tissues (Janis, 1990). Although low-impact dance also helps enhance cardiorespiratory fitness (Shimamoto, Adachi, Takahashi, & Tanaka, 1998), few studies on the effects of low-impact dance on knee torque and range of motion (ROM) in lower extremity joints have been conducted. Both parameters play important roles in reducing fall risk in older adults. This study investigated the effects of low-impact dance on these parameters in participants and compared results with those of a physically inactive cohort. We hypothesized that women in the dance group (DG) would have significantly better parameter values compared with those in the inactive cohort.

Methods

Participants

This was designed as a cross-sectional comparative study. The age range of participants was 50 to 70 years. All participants were women and were prescreened by a physician to ensure cardiovascular, metabolic, and pulmonary health. Also, individuals with problems or diseases of the musculoskeletal system or who had taken any hormone-related medicine for menopause within 6 months before the study were excluded. Individuals who had engaged in low-impact aerobic dance for at least 3 years (30 minutes each time, five times per week) were included in the DG. These conditions, with respect to regular physical activity, match ACSM recommendations (Haskell et al., 2007). Individuals who did not exceed 20 minutes of structured physical activity during a week or did not engage in physical labor in their occupations were included in the control group (CG). Initially, 33 individuals in the DG and 19 individuals in the CG expressed their interest to join the study. All lived in Pingtung City or its suburbs and were responsible for light household work. After screening to confirm eligibility, 26 low-impact dancers were enrolled in the DG and 12 were enrolled in the CG. Those disqualified from participation did not differ significantly from the participants in terms of age and body mass index (BMI). All eligible subjects provided written informed consent before participation. According to the instructor records, the compliance rate for low-impact dance participants exceeded 85% each month. Approval for this study was obtained from the human subject internal review board of the hospital. All measurements were taken in a sports biomechanics laboratory.

Participant Anthropometric Measurements

The height and weight of all participants were measured using an electronic stadiometer (Seca, Model 242, Hanover, MD, USA) and a digital scale (Tanita, Model BWB-627A, Hong Kong, China), respectively. BMI was calculated by dividing weight (kg) by height (m) squared (kg/m²). In addition, percentage of body fat was measured using InBody 720 (BIOSPACE, Seoul, South Korea). The measurement was carried out in the morning, after an overnight fast.

ROM of Knee and Ankle Joints

The researchers analyzed parameters related to lower extremities by the dominant and nondominant legs, respectively, to examine differences between legs for habitual low-impact dancers. This was because the dominant leg may reflexively execute certain actions, such as standing on one leg, circling around, and stepping sideways. The dominant leg was identified by asking participants with which leg they would normally kick a ball (Ricotti & Ravaschio, 2011). An experienced physiotherapist blinded to the group categories measured participant knee joint flexion and extension and ankle joint inversion, eversion, plantarflexion, and dorsiflexion ROMs using a goniometer (NexGen Ergonomics, Quebec, Canada). The methods of Norkin and White (1995) for knee and ankle joint ROM were adopted in the current study. Before testing, participants were asked to warm up for 3 to 5 minutes. All values of ROM that were measured for these joints were obtained from the mean of two measurements. A third measurement was performed if the difference between the two measurements of any variable exceeded 2°.

BMD

The authors used a GE Bone Ultrasonometer (Madison, WI, USA) to measure BMD in the dominant and nondominant calcanei. The manufacturer provided a reference population to compare DG and CG participants against. In addition, this study referred to criteria published by the World Health Organization (WHO, 1994) concerning diagnosis levels (i.e., normal, T-score ≥ −1.0; osteopenia, −1.0 > T-score ≥ −2.5; osteoporosis, T-score < −2.5).
Knee Joint Extension Torque Test
The mean peak torque with each knee extension of all participants was determined by averaging the peak torque values from three maximal trials with an intervening 2-minute rest between trials. Subjects were tightly secured to a fixed chair using waist, chest, and thigh straps. The knee was positioned at 120° of flexion, and the hip was at 90° of flexion. The lateral condyle of the tibia was aligned with the axis of the torque sensor. The force measurement device measured the force generated at the knee extension using a torque sensor (Jihsense RT-100, Taipei, Taiwan, ROC). When one leg knee torque measurement was completed, a side measurement began after a 3-minute rest. This torque instrument was calibrated according to manufacturer’s utilization instructions before measurement. Inter- and intra-individual coefficients of variation for all variables in this study were lower than 7%. Authors further examined test-retest reliability using the intraclass correlation coefficient (R) between two measurements. The R values for knee torque and lower extremity joint ROM were .91 and .94, respectively.

Low-Impact Aerobic Dance Intensity
The general program in the low-impact dance consisted of three parts: warm up, review recently taught actions and perform the entire activity program to music, and teach new actions. The middle part occupied the most time of the three. Main exercises for lower extremities were side steps; walking forward and backward; circling; leg lifts; tiptoeing forward, sideward, and backward; and heel rises. Main exercises for upper extremities were stretch, circle, shrug, abduction, adduction, and circumduction.

The heart rate (HR) and rating of perceived exertion (RPE) on Borg’s scale (Borg, 1970) were used to provide a reference of exercise intensity for the low-impact aerobic dance in the current study. Both were determined by the average values from five dance sessions. The HR while dancing was measured and recorded using a Polar S610i (Kempele, Finland).

Statistical Analysis
Results of all parameters are expressed as the mean ± SD. These variables from the two different groups were compared using an independent Student’s t test. All data analyses were performed using SPSS version 15.0 (SPSS, Inc., Chicago, IL, USA). The significance level was set to \( p < .05 \).

Results
For the knee extension torque, a statistical power analysis (G*Power 3.0; Franz Faul, Kiel University, Germany) indicated that a sample size of 38 subjects would be sufficient to give statistical power of 80% with a significance level of \( p < .05 \). The average number of days per week that participants engaged in low-impact dance in the DG was 5.9 ± 0.8 days, which met the physical activity recommendations of the ACSM for adults. Age, BMI, body fat percentage, and waist-to-hip ratio of participants in these two groups are presented in Table 1. The participants of this study were categorized as overweight according to their BMI values (>25), and results showed no significant differences between the two groups, although the BMI values and percentages of body fat were slightly higher in the CG than in the DG. In addition, T-score results showed that those of the DG were significantly higher than those of the CG in both the dominant and nondominant leg calcanei (Table 2). According to the WHO criteria (WHO, 1994), the DG and CG had normal and osteopenic levels, respectively.

These ROMs of the knee and ankle joints of participants in these two groups are given in Table 2. For inversion of the ankle, the DG had significantly higher values than the CG for both the dominant and nondominant legs \( (p < .05) \). In addition, ankle plantarflexion and dorsiflexion in the dominant leg were significantly higher in the DG than in the CG \( (p < .05) \). On the other hand, no significant differences were found in ankle inversion of the dominant \( (p > .05) \) or nondominant leg \( (p > .05) \) or ankle plantarflexion or dorsiflexion of the nondominant leg between these two groups, although these parameters were higher in the DG than in the CG.

Table 2 also shows the knee extension torque of the dominant and nondominant legs in the DG and CG. Although this variable in the dominant \( (DG: 57.9 ± 20.6 \text{ N m vs. CG: } 43.3 ± 13.9 \text{ N m, } p = .053) \) and nondominant legs \( (DG: 57.2 ± 22.2 \text{ N m vs. } 40.3 ± 16.5 \text{ N m, } p < .05) \) was higher in the DG than in the CG, a significant difference was found only in the nondominant leg between these two groups.

Discussion
Previous studies of aerobic dance indicated that both low- and high-impact aerobic dancing was beneficial to cardiorespiratory fitness in overweight women (Dowdy et al., 1985; Shimamoto et al., 1998). However, data on the torque and ROM of lower extremity joints from low-impact dance are scarce. Compared with physically inactive women, the results of the current study support the argument that...
low-impact dance has a positive influence on the parameters studied.

**HR and RPE**

The ACSM recommends that adults should engage in a moderate-intensity physical activity for at least 5 days or a vigorous-intensity activity for 3 days per week (Haskell et al., 2007). In older individuals, a higher exercise intensity poses a potential injury risk for muscles, bones, and soft tissues, although it enhances cardiorespiratory fitness. An appropriate exercise intensity should also be carefully considered for individuals who are overweight or who seldom engage in physical activities before they begin any physical activity or exercise. In addition, the ACSM (1998) recommends that a light-to-moderate exercise intensity is beneficial for the age-associated deterioration of numerous physiological functions. The literature relating to low-impact dance, however, has not provided the reference for the intensity of low-impact dance in the past. In the current study, the intensity of low-impact aerobic dance was moderate according to the HR (108.0 ± 8.5 beats/minute) and RPE (11.0 ± 0.9). As a result, exercise intensity in low-impact aerobic dance can be regarded as appropriate for older people.

**ROM**

Several studies have indicated that the ROMs of the ankle and knee joints of women and men decrease with age (James, & Parker, 1989; Sepic, Murray, Mollinger, Spurr, & Gardner, 1986) and that the ROMs of these joints in women declined more obviously and faster than those of men (Vandervoort et al., 1992). These negative developments (of reduced ROMs of the ankle and knee joints) are likely to increase the chances of losing one’s balance and lead to falls (Mecagni, Smith, Roberts, & O’Sullivan, 2000; Vandervoort, Hill, Sandrin, & Vyse, 1990). Several studies reported that the intervention of a battery of physical activities or exercises improved the ROMs of the ankle and knee joints, and these positive changes could contribute to reduced fall incidents (Cao, Maeda, Shima, Kurata, & Nishizono, 2007; Katzman, Sellmeyer, Stewart, Wanek, & Hamel, 2007). In the current study, in addition to a few ROMs of joints in the nondominant leg of the DG tending to be higher when compared with those of the CG, most ROMs of joints in the dominant leg, ankle inversion, plantarflexion, and dorsiflexion were significantly higher in the DG than in the CG. These results were in agreement with the study by Cao et al. (2007), which supported the positive influence from exercise on ROMs of lower extremity joints. We inferred that diverse dance steps such as side steps; walking forward and backward; circling; leg lifts; tiptoeing forward, sideward, and backward; and heel rises were frequently executed with the fixed dominant leg. This bias of utilization is likely the reason for the difference between the two groups. On the other hand, although a few movements, such as knee bends and squats, seemed useful for the ROM of these joints, no significant difference was found in the ROMs of knees between the DG and CG. It is difficult for us to speculate on the reason for this. Accordingly, further studies should explore possible reasons for this apparent anomaly. The ability of maintaining a low-impact dance regimen to sustain a certain level of ROM of lower extremity joints from low-impact dance, especially of the dominant leg, is a novel finding of this study. Studies with older persons reported that maintenance or improvement of the ROM of the lower extremity with exercise can boost performance of activities of daily living (Alexander, Gross, Medell, & Hofmeyer, 2001; Stanziano, Roos, Perry, Lai, & Signorile, 2009). Low-impact dancers have this beneficial feature because the ROMs of their lower limbs are typically superior than those of physically inactive individuals.

### Table 2.

<table>
<thead>
<tr>
<th>Item</th>
<th>Dance Group M SD</th>
<th>Control Group M SD</th>
<th>t</th>
<th>p</th>
<th>Dance Group M SD</th>
<th>Control Group M SD</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee extension</td>
<td>122.5 6.0</td>
<td>119.8 19.9</td>
<td>0.8</td>
<td>.43</td>
<td>125.0 6.0</td>
<td>121.8 6.2</td>
<td>1.1</td>
<td>.76</td>
</tr>
<tr>
<td>Knee flexion</td>
<td>-2.0 1.1</td>
<td>-1.6 1.7</td>
<td>0.3</td>
<td>.24</td>
<td>-2.1 1.5</td>
<td>-1.7 1.5</td>
<td>0.3</td>
<td>.63</td>
</tr>
<tr>
<td>Ankle inversion</td>
<td>17.2 4.9</td>
<td>8.3 4.6</td>
<td>5.0</td>
<td>&lt;.01*</td>
<td>15.7 3.9</td>
<td>8.6 2.6</td>
<td>5.4</td>
<td>&lt;.01*</td>
</tr>
<tr>
<td>Ankle eversion</td>
<td>12.9 5.0</td>
<td>11.7 4.8</td>
<td>1.5</td>
<td>.89</td>
<td>13.6 4.0</td>
<td>11.6 2.7</td>
<td>1.8</td>
<td>.25</td>
</tr>
<tr>
<td>Ankle plantarflexion</td>
<td>37.6 5.6</td>
<td>33.2 5.2</td>
<td>2.2</td>
<td>.04*</td>
<td>35.1 4.4</td>
<td>34.8 7.4</td>
<td>1.1</td>
<td>.81</td>
</tr>
<tr>
<td>Ankle dorsiflexion</td>
<td>18.3 5.0</td>
<td>14.0 5.7</td>
<td>2.2</td>
<td>.03*</td>
<td>17.1 5.0</td>
<td>15.1 4.3</td>
<td>0.1</td>
<td>.52</td>
</tr>
<tr>
<td>T-score</td>
<td>-0.9 1.7</td>
<td>-1.8 0.7</td>
<td>2.1</td>
<td>.01*</td>
<td>-0.8 2.0</td>
<td>-2.0 0.7</td>
<td>2.6</td>
<td>.04*</td>
</tr>
<tr>
<td>Torque (Newton meter)</td>
<td>57.9 20.6</td>
<td>43.3 13.9</td>
<td>1.8</td>
<td>.053</td>
<td>57.2 22.2</td>
<td>40.3 16.5</td>
<td>2.5</td>
<td>&lt;.05*</td>
</tr>
</tbody>
</table>

Note. Range of motion of joints is presented in degrees. *p < .05.

Vandervoort, Hill, Sandrin, & Vyse, 1990). Several studies reported that the intervention of a battery of physical activities or exercises improved the ROMs of the ankle and knee joints, and these positive changes could contribute to reduced fall incidents (Cao, Maeda, Shima, Kurata, & Nishizono, 2007; Katzman, Sellmeyer, Stewart, Wanek, & Hamel, 2007). In the current study, in addition to a few ROMs of joints in the nondominant leg of the DG tending to be higher when compared with those of the CG, most ROMs of joints in the dominant leg, ankle inversion, plantarflexion, and dorsiflexion were significantly higher in the DG than in the CG. These results were in agreement with the study by Cao et al. (2007), which supported the positive influence from exercise on ROMs of lower extremity joints. We inferred that diverse dance steps such as side steps; walking forward and backward; circling; leg lifts; tiptoeing forward, sideward, and backward; and heel rises were frequently executed with the fixed dominant leg. This bias of utilization is likely the reason for the difference between the two groups. On the other hand, although a few movements, such as knee bends and squats, seemed useful for the ROM of these joints, no significant difference was found in the ROMs of knees between the DG and CG. It is difficult for us to speculate on the reason for this. Accordingly, further studies should explore possible reasons for this apparent anomaly. The ability of maintaining a low-impact dance regimen to sustain a certain level of ROM of lower extremity joints from low-impact dance, especially of the dominant leg, is a novel finding of this study. Studies with older persons reported that maintenance or improvement of the ROM of the lower extremity with exercise can boost performance of activities of daily living (Alexander, Gross, Medell, & Hofmeyer, 2001; Stanziano, Roos, Perry, Lai, & Signorile, 2009). Low-impact dancers have this beneficial feature because the ROMs of their lower limbs are typically superior than those of physically inactive individuals.


**Torque**

Longitudinal and cross-sectional studies have reported that maintenance or intervention using physical activities or exercise to enhance muscular strength in older individuals (Chandler, Duncan, Kochersberger, & Studenski, 1998; Hortobágyi, Tunnel, Moody, Beam, & DeVita, 2001) and even lower-intensity exercises such as walking, cycling, and tai chi (Macaluso, Young, Gibb, Rowe, & De Vito, 2003; Melzer, Benjuya, & Kaplan, 2003; Qin et al., 2005) is effective in improving muscular strength. In addition, interventions with the aforementioned physical activities have significant advantages and improvements for individuals with knee osteoarthritis (Mangione et al., 1999). In this study, the nondominant leg knee extension torque in the DG was significantly higher than in the CG. Moreover, the dominant leg knee torque tended to be higher in the DG than in the CG, although statistical significance was not reached ($p = .053$). We know that low-impact dance practitioners performed their dance steps with frequent contact with the ground. These repetitive movements reinforce muscle groups of the lower extremities through ground contact impacts and increased muscle contractions. We suggest this model in the low-impact dance as a possible reason for the significant nondominant leg difference between the DG and CG. In fact, the above-mentioned stimulations resemble weight-bearing exercises in several studies (Bravo et al., 1996; Kukuljan, Nowson, Sanders, & Daly, 2009), which support the beneficial effects of impact from exercise on muscles.

One study (Knapik, Bauman, Jones, Harris, & Vaughan, 1991) indicated that imbalanced torque in the lower limbs or an overdependence on the dominant limb may lead to weakness in nondominant limb muscle groups. Studies also indicated that fallers tended to be weaker with less symmetrical muscular strength in the legs and between legs than nonfallers (Perry, Carville, Smith, Rutherford, & Newham, 2007; Skelton, Kennedy, & Rutherford, 2002). On the other hand, the previous literature (Engels, Drouin, Zhu, & Kazmierski, 1998; Hopkins, Murrah, Hoeger, & Rhodes, 1990) reported that low-impact dance benefited balance and muscular strength in the lower extremities. We concluded from a review of the literature that symmetric torque between legs with more powerful muscular strength helps decrease fall incidents. Although the results relating to the current study supported higher torque in the lower extremities in those who engaged in low-impact dance, unfortunately, the symmetry, that is, the difference between the dominant and nondominant legs relative to the dominant leg between these two groups, did not significantly differ (data not shown). Subsequently, further studies on the influence of low-impact dance on the symmetry of torque and muscular strength between legs are warranted in the near future, because stronger muscular strength and more equal torque between legs can decrease fall incidents.

One of the traits in low-impact dance is not allowing both legs to leave the ground simultaneously. Tai chi, a tradition martial art, also has this characteristic in addition to slow movements with stabilized lower extremities. Tai chi is a low-impact exercise (Cheng, 1999). Several studies (Li, Xu, & Hong, 2009; Xu, Li, & Hong, 2006) have indicated that tai chi has a significant influence on muscular strength and balance in older individuals. Maintaining stable torque or muscular strength is one of the important factors for daily life function in older persons. Because some of the features of low-impact dance were similar to those of tai chi from our primary observation and surmise, research on similarities and differences between low-impact dance and tai chi is warranted.

**Limitations**

One of the aims of interventions of physical activity and exercise in older people is to investigate BMD changes between pre- and postintervention. This study provided such information and referred to WHO standards. Results indicated that BMDs in both dominant and nondominant legs are significantly higher in the DG than in the CG. Participants in the DG and CG were categorized as normal and osteopenia, respectively. The reason for this difference is that low-impact dance is similar to weight-bearing exercises (Coupland et al., 1999; Feskanich, Willett, & Colditz, 2002), which help individuals with similar exercise-attenuating declines in BMD and increases in bone fracture risks. However, we avoided drawing conclusions on the effects of low-impact dance on whole-body BMD because this study only provided BMD data for the calcaneus, which is extensively used in low-impact dance. This is a limitation of this study. We suggest that whole-body BMD measurements such as dual-energy X-ray absorptiometry scans be considered for future research. Because the present research was a cross study of comparisons between low-impact dancers and physically inactive individuals, interpretation of these results with regards to cause–effect should be done only with great care. This is also another limitation of this study.

**Conclusion**

Parameters examined in this study, including torque and lower extremity ROM, were stronger in regular low-impact dancers than in those who were physically inactive. In addition, as far as exercise loading and exertion are concerned, low-impact dance is appropriate for the middle-aged and older individuals. However, we cannot infer causality from the aforementioned results, because this study was not designed as an intervention study. However, these promising findings should encourage future studies to investigate the association between low-impact dance and fall cases.

**References**


低衝擊舞蹈對中老年女性從事者的膝關節力矩與下肢活動度的影響

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背景 雖然低衝擊舞蹈是晨間運動常見項目之一，然而並不瞭解長期從事這項運動，對中老年婦女的下肢關節活動度與膝關節力矩的影響。

目的 比較中老年婦女長期從事低衝擊舞蹈者與無規律身體活動者的下肢關節活動度與膝關節力矩的差異。

方法 26位長期從事低衝擊舞蹈的婦女與12位無規律身體活動習慣（控制組）的婦女，進行身體組成、膝關節力矩、踝關節與膝關節之關節活動度及跟骨超音波骨質密度測量。

結果 在低衝擊舞蹈組慣用腳的踝關節內翻、屈靭、屈足背的活動度皆顯著高於控制組（p < .05）；再者，低衝擊舞蹈組非慣用腳的踝關節內翻也顯著高於控制組（p < .05）。低衝擊舞蹈組非慣用腳的膝關節伸直力矩顯著高於控制組（p < .05）。

結論 雖然本研究不是介入型的研究，但藉由與無規律身體活動習慣者相比較，低衝擊舞蹈有助於維持較高的下肢關節活動度與膝關節力矩。這些正面特點，在未來將有助於低衝擊舞蹈介入對降低跌倒風險因子的相關研究。

關鍵詞：低衝擊舞蹈、關節活動度、膝關節力矩。