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TITLE PAGE

Postural stability of older female Scottish country dancers in comparison to physically active controls.

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1 Abstract

2 Physical activity assists older individuals' functional ability and postural stability. Recently,
3 Scottish country dance (SCD) was reported as being a beneficial form of physical activity for
4 functional ability in older females. This study aims to examine the effect of SCD on postural
5 stability. Scottish country dancers ($n=20$) were compared to physically active controls ($n=33$) for
6 static postural sway measured on a force platform. The Romberg and Tandem stances were used,
7 under 'eyes open' and 'eyes closed' conditions. 95% ellipse area and sway velocity were
8 calculated from the center of pressure displacement. 95% ellipse area was the same for both
9 groups in all tests. The control group had greater sway velocity for all tests ($p<0.01$) except
10 Tandem eyes closed. SCD participation resulted in similar postural sway as participation in other
11 physical activities, however non-dancers may need a greater amount of regulatory activity to
12 maintain balance.

13 *Keywords:* aging, balance in elderly, dance, functional ability

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1 Postural stability of older female Scottish country dancers in comparison to physically active
2 controls.

3 **Introduction**

4 Recent reports and initiatives have highlighted the importance of physical activity in
5 older adults, not only for the prevention of disease, but more specifically on postural stability, in
6 a bid to reduce the incidence of falls in this population (American College of Sports Medicine et
7 al., 2009; Howe, Rochester, Neil, Skelton, & Ballinger, 2011). Physically active older
8 participants have been shown to have better static and dynamic postural control than sedentary
9 age-matched individuals (Bulbulian & Hargan, 2000; Perrin, Gauchard, Perrot, & Jeandel, 1999).
10 Indeed, various intervention studies including specific balance training (Clemson et al., 2010),
11 strength training (Henwood & Taaffe, 2006), walking (Brooke-Wavell, Athersmith, Jones, &
12 Masud, 1998), vibration platform training (Cheung et al., 2007), square stepping (Shigematsu et
13 al., 2002), and Tai Chi (Taylor-Piliae et al., 2010) have all been found to improve static postural
14 stability in healthy older adults. Notwithstanding the success of these interventions, the most
15 recent Cochrane review on exercise for improving postural stability in older people highlighted
16 the need to examine further the effects of different forms of physical activity on postural stability
17 in an attempt to strengthen the currently weak evidence (Howe et al., 2011).

18 Group exercise is one of the most popular physical activities among middle-aged and
19 older adults (Hunt, Ford, & and Mutrie, 2001). In particular, social dancing is an activity that is
20 practiced by middle-aged and older adults all over the world. The cultural resonance and social
21 benefits that come with group dance make this an appealing activity for the older age group
22 (Cooper & Thomas, 2002; Lima & Vieira, 2007; Wikstrom, 2004). Varying forms of dance
23 interventions including Traditional Greek, Caribbean, Argentinian tango, Traditional Korean,

1 Turkish Forlore and aerobic dance have shown to benefit both static and dynamic postural
2 stability in older participants (Eyigor, Karapolat, Durmaz, Ibisoglu, & Cakir, 2009; Federici,
3 Bellagamba, & Rocchi, 2005; Hackney, Kantorovich, & Earhart, 2007; Hopkins, Murrah,
4 Hoeger, & Rhodes, 1990; Jeon, Choe, M,A, & Chae, 2000; Sofianidis, Hatzitaki, Douka, &
5 Grouios, 2009). Less research is available on habituated older exercisers, however it has been
6 reported that habituated older folk dancers and gymnasts have better dynamic postural stability
7 than aged matched controls (Uusi-Rasi et al., 1999) likely due to the stresses placed on the
8 neuromotor system.

9 Scottish country dance is a hugely popular activity in older individuals, not only in
10 Scotland, but also in North America, Australia and New Zealand. Scottish country dance, like
11 other traditional dance forms such as square dancing and folk dancing, articulates choreographed
12 multidirectional movements incorporating many elements of neuromuscular control. It consists
13 of a number of set dances in pairs and groups, with varying degrees of intensity. Participants
14 perform various vertical and lateral movements, turning and spinning around in different
15 directions to the rhythms of both slow and faster tempos, therefore continuously altering and
16 stressing their postural stability.

17 Scottish country dance has recently been shown to be beneficial to functional ability of
18 older individuals (Dewhurst, Nelson, Dougall, & Bampouras, in press). The aim of the present
19 study was to compare the postural stability in Scottish country dancers and age-matched
20 physically active controls. It is hypothesized that due to the challenging postural demands of
21 Scottish country dance, the dance group will show better postural stability than the age-matched
22 physically active group, while preventing an increased reliance on the visual system which is
23 normally reported in older adults (Choy, Brauer, & Nitz, 2003; Dewhurst, Riches, & De Vito,

1 2007). Women are the focus of the present study as it has been reported that women tend to fall
2 more often (Schultz, Ashton-Miller, & Alexander, 1997) and have twice the rate of hip fracture
3 than men (Kannus et al., 1999).

4 **Methods**

5 **Participants**

6 Fifty three healthy older females participated in the study after providing written
7 informed consent. The sample consisted of Scottish country dancers ($n = 20$, age 67.9 ± 5.9
8 (range 60 - 79) years, , body mass 67.2 ± 9.1 kg, stature 1.61 ± 0.06 m) and controls ($n = 33$,
9 age 71.1 ± 5.7 (range 62 - 79) years, body mass 65.0 ± 10.6 kg, stature 1.57 ± 0.07 m).
10 Participants had no known neuromuscular disorders and had to be considered as medically
11 stable, according to the criteria described by Greig et al (1994). All participants were physically
12 active, engaging in some form of physical activity at least three times a week. The dancers had a
13 minimum of 10 years participatory involvement in Scottish country dancing. Ethical approval
14 was obtained from the University of Strathclyde and all procedures followed were in accordance
15 with the Helsinki Declaration of 1975.

16 **Physical activity assessment**

17 Current levels of physical activity were measured using the Rapid Assessment of
18 Physical Activity (RAPA) scale which is an easy-to-use, valid measure of physical activity for
19 use with older adults (Topolski et al., 2006). This scale consists of 9 tick box responses relating
20 to level and intensity of usual physical activity, as well as additional strength and flexibility
21 activities. RAPA 1 measures cardio-respiratory based physical activity (scoring 1-7 points, with
22 a maximum score of 7), RAPA 2a and 2b measures strength- and flexibility-based physical
23 activity, respectively (yes/ no answer).

1 **Static postural stability assessment**

2 Participants performed the Romberg (standing feet together with arms resting by the side
3 of the body) and the Tandem (feet are aligned heel to toe with the dominant foot at the back)
4 tests standing barefoot and centrally aligned on a force platform (AMTI OR6-6; Advanced
5 Mechanical Technology, Inc., Watertown, Massachusetts). Trials were performed under two
6 visual conditions, eyes open (EO) and eyes closed (EC), administered in a randomised order, and
7 each position was maintained for 35 s with the first 5 s discarded. Two minutes rest was given
8 between trials. If participants lost their balance during a trial, they were allowed to repeat. A
9 successful trial was one in which the subject did not move her feet or, in the case of the EC trials,
10 open their eyes while standing on the platform during the assessment period. A maximum of
11 three attempts were given per trial. During the EO trials, subjects had to focus on a visual target
12 placed two meters in front of the subjects at eye level; participants were allowed to wear
13 spectacles, if required.

14 Data were obtained from the force platform with a sampling frequency of 100 Hz
15 (NetForce, Advanced Mechanical Technology, Inc., Watertown, Massachusetts) and centre of
16 pressure (CoP) based time domain parameters were calculated (BioAnalysis, Advanced
17 Mechanical Technology, Inc., Watertown, Massachusetts). 95% ellipse area (sway area)
18 indicates the amount of CoP movement and is a method used to estimate the confidence area of
19 the CoP path where approximately 95% of the points on the COP path are enclosed in. Sway
20 velocity indicates the speed at which CoP adjustments are made. Both measurements have been
21 used extensively to assess postural balance in older individuals (Brooke-Wavell et al., 1998;
22 Dewhurst et al., 2007; Prieto, Myklebust, Hoffmann, Lovett, & Myklebust, 1996). Finally, in
23 order to assess the influence of vision on the CoP parameters, the Romberg quotient and Tandem

1 quotient were calculated as the ratio of the eyes closed value to the eyes open value for the sway
2 area.

3 **Statistical analysis**

4 Current levels of physical activity, strength and flexibility exercise participation scores
5 taken from the RAPA scale were analysed using chi-square. Normality of data of the CoP
6 parameters was examined using the Kolmogorov-Smirnov test. As normality was not confirmed
7 for all variables, non-parametric tests were utilized for the analysis. Subsequently, Spearman's
8 correlation was used to examine for relationships between age and sway area or sway velocity
9 and the Mann-Whitney U test was used to examine for differences between dancers and controls.
10 When differences between dancers and controls were revealed, non-parametric effect sizes (ES)
11 were calculated with 0.1 denoting a small effect, 0.3 a medium effect and 0.5 a large effect
12 (Grissom and Kim, 2011). Significance was set at 0.05. For all statistical analyses, IBM SPSS v
13 19.0 (SPSS, Chicago, ILL) was used.

14 **Results**

15 **Physical activity assessment**

16 The quantification of physical activity showed the median score for the cardio-respiratory
17 based physical activity for both groups being 6 on the RAPA scale: "I do 30 minutes or more a
18 day of moderate physical activities, 5 or more days a week". The two groups were not
19 significantly different in participating in strength training ($\chi^2 < 0.05$, 15% for both groups) but
20 the controls participated in flexibility training more than the dancers ($\chi^2 < 0.05$, 61% and 43%,
21 respectively).

22 **Static stability postural assessment**

1 Completion rates per group for each test can be found in Table 1. The age of the groups
2 was not significantly different ($U = 229, p = 0.63$). No significant correlation was found for age
3 with Romberg EC and Tandem EC sway area. Further no significant correlation was found for
4 age with Tandem EO sway velocity. Finally, although significant correlations were found for age
5 with Romberg EO and Tandem EO sway area as well as Romberg EO, Romberg EC and
6 Tandem EC sway velocity they were all low (Spearman's ρ range: 0.317 – 0.392).

7 Sway area was the same for dancers and controls in all of the postural assessments
8 (Figure 1A and B). Sway velocity was greater in controls than dancers in the Romberg EO ($U =$
9 $63, p = 0.001, ES = 0.11$), Romberg EC ($U = 113, p = 0.001, ES = 0.21$) and Tandem EO ($U =$
10 $146, p = 0.003, ES = 0.25$) but not Tandem EC. Finally, neither Romberg quotient nor Tandem
11 quotient were affected by the participation in dance (Figure 2).

12

13 INSERT FIGURE 1 HERE

14 INSERT FIGURE 2 HERE

15

Discussion

16 The main finding of the present study was that although Scottish country dancers have
17 similar sway area to physically active age-matched controls, an increased amount of regulatory
18 activity may have been needed to maintain it compared to their physically active counterparts, as
19 suggested by the difference in sway velocity.

20 Scottish country dance involves a combination of proprioceptively challenging moves
21 including unipedal stance and hopping, while maintaining a straight posture with a constant
22 shifting of the center of gravity. Additionally, the vestibular system is challenged during dances
23 as multiple spinning actions are involved. Both the proprioceptive and vestibular systems are

1 responsible for maintaining an upright posture (Dewhurst et al., 2007). It was hypothesized that
2 the stimulation provided by Scottish country dance to the sensory systems and consequently the
3 motor control systems will result in better postural stability when compared to non-dance
4 physical activity participation. While no additional benefits of participation in Scottish country
5 dance were shown for sway area when compared to physically active controls, it appears that
6 mechanisms to achieving this sway area differ between the groups.

7 Sway velocity is related to the amount of activity needed in order to maintain a given
8 level of postural stability (Prieto et al., 1996) and it is an important factor in maintaining postural
9 control in quiet standing (Masani, Popovic, Nakazawa, Kouzaki, & Nozaki, 2003). Increased
10 sway velocity has been linked with reduced balance ability in older individuals (Brooke-Wavell
11 et al., 1998; Dewhurst et al., 2007; Prieto et al., 1996) and increased incidence of falls (Ferne,
12 Gryfe, Holliday, & Llewellyn, 1982). The greater sway velocity of the control group in
13 comparison to the dancers may suggest that more regulatory activity was needed to achieve the
14 same level of sway area, suggesting poorer postural control.

15 The maintenance of a quiet upright stance involves a complex integration of the sensory
16 systems (somatosensory, visual and vestibular), the motor system and a central integrating
17 control system (Horak & MacPherson, 1996). The lower sway velocity in the dancers could be a
18 consequence of a more sensitive sensory input and/or a superior motor response system. As
19 mentioned previously, the vestibular and proprioceptive senses would be continually stressed
20 during the Scottish country dance routines; this in turn may have delayed or reduced the age
21 associated decline in the sensitivity of the mechanoreceptors within the vestibular apparatus and
22 proprioceptors within the joints, tendons and muscles to a greater extent than less dynamic
23 physical activities. In addition, Scottish country dance has been shown to benefit functional

1 motor tasks such as walking speed and 8 foot up and go (Dewhurst et al. in press). This
2 beneficial effect on the motor system may translate to a better regulative motor response. As
3 regular physical activity in older individuals has been found to develop or maintain the efficiency
4 of the reflexes involved in postural control (Gauchard, Gangloff, Jeandel, & Perrin 2003), we
5 propose that it is possible that the nature of Scottish country dance further develops or maintains
6 these reflexes.

7 The ratio between eyes closed to eyes open sway area assesses reliance on the visual
8 system, with an increased ratio suggesting larger reliance on vision (Choy et al., 2003; Dewhurst
9 et al., 2007). When comparing physically active older individuals to sedentary controls, Perrin et
10 al (1999) reported that active individuals relied less on vision during both static and dynamic
11 postural stability tasks. Further, dance has been shown to strengthen the accuracy of
12 proprioceptive inputs and shift sensorimotor dominance from vision to proprioception during a
13 dynamic postural task (Golomer, Cremieux, Dupui, Isableu, & Ohlmann, 1999) however, in the
14 present study the eyes open to eyes closed ratio did not differ between the groups for either the
15 Romberg or the Tandem tests.

16 The lack of a strong relationship between age and postural stability measures reported
17 here may appear contradictory to literature, as static postural stability has been extensively
18 reported to reduce with increased age (e.g. Browne, O'Hare, Finn, & Colin, 2002; Dewhurst et
19 al., 2007; Prieto et al., 1996;). However, although studies have used older subjects of similar
20 characteristics to the present study, the comparisons made are with young counterparts, rather
21 than within the older individuals' age range. This only provides a limited picture as to how
22 balance degrades over years. Baloh et al (1998) reported that in a 3-year follow up of 79-91 year
23 olds, dynamic sway velocity increased annually. However, the age of the participants is outside

1 the age range used in the present study. A comparison of balance in 60-70 and 70-80 year old
2 participants showed a trend for decreased balance with increasing age (Steffen, Hacker, &
3 Mollinger, 2002), however this contradicted a previous study which, similar to our findings,
4 reported little relationship of age to balance (Bogle Thorbahn & Newton, 1996). Given the
5 importance of balance in this specific population, we concur with the call by Steffen et al (2002)
6 for more work in the area with appropriate sample sizes that will allow norms to be established.

7 Static postural stability has been extensively used as a measure of balance in older
8 individuals (Amiridis, Arabatzi, Violaris, Stavropoulos & Hatzitaki, 2005; Dewhurst et al., 2007;
9 Prieto et al., 1996). However, dynamic postural assessment has also been shown to be a sensitive
10 measure in detecting the effect of aging on postural stability (Baloh, Fife, Zwerling, Socotch,
11 Jacobson et al., 1994). Given the dynamic nature of Scottish country dance, dynamic postural
12 assessment may have been more suited to detecting differences between Scottish country dancers
13 and other physically active individuals. Dynamic postural control should be assessed in future
14 works along with fall frequency in dancers compared to other physically active individuals.

15 Bulbulian and Hargan (2000) and Perrin et al. (1999) highlighted the importance of
16 physical activity for postural stability, reporting that physically active older individuals had
17 better postural stability than inactive controls, with suggestions of a dose response both with the
18 length of engagement in physical activity (Bulbulian & Hargan, 2000; Perrin et al., 1999) as well
19 as the quantity of physical activity (Brooke-Wavell et al., 1998). The present study posits that it
20 is possible to maintain postural stability in older adults not only through general physical activity
21 but also through more specific activities such as Scottish country dance.

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1 **Table legend**

2 Table 1. Completion rates (in percentages) per group for each static postural assessment. EO,
3 eyes open; EC, eyes closed.

4

1 Table

2

	Sway area				Sway velocity			
	Romberg	Romberg	Tandem	Tandem	Romberg	Romberg	Tandem	Tandem
	EO	EC	EO	EC	EO	EC	EO	EC
Controls	94	97	94	82	91	97	94	76
Dancers	95	100	90	70	95	85	95	70

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1 **Figure Legends**

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3 Figure 1. Posturography parameters during the Romberg and Tandem assessment: 95% Ellipse
4 Area Romberg (A), 95% Ellipse Area Tandem (B), Sway Velocity Romberg (C), Sway Velocity
5 Tandem (D) for the eyes open (Romberg (REO) and Tandem (TEO)) and eyes closed (Romberg
6 (REC) and Tandem (TEC)) trials. Both dancers (open bars) and control groups (filled bars) are
7 shown.

8 * denotes significant difference between the dancers and control groups ($p < 0.01$). Data are
9 presented as mean \pm standard error.

10

11 Figure 2. 95% Ellipse Area Quotient (eyes closed/ eyes open). Romberg quotient (RQ) and
12 Tandem quotient (TQ) are displayed for the dancers (open bars) and control groups (filled bars).
13 Data are presented as mean \pm standard error.

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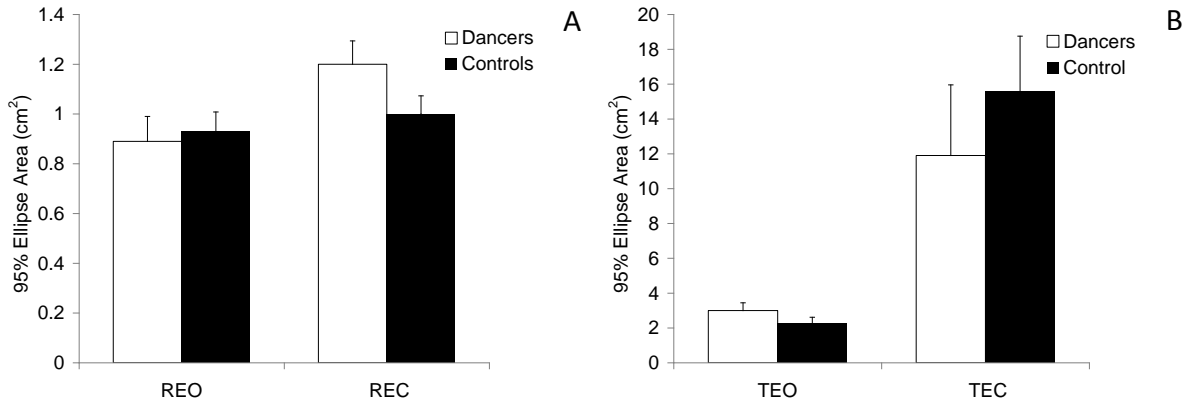
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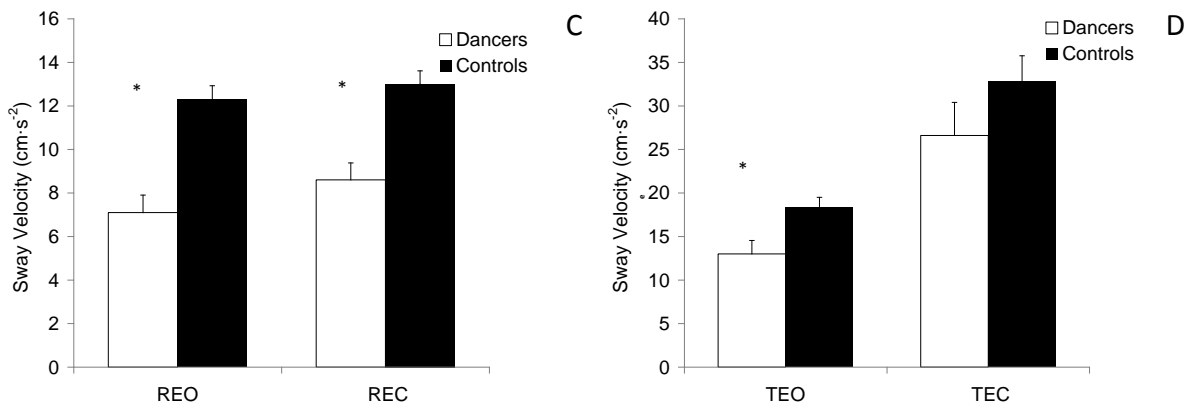
Figures

2 Figure 1.

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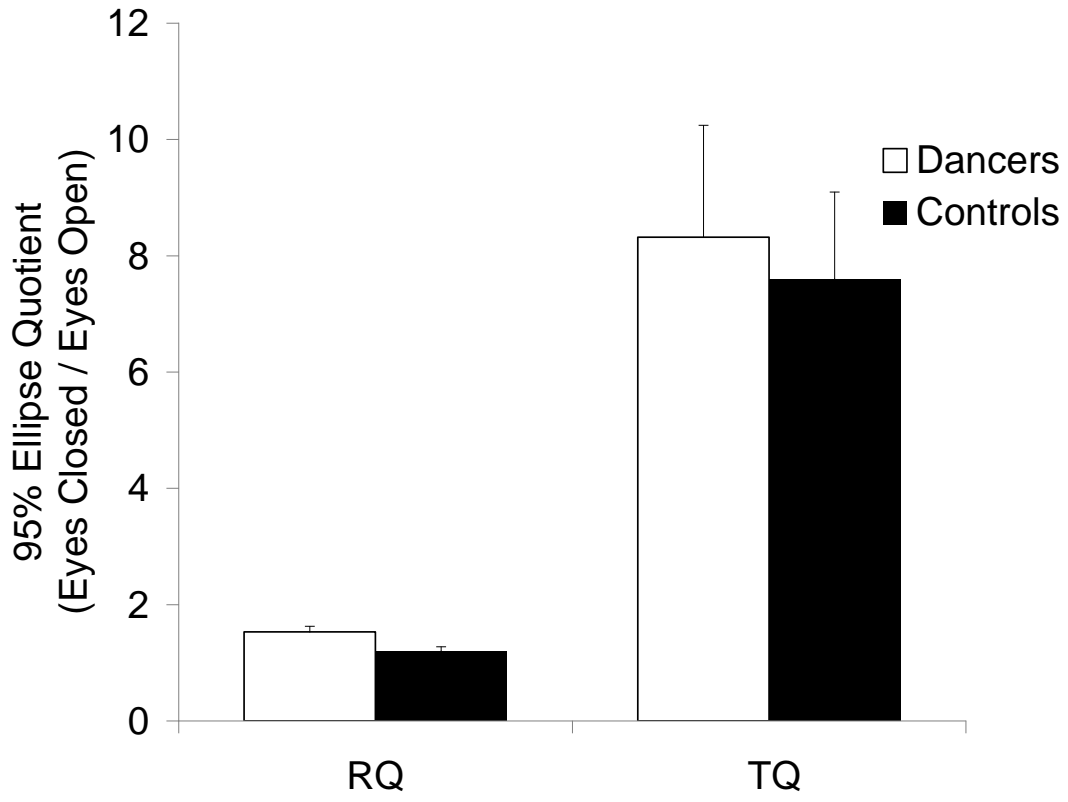
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1 Figure 2



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