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*Original Research*

# Improvements in Postural Stability, Dynamic Balance, and Strength Following 12 Weeks of Online Ballet-Modern Dance Classes for Older Women

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ABSTRACT

***International Journal of Exercise Science 17(1): 682-701, 2024.*** Falls are the leading cause of injury-related deaths among older adults and affect women at disproportionate rates. Dance has been used to improve postural stability, balance confidence and strength of older adults, but in-person classes are often inaccessible. This quasi-experimental pre-mid-post design study investigates whether 12 weeks of online dance classes can improve postural stability, dynamic balance and strength of women aged 65 plus. 16 participants (median=74 years, IQR=6) recruited via convenience sampling completed 12 weeks of twice weekly 75-minute online dance classes. In-person pre, mid and post assessments used 30-second trials of quiet standing, Star Excursion Balance Test, 30-second Sit-to-Stand and Calf-Raise-Senior. Significance was evaluated using Friedman's test with Wilcoxon Signed-Rank test post-hoc ($p \leq .05$). Participants demonstrated a high attendance rate (median=87.5, IQR=4.2%). Decreased mediolateral sway was observed pre-mid in eyes closed ($p$=.003, r=.76) and foam ($p$=.02, r=.60) conditions, where the latter also produced decreased sway area ($p$=.015, r=.63). Greater dynamic balance was demonstrated when reaching laterally (pre-mid $p$=.008, r=.68; pre-post $p$=.008, r=.69) and posterior-laterally (pre-post $p$=.009, r=.75). Participants significantly improved their number of repetitions on the Calf-Raise Senior (mid-post $p$=.02, r=.60; pre-post $p$=.015, r=.63). Online dance classes are engaging, accessible and effective in decreasing older women's risk of falls and maintaining their independence.

KEY WORDS: Dance-based exercise, aging, fall prevention, tele-health

## INTRODUCTION

Falls among older adults are a leading cause of injury, loss of independence and mortality as approximately 30% experience falls each year (52). Furthermore, these incidents cause 95% of hip fractures, leading to fatality among 20% of cases (35). Globally the average cost of these injuries is estimated to be $26,483 USD per hospitalized faller (13).

Women are disproportionately affected by falls across all age-groups (14) and comprise 70.5% of all subsequent emergency visits (41). This elevated incidence likely reflects differences in

physical activity levels, muscular strength and bone mass density - all essential components of postural stability (7,14,41).
Beginning at age 40, women undergo a significant loss of relative leg extensor power at a rate of 1.5% per year, worsening to 1.8% as of 75 years old (1). This may also be due to reductions in Type I and, particularly, Type II muscle fibers when compared to non-falling age-matched individuals (23). This age-related atrophy may interfere with the ability to correct body positioning in response to environmental hazards to avoid falls. While remaining physically active in older age helps preserve muscle strength, muscle mass and bone strength (19), only 3.8% of women aged 60-79 years old accumulate at least 30 minutes of physical activity per day (10). As the number of older women is projected to double by 2050 to 832 million (47), the World Health Organization has highlighted the urgent need for fall prevention programs (53).

Optimal forms of balance training require high precision of movement, which may be found while learning dance steps (46). Dance is an increasingly popular form of exercise and balance training for older adults as its fun, engaging and social environment offers opportunities for creative expression (39). High attendance (84.3%) to dance interventions targeted at improving postural stability has been observed primarily among women, likely due to gendered stereotypes regarding dance (5). Previous studies using traditional, folkloric, ballroom, and contemporary dance have observed improvements in postural stability after as little as two hours of class per week for 10 weeks among adults older than 50 (16,17,30,39,54). Decreases in postural excursions have clinical relevance as Stel and colleagues (40) found in 1 year follow-up, older adults who experienced recurrent falls displayed greater mediolateral excursions, presenting predictive value for risk of falling (OR=3.4, 95%CI [1.5–7.5]). This decreased risk is further reflected by increases in balance confidence following dance programs (5,30).

The improvements in postural stability from dance are linked to developments across cognitive and perceptual-motor domains (54), by enhancing: 1) attention to the surroundings, 2) rapidity and coordination in implementing corrective postural strategies and 3) strength needed for these corrections. As participants must coordinate their movements to both the music and instructions, they demonstrate improvements in attentional control (11) and reaction time on dual task activities (54). Furthermore, dance interventions stimulate greater lower limb strength as measured by Sit-to-Stand tests (16,30) which has moderate correlation to weight adjusted leg press among older women (r=0.71) (22) and is capable of discriminating fallers vs non-fallers (37). While plantarflexor strength is additionally important in facilitating small postural corrections, there are few studies that directly evaluate the effects of dance on this among older adults.

Despite the effectiveness of dance for improving postural stability, in-person classes may be inaccessible for many: living in remote locations, lacking transport, being a caregiver at home, or being immunocompromised may all act as barriers to participation. Presently, there is limited evidence on the potential of online dance classes to improve the postural stability of older adults. To reduce fall risk during interventions, typical in-person dance programs are conducted with close monitoring and sometimes, several assistants. In an online environment, where

monitoring is limited, to ensure safety during exercise, intensity must be lowered. As intensity is an essential variable in stimulating gains, this presents the question of whether online classes would still be effective in reducing fall risk.
Online dance classes are simple to implement, low cost, accessible and consequently warrant exploration for use in fall prevention. The purpose of this study is to investigate whether 12 weeks of online dance classes reduce the risk of falls for women aged 65 years and above through evaluating postural sway, dynamic balance, lower limb strength, balance confidence and health related quality of life. It is hypothesized that following the 12 weeks, participants will demonstrate improvements on each outcome.

## METHODS

*Participants*

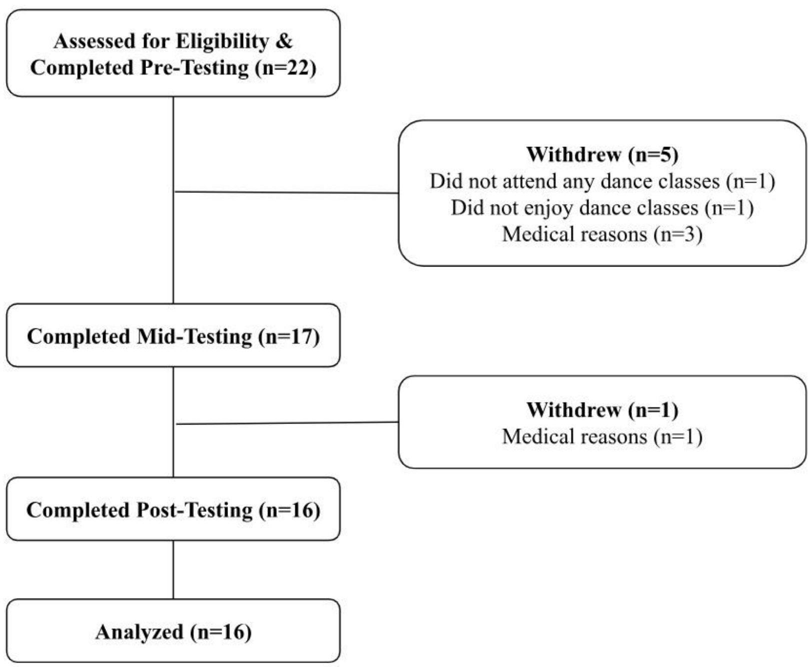


**Figure 1.** Participant flow diagram: 22 participants were recruited and completed pre-testing. Between pre and mid-testing, five participants discontinued and between mid and post-testing, another participant withdrew. Reasons for withdrawal are outlined.

This study was conducted during the COVID-19 pandemic. A power calculation was not conducted due to the convenience sampling nature of this study and a since posteriori power analysis is not recommended. Clinical relevance was additionally prioritized as there is a lack of long-term correlational data for postural stability measures among healthy and active older women. A target of 18 participants was taken from the average sample sizes of dance groups in similar in-person interventions (5,6,16,17,20,39,54). Recruitment ads for a 12-week quasi-experimental online dance study with in-person pre, mid and post-testing were sent to members of the local community using an existing participant list and through ads in local recreation centers. In total, 22 women responded, they all met eligibility criteria and were recruited. Inclusion criteria consisted of being female above the age of 65, having an understanding of

English, having access to internet and Zoom, being able to visit for three in-person testing sessions and having no contraindications to physical activity from their physician. 65 years old was selected as it is the retirement age in Canada and the age at which government organizations begin reporting fall rates among older adults. The occurrence of a stroke, vertigo, concussion or lower extremity injury during the 12-week period was used as exclusion criteria.

In total 16 women (median 74 years, IQR=6) completed the 12-week intervention, withdrawals are outlined in *Figure 1*. Baseline characteristics (age and BMI) and physical activity levels as measured by the Physical Activity Scale for the Elderly (PASE) are listed in *Table 1*. Baseline physical activity levels were measured in accordance to Washburn and colleagues (50) to aid in providing context and generalizing findings. The PASE is tailored to older adults and considers the number of hours per week participants spend doing 1) household and work activities; 2) leisure time physical activity; 3) light intensity physical activity; 4) moderate intensity physical activity; 5) vigorous intensity physical activity. After providing the number of hours, participants were asked to list the activities they were engaged in for each category (i.e. gardening, walking the dog, swimming etc.).The PASE demonstrates high internal consistency (α=.073, p-value not reported), test-retest reliability over a 3 week period (r=0.933, p-value not reported) (26) and moderate validity among adults over the age of 70 when compared to accelerometer data (r=.64, $p$<.05)(49).

**Table 1.** Median (interquartile range) of participant characteristics and PASE scores.

| | **Participant Characteristics** *Median (IQR)* |
|---|---|
| N | 16 |
| Age (years) | 74.00 (6.00) |
| BMI (kg/m$^2$) | 22.83 (1.88) |
| PASE | 140.5 (40.75) |

BMI = body mass index; PASE = Physical Activity Scale for the Elderly.

This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (31). Certification of Ethical Acceptability for Research Involving Human Subjects (ID: 30016017) was approved by the Human Research Ethics Committee at Concordia University which is guided by Tri-Counsel Policy Statements and adheres to Helsinki Declarations (1975 and 2000). Informed consent along with medical history and baseline physical activity levels were collected from participants prior to pre-testing.

*Protocol*

In-person assessments of postural stability, dynamic balance, and strength were conducted at pre (week 0), mid (week 6) and post (week 13) in the Department of Health, Kinesiology and Applied Physiology, Concordia University. At the first assessment, participants received further information on the dance sessions, the Zoom platform, expectations, and training goals; and any remaining questions were answered by the research team. Subsequent assessments were conducted with a minimum break of 24 hours following the dance classes. Each assessment followed the same order: 1) quiet standing; 2) Star Excursion Balance Test (SEBT); 3) 30 second Sit-to-Stand (30STS); 4) Calf-Raise Senior (CRS).

Dance Intervention: 75-minute group dance classes were held over Zoom (55 Almaden Blvd 6th Floor, San Jose, CA), every week on Tuesdays and Thursdays, for the 12-week semester. Each session started with a 15-minute warm-up, followed by ballet exercises (*pliés*, *tendus)*, modern-dance exercises (*Graham* and *Limón* technique), and a five-minute stretch recovery (recordings of the classes are available upon request). Movements were selected as they emphasized transfer of weight, dynamic balance while standing on one limb, bringing the body off center, fall recovery and strengthening of the lower limbs and core. The intensity of the group classes was determined by the qualified instructor who guided each movement and provided detailed explanations. Through the 12 weeks, progressions were made; for example, changing movements from double-leg to single leg stances, adding knee flexion on single-leg, going from flat feet to the balls of the feet (i.e., demi-pointe), as well as adding arm and head movements in opposite directions. To ensure safety, a helper was present to monitor each Zoom session and participants were asked to keep their webcams on. The helper was additionally tasked with tracking attendance, defined as class completion, and ensuring participants were following the class. Recordings of the class were provided to anyone who was unable to attend and their completion was noted.

Postural Stability: Two force plates (Advanced Medical Technology Inc. with the NetForce Software™, 176 Waltham Street, Watertown, MA) were used for multi-axial data acquisition sampled at 100 Hz. Participants completed 30-second trials of quiet standing under three conditions: 1) eyes open, 2) eyes closed, 3) on a two-inch-thick foam pad. Each condition was repeated three times and trials were staggered to avoid any effects due to fatigue(36).

Following instructions by Quijoux and colleagues (36), participants were asked to stand comfortably with one foot on each force plate and arms by their side. They were instructed to stay as still as possible for the duration of each 30-second trial while looking straight ahead to a point at eye-level on the wall. Measures of center of pressure (COP) excursions (cm) in anteroposterior and mediolateral directions and total sway area ($cm^2$) were collected. The selected variables show moderate to good test-retest reliability (ICC=0.65-0.98, $p<.05$) and strong criterion validity when compared to Berg Balance Scale scores of older adults ($r=-0.87$ to $-0.71$, p-values not presented)(25).

Dynamic Balance: The SEBT was selected to assess dynamic balance as it is predictive of dynamic balance deficits, is capable of identifying lower extremity injury ($p=.05$) (33), and was previously accepted for use among older adults (test-retest reliability: ICC=0.91-0.95, p-values not presented) (42).Participants were asked to stand on their non-dominant leg in the center of a star taped to the ground composed of eight lines $45^o$ apart. Without touching the floor, they were instructed to reach their dominant leg along the line as far as possible before tapping the foot to the floor on the tape, and then returning their foot to center. They then moved to the next line starting from the anterior line, moving laterally, and finishing with anterior-medial. A mark was placed on the ground where the participant touched the tape and it was measured to the nearest 0.50cm. A modification was made to allow participants to tap their toe upon returning to the center to reduce fatigue and apprehension. Two practice trials were given before the third was recorded. Additionally, a helper was present to ensure participant safety in the event of loss of balance. If they lost their balance or moved their supporting leg, the distance was not recorded.

Strength: The 30STS measured lower body strength via the number of repetitions recorded in 30 seconds. Participants were instructed to complete the tests according to methods outlined and validated by Jones and colleagues (22) who demonstrated the 30STS to have strong test-retest reliability among older women (ICC=0.92, 95%CI=0.87-0.95) and validity when correlation to maximal weight adjusted leg press (r=0.71, 95%CI=0.53-0.84). The CRS was used to evaluate plantarflexor strength as it has good criterion validity when compared to isokinetic dynamometry (r=0.86, *p*<.001) and strong reliability (test-retest reliability: ICC=0.90, *p*<.001; interrater reliability: ICC=0.93-0.96, *p*<.05)(3). The procedure as validated and described by André and colleagues (3,4) was followed and the number of complete repetitions was recorded. The minimally important difference of 3.50 repetitions determined by André and colleagues (4) was used to evaluate clinical significance. Participants completed the 30STS and CRS once per testing time point.

Health Questionnaire: Following each assessment, the 36 Item Short-Form (SF-36) by Ware and Sherbourne (48) was completed by participants to evaluate any changes in their health or quality of life. The SF-36 has high to excellent internal consistency across items (α=0.82-0.94) and has good content validity as it can discriminate older adults who have been admitted to hospital over a 1 year period (*p*=.05-.001)(28). The SF-36 asks participants to rate changes in their health status over the preceding four weeks across categories of: general health, mental health, energy, bodily pain. It also asks participants to rate any limitations in physical, social and role activities due to physical or emotional difficulties. Participants were then provided a comment box if they wanted to elaborate on any physical or emotional health changes.

*Statistical Analysis*

Shapiro-Wilk test and Kolmogorov-Smirnov test revealed the data was not normally distributed. Non-parametric Friedman's test with a Wilcoxon Signed-Rank post-hoc was used to evaluate the longitudinal effects in the raw test values of our participants. As improvements on each individual outcome rather than a universal null hypothesis were of interest, the significance level was reported unadjusted for post-hoc tests (alpha value of 0.05, *p≤.05*). Results following post-hoc Bonferroni corrections for the three testing time points are described in-text as well as in all table and figure captions (alpha value of 0.017, *p≤.017*). All statistical analyses were performed on IBM® SPSS-28® (1 New Orchard Road, Armonk, NY). Effect sizes for the Friedman's test were calculated using Kendall's W, while effect sizes for the Wilcoxon Signed-Rank were calculated using Pearson's r. As non-parametric statistics were employed, all results are reported using median and interquartile range (IQR).

## RESULTS

Weight and BMI: No significant changes in weight or BMI were found following the intervention. At pre, participants had an median weight of 62.2, IQR=7.7 kg and BMI of 22.8, IQR=1.88 kg/m$^2$ and at post weight remained at 62.3, IQR=7.0 kg with a BMI of 23.2, IQR=1.71 kg/m$^2$.

Attendance: Participants demonstrated a high attendance rate (median=87.5, IQR=4.2%). When recordings were added to the calculation (for participants that missed the live class) high attendance remained unchanged (median=87.5, IQR=4.24%) with 10 out of 16 participants (62.5%) completing at least 80% of all classes (both live and with recordings).

Postural Stability: As *Figure 2 and Table 2* illustrate, large significant reductions in mediolateral excursions were found from pre-mid in eyes closed ($p$=.003, r=.76) and foam conditions ($p$=.020, r=.60). Additionally, large significant drops in sway area were observed in *Figure 3 and Table 2* when standing on the foam from pre-mid ($p$=.015, r=.63), and similar trends were detected during eyes closed ($p$=.057, W=.19). When Bonferroni corrections were applied to the post-hoc tests, reduced excursions during eyes closed and the sway area during foam remained significant. While no significant differences were found during trials with the eyes open, trends with small effect sizes in excursions were found in both mediolateral ($p$=.074, W=.17) and anteroposterior directions ($p$=.074, W=.17).

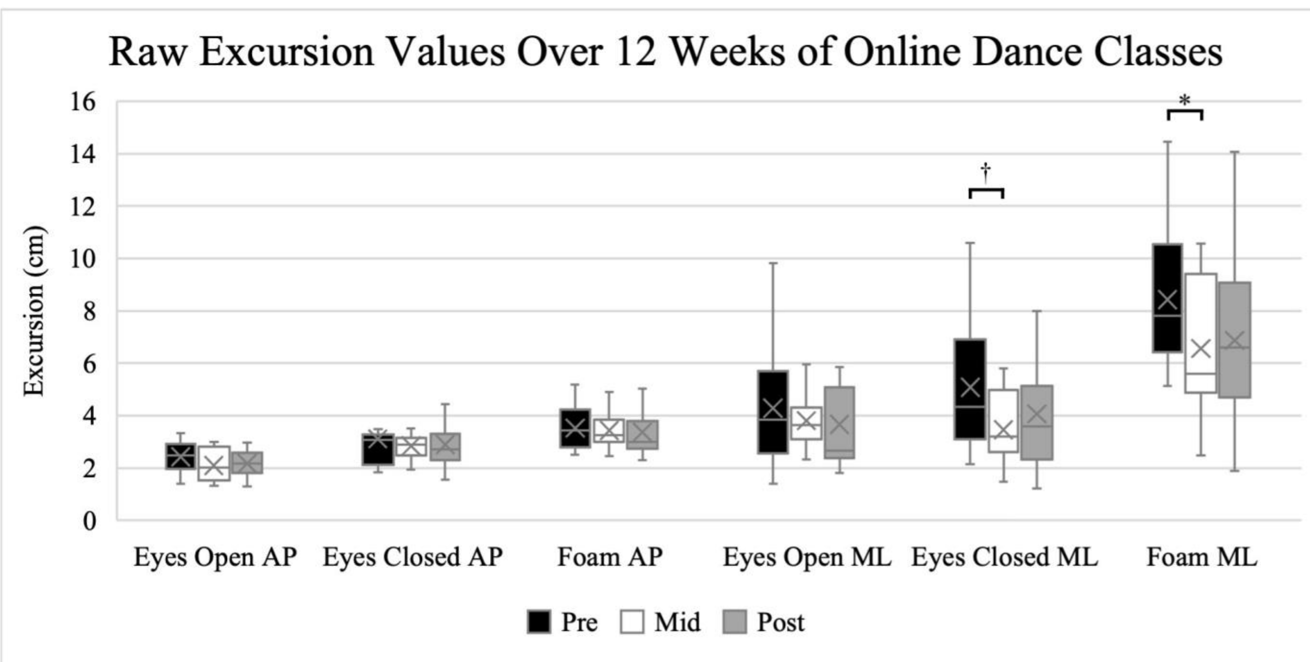


**Figure 2.** Median excursions pre, mid and post 12 weeks of online dance classes. Error bars represent interquartile range. Asterisk (*) denotes $p \leq 0.05$; Dagger (†) denotes $p \leq 0.01$. Following Bonferroni corrections to post-hoc tests, only reductions during eyes closed remained significant. AP = Anteroposterior Excursions; ML = Mediolateral Excursions.

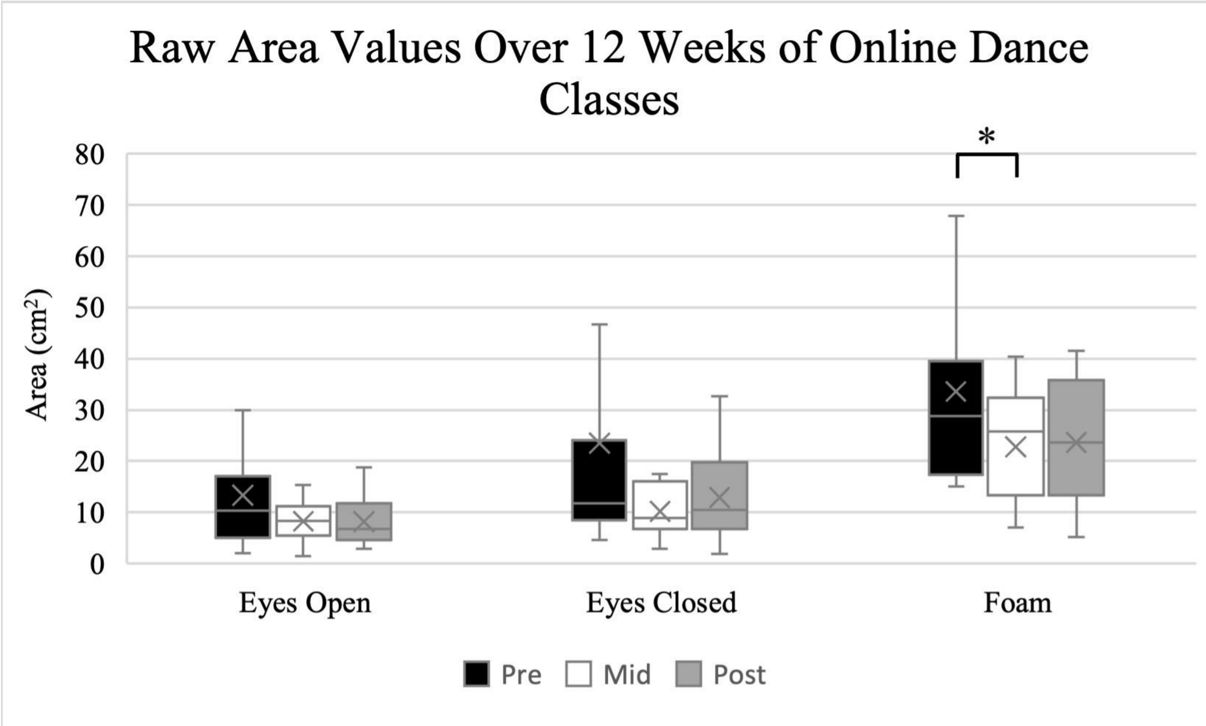


**Figure 3.** Median area pre, mid and post 12 weeks of online dance classes. Error bars represent interquartile range. Asterisk (*) denotes $p \leq 0.05$. After applying a Bonferroni correction to post-hoc tests, reductions in sway area remained significant.

**Table 2.** Center of pressure excursion and area pre, mid and post 12 weeks of online dance classes.

| | *Pre*<br>*Median (IQR)* | **Mid**<br>*Median (IQR)* | **Post**<br>*Median (IQR)* |
|---|---|---|---|
| *Eyes Open* | | | |
| Mediolateral excursion (cm) | 3.83 (3.15) | 3.64 (1.19) | 2.67 (2.70) |
| Anteroposterior excursion (cm) | 2.49 (0.94) | 2.01 (1.28) | 2.16 (0.78) |
| Area ($cm^2$) | 10.33 (12.06) | 8.34 (5.76) | 6.69 (7.19) |
| *Eyes Closed* | | | |
| Mediolateral excursion (cm) | 4.33 (3.37)[a] | 3.19 (1.72)[a] | 3.58 (2.27) |
| Anteroposterior excursion (cm) | 3.07 (0.94) | 2.39 (0.57) | 2.71 (0.88) |
| Area ($cm^2$) | 11.70 (13.89) | 8.89 (7.99) | 10.4 (10.02) |
| *Foam* | | | |
| Mediolateral excursion (cm) | 7.81 (3.31)[a] | 5.59 (3.81)[a] | 6.59 (4.00) |
| Anteroposterior excursion (cm) | 3.42 (1.18) | 3.24 (0.71) | 3.00 (0.99) |
| Area ($cm^2$) | 28.84 (21.50)[a] | 25.86 (16.65)[a] | 23.67 (21.13) |

Symbol ([a]) denotes significant difference $p \leq 0.05$ between time points from pre-mid. When Bonferroni corrections were applied to the post-hoc tests, reduced excursions during foam no longer reached significance.

Dynamic Balance: As shown in *Table 3*, at mid-testing, large effects were observed as participants were able to reach significantly further when completing lateral leg stretches (*p*=.008, r=.68). This gain was also observed from pre-post (*p*=.008, r=.69). Large improvements in the posterior-lateral direction were also found from pre-post (*p*=.009, r=.75) with trends and large effects seen from mid-post (*p*=.054, r=.56). Significance was retained when Bonferroni corrections were used in post-hoc tests.

**Table 3.** Distances reached during a modified SEBT pre, mid and post 12 weeks of online dance classes.

| | **Pre** *Median (IQR)* | **Mid** *Median (IQR)* | **Post** *Median (IQR)* |
|---|---|---|---|
| Anterior (cm) | 54.00 (12.00) | 60.50 (13.00) | 61.00 (10.50) |
| Anterior-Lateral (cm) | 60.50 (12.75) | 67.50 (14.25) | 66.50 (9.75) |
| Lateral (cm) | 63.50 (12.50)[ab] | 65.50 (17.25)[a] | 66.00 (12.00)[b] |
| Posterior-Lateral (cm) | 58.50 (13.00)[b] | 67.50 (11.00) | 66.25 (19.50)[b] |
| Posterior (cm) | 61.50 (18.00) | 62.25 (11.63) | 64.00 (6.00) |
| Posterior-Medial (cm) | 50.50 (24.13) | 60.25 (24.00) | 65.00 (21.63) |
| Medial (cm) | 45.50 (13.00) | 46.00 (13.00) | 49.00 (12.00) |
| Anterior-Medial (cm) | 50.50 (13.13) | 55.00 (11.38) | 54.5 (10.75) |

Symbols ([a,b]) denote significant differences $p \leq 0.05$ between time points: ([a]) pre-mid; ([b]) pre-post. Significance remained following Bonferroni corrections to post-hoc tests. SEBT = Star Excursion Balance Test.

Strength: No significant differences in the number of repetitions were observed in *Figure 4* using the 30STS while the CRS was significantly higher from pre-post (*p*=.015, r=.63) and from mid-post (*p*=.020, r=.60), as well as demonstrated large effect sizes. Upon application of a Bonferroni correction to post-hoc tests, changes from pre-post remained significant, while those from mid-post did not. Furthermore, the change in plantarflexor strength demonstrated clinical significance as there was a mean difference of 4.44 from mid-post (minimally important difference = 3.50 (27)).

Health Questionnaire: No significant differences in scores of general health on the SF-36 were found through the 12-week session (pre: median= 70, IQR=17.5; mid: median= 70, IQR=25; post: median=60, IQR=22.5).

Chi-squared values, Z-scores, p-values and effect sizes for all variables of interests can be found in *Table 4*. To ease comparison to other studies, mean and standard deviation for all variables of interest can be found in *Table 5*.

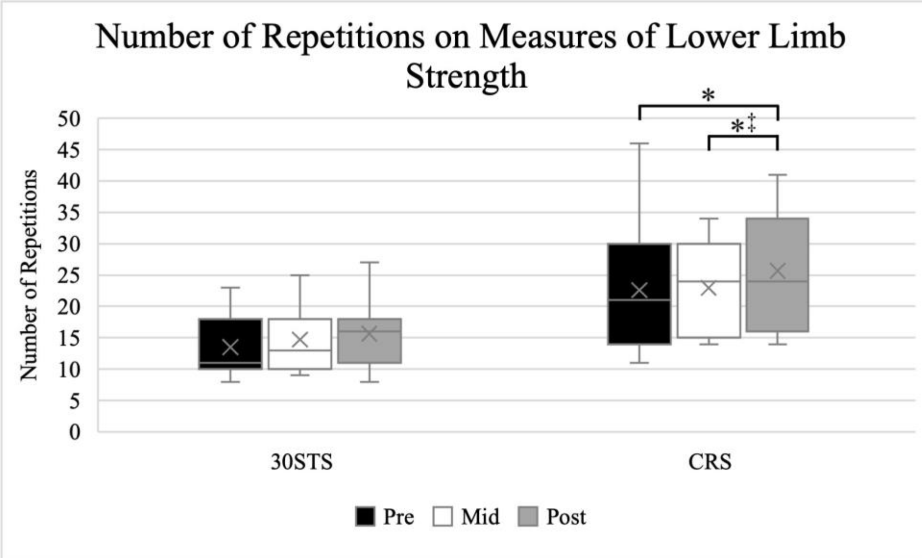


**Figure 4.** Median lower limb strength pre, mid and post 12 weeks of online dance classes. Error bars represent interquartile range. Asterisk (*) denotes $p \leq 0.05$; Double dagger (‡) denotes clinical significance. Following Bonferroni corrections to post-hoc tests, changes from pre-post remain significant while those from mid-post do not.

**Table 4.** Chi-Squared, Z-scores, p-values and effect sizes for postural stability, dynamic balance, and lower limb strength data.

| | Friedman | | | Wilcoxon Pre-Mid | | | Wilcoxon Mid -Post | | | Wilcoxon Pre-Post | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *X*² | *P* | *W* | *Z* | *P* | *ES* | *Z* | *P* | *ES* | *Z* | *P* | *ES* |
| *Postural Stability Eyes Open* | | | | | | | | | | | | |
| Mediolateral excursion (cm) | 5.20 | .074 | 0.17 | - | - | - | - | - | - | - | - | - |
| Anteroposterior excursion (cm) | 5.20 | .074 | 0.17 | - | - | - | - | - | - | - | - | - |
| Area (cm²) | 2.53 | .282 | 0.08 | - | - | - | - | - | - | - | - | - |
| *Postural Stability Eyes Closed* | | | | | | | | | | | | |
| Mediolateral excursion (cm) | 7.60 | .022* | 0.25 | 2.95 | .003† | 0.76 | 1.82 | .069 | 0.47 | 1.65 | .100 | 0.43 |
| Anteroposterior excursion (cm) | 0.13 | .936 | 0.00 | - | - | - | - | - | - | - | - | - |
| Area (cm²) | 5.73 | .057 | 0.19 | - | - | - | - | - | - | - | - | - |
| *Postural Stability Foam* | | | | | | | | | | | | |
| Mediolateral excursion (cm) | 8.40 | .015* | 0.28 | 2.33 | .020* | 0.60 | 0.45 | .650 | 0.12 | 1.70 | .088 | 0.44 |
| Anteroposterior excursion (cm) | 1.20 | .549 | 0.04 | - | - | - | - | - | - | - | - | - |
| Area (cm²) | 6.40 | .041* | 0.21 | 2.44 | .015* | 0.63 | .11 | .910 | 0.03 | 1.70 | .088 | 0.44 |
| *SEBT* | | | | | | | | | | | | |
| Anterior (cm) | 1.60 | .449 | 0.05 | - | - | - | - | - | - | - | - | - |
| Anterior-Lateral (cm) | 3.60 | .165 | 0.12 | - | - | - | - | - | - | - | - | - |
| Lateral (cm) | 5.93 | .052 | 0.20 | 2.65 | .008† | 0.68 | 0.28 | .776 | 0.07 | 2.67 | .008† | 0.69 |
| Posterior-Lateral (cm) | 7.17 | .028* | 0.30 | 1.57 | .117 | 0.45 | 1.93 | .054 | 0.56 | 2.59 | .009† | 0.75 |
| Posterior (cm) | 2.68 | .262 | 0.11 | - | - | - | - | - | - | - | - | - |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Posterior-Medial (cm) | 2.85 | .240 | 0.12 | - | - | - | - | - | - | - | - | - |
| Medial (cm) | 2.00 | .368 | 0.08 | - | - | - | - | - | - | - | - | - |
| Anterior-Medial (cm) | 2.29 | .319 | 0.08 | - | - | - | - | - | - | - | - | - |
| *Strength* | | | | | | | | | | | | |
| 30STS (# Repetitions) | 4.86 | .088 | 0.16 | - | - | - | - | - | - | - | - | - |
| CRS (# Repetitions) | 8.98 | .011* | 0.30 | 0.98 | .326 | 0.25 | 2.33 | .020* | 0.60 | 2.43 | .015* | 0.63 |

Asterisk (*) denotes $p \leq 0.05$; Dagger (†) denotes $p \leq 0.01$. SEBT = Star Excursion Balance Test; 30STS = 30 second Sit-to-Stand; CRS = Calf-Raise Senior

**Table 5.** Mean and SD for all variables of interest.

| | ***Pre*** ***M (SD)*** | **Mid** ***M (SD)*** | **Post** ***M (SD)*** |
|---|---|---|---|
| *Participant Characteristics* | | | |
| N | 16 | | |
| Age (years) | 74.38 (5.62) | | |
| BMI (kg/m$^2$) | 23.38 (2.82) | | |
| PASE | 142.00 (65.00) | | |
| *Postural Stability Eyes Open* | | | |
| Mediolateral excursion (cm) | 4.29 (2.21) | 3.80 (1.43) | 3.66 (2.05) |
| Anteroposterior excursion (cm) | 2.43 (0.51) | 2.09 (0.58) | 2.17 (0.48) |
| Area (cm$^2$) | 13.31 (11.23) | 8.23 (3.80) | 8.20 (4.51) |
| *Postural Stability Eyes Closed* | | | |
| Mediolateral excursion (cm) | 5.08 (2.47)[a] | 3.46 (1.25)[a] | 4.07 (1.91) |
| Anteroposterior excursion (cm) | 3.12 (1.41) | 2.84 (0.48) | 2.90 (0.95) |
| Area (cm$^2$) | 23.45 (33.39) | 10.20 (4.64) | 12.89 (8.88) |
| *Postural Stability Foam* | | | |
| Mediolateral excursion (cm) | 8.43 (2.76)[a] | 6.56 (2.66)[a] | 6.87 (3.37) |
| Anteroposterior excursion (cm) | 3.53 (0.87) | 3.44 (0.65) | 3.37 (0.78) |
| Area (cm$^2$) | 33.59 (20.08)[a] | 22.79 (10.53)[a] | 23.67 (12.05) |
| *Star Excursion Balance Test* | | | |
| Anterior (cm) | 57.70 (10.63) | 56.90 (13.09) | 59.83 (9.39) |
| Anterior-Lateral (cm) | 61.90 (10.10) | 64.13 (10.49) | 64.97 (8.01) |
| Lateral (cm) | 61.57 (8.72)[ab] | 64.80 (10.61)[a] | 65.60 (7.74)[b] |
| Posterior-Lateral (cm) | 61.17 (11.49)[b] | 63.50 (13.80) | 67.46 (11.26)[b] |
| Posterior (cm) | 61.75 (15.33) | 61.75 (12.62) | 63.29 (7.95) |
| Posterior-Medial (cm) | 55.21 (15.60) | 58.29 (13.48) | 59.58 (13.11) |
| Medial (cm) | 46.19 (12.08) | 45.96 (8.91) | 46.96 (9.17) |
| Anterior-Medial (cm) | 53.86 (9.35) | 55.75 (9.08) | 54.86 (8.27) |
| Strength | | | |

| | | | |
|---|---|---|---|
| 30STS (# Repetitions) | 13.53 (4.67) | 14.73 (5.09) | 15.67 (4.94) |
| CRS (# Repetitions) | 22.60 (10.15)[b] | 22.93 (7.62)[c] | 25.67 (9.18)[bc] |

Symbols ([a,b,c]) denote significant differences $p \leq 0.05$ between time points: ([a]) pre-mid; ([b]) pre-post; ([c]) mid-post. When Bonferroni corrections are applied to post-hoc tests, mediolateral improvements during foam and increased repetitions from mid-post no longer reach significance. SD = Standard Deviation; BMI = body mass index; PASE = Physical Activity Scale for the Elderly; SEBT = Star Excursion Balance Test; 30STS = 30 second Sit-to-Stand; CRS = Calf-Raise Senior.

## DISCUSSION

The aim of this study was to determine whether online dance classes can improve postural stability, dynamic balance and strength for women aged 65 years and above. While prior studies have explored the psychosocial impacts of online dance classes, few studies have specifically examined their efficacy as fall prevention programming for older women(21,43).

Attendance: When transitioning to the online platform, maintaining comparable attendance rates to in-person programming was of initial paramount. A meta-analysis by Clifford and colleagues (9) of 19 studies revealed in-person dance classes, designed as tailored fall prevention programming for older adults, reported an attendance rate above 80%. Our attendance rate of 87.5% is comparable. This indicates that online classes (and recordings) are engaging and viable.

Postural Stability: The reported decreases in mediolateral excursion during eyes-closed and on foam (from pre-to-mid) are consistent with previous work investigating in-person dance classes. Granacher and colleagues (20) found trends towards reduced mediolateral excursions when participants completed a 30 second single leg stand following 8 weeks of salsa classes. Additionally, Sofianidis and colleagues (39) showed significant decreases in mediolateral excursion following 10 weeks of traditional Greek dancing. Interestingly, like us, they did not report improvements in the anteroposterior direction. To be visible to the audience, most dance is designed for movement in the frontal plane. This is unlike other balance programs that mimic daily tasks, such as walking and climbing stairs, which are focused on functional movements in the sagittal plane. These lateral motions ascribed to dance, along with accrued use of external rotation, leads to higher recruitment and improved neural control of the glutes, adductors and abductors when compared to traditional balance programs and can explain these reductions in mediolateral excursion (45).

Additionally, base of support was intentionally not enforced, measured or mentioned when testing. That is, as individuals age and muscle atrophy is present, a narrower base of support has been observed (32,36). Strength work of the glute, abductor and adductor muscles completed in dance can all serve to widen the base of support, which improves mediolateral control. Though base of support is beyond the scope of the present study, the mediolateral improvements could also indicate that participants learned to widen their base of support (32).

A meta-analysis conducted by Quijoux and colleagues (36) found that mediolateral excursion can accurately predict fall status, and has superior prediction abilities to anteroposterior values. This suggests that the improvements we observed in mediolateral excursion following only six weeks of dance classes are clinically significant as this may in fact translate into tangible reductions in fall risk and rate, further demonstrating online dance classes as practical fall prevention programming.

Postural stability is heavily dependent on visual feedback; this can explain why no significant changes were observed in the eyes-open condition. Low and colleagues (27) have suggested that the reliance on visual feedback during eyes-open obscures potential improvements in postural control following exercise, as the sensorimotor and neuromuscular paths that improve with exercise are not given sensory weight.

Dynamic Balance: Participants exhibited enhanced dynamic balance, evident by the significant improvements reported in the lateral (from pre-mid and maintained through post) and posterior-lateral (from pre-post and mid-post) directions. As well, although testimonial, notable gains in confidence were observed in participants when completing this test. For example, at pre, many participants indicated that they felt unsteady during the trial and were only comfortable keeping their supporting knee straight, thereby limiting their reach. By post, participants appeared much more comfortable in bending their supporting knee while trying to stretch further. Movements practiced during the dance classes, particularly *tendus*, mirrored the SEBT and could have led to an improvement in neuromuscular pathways and the transfer of skills (2,8). *Tendus* are performed by standing on the supporting leg and sliding the foot along the ground out and in (38). *Tendus* are typically performed in anterior, lateral and posterior directions, which could explain why improvements were seen in lateral and posterolateral directions (8,38). Continuous motor practice is known to enhance corticospinal excitability, with benefits lasting for several days after practice stops (8). The greater reaches participants displayed in specific practiced directions may reflect this mechanism and indicate improved control. Neuromuscular changes generally occur in the first 3-5 weeks of training (34) which explains the initial increase from pre-mid in lateral reaches. Earl and Hertel (15) used surface electromyography during the SEBT to demonstrate that lateral and posterior-lateral directions utilize higher activation of biceps femoris and tibialis anterior; gastrocnemius keeps a consistent level of activation in all directions. Through the online dance classes, which specifically exercised those muscles (45), activation could have been improved. Furthermore, Earl and Hertel (15) found that lateral and posterior-lateral directions require the least amount of knee flexion, perhaps leaving room for improvement detected after the end of the dance classes.

Similarly, in professional modern dancers, Ambegaonkar and colleagues (2) found significantly further reach on the SEBT when compared to non-dancers. This is consistent with findings of Krityakiarana & Jongkamonwiwat (24) who reported that Thai Khon masked dancers reached further in all directions when compared to non-dancers. Our results are further comparable to other types of fall prevention programs. In a 12-week combined strength, balance-training, and

Tai Chi Chuan class for adults aged 60-80 participants reached significantly further in all directions except medial when compared to pre and when compared to a control group (55).

The improvement in dynamic balance can translate to reducing fall risk during activities of daily living that involve changing body positions and transfers of weight such as walking to the shop, sweeping the house, or stepping down from the sidewalk (51).

Lower Limb Strength: A clear training effect in plantarflexor strength was demonstrated by the improvements observed in the CRS. While there were no significant changes from pre to mid, there were both statistically and clinically significant increases from mid to post and pre to post. Neuromuscular adaptations are the main drivers comprising early phases (weeks three to five) of strength enhancements(34). As our effects were found at a later phase (after 12 weeks), it suggests that hypertrophy produced these improvements in strength.

Surprisingly, we were only able to find a single study using dance as fall prevention which specifically assessed plantarflexor strength (6). Cepeda and colleagues (6) suggested, that the significant improvements in plantarflexor strength following eight weeks of ballroom dancing can be attributed to increases in pennation angle, muscle thickness and fascicle length in the gastrocnemius. This supports our findings of increased repetitions in the CRS. With greater gastrocnemius strength, participants may have increased ease in controlling anteroposterior sway with plantarflexors contractions and relaxations (51). Though no improvements in anteroposterior sway were found, higher repetitions on the CRS may be enough to explain better anteroposterior control.

While we did not observe improvements in knee and hip extensor strength on the 30STS, previous work may allude to our limitations. Prior studies of in-person dance classes by Cruz-Ferreira and colleagues (12) only reported significant increases in knee extensor strength after 24 weeks and not at their 12-week mid-test. McKinley and colleagues (30) were able to report significant increases in knee extensor strength by 10 weeks but their participants were completing an extra 90 minutes of dance classes every week when compared to our current methodology. Franco and colleagues (18) demonstrated significant reductions in the amount of time needed to complete the Sit-to-Stand test, but authors noted that the classes were designed to be of a moderate intensity - which may not be safe in the online environment. This suggests that significant improvements in knee and hip extensor strength may have been found with an increased length of intervention, the duration of each session, or intensity.

Limitations: Several limitations are acknowledged, namely our lack of a control group is a flaw and presents a primary limitation in the ability to eliminate possible confounding factors, such as nutrition, supplements, or prior history of physical activity, as well as draw correct conclusions. As this study was completed during the COVID-19 pandemic, institutional policies on minimizing contact and in-person testing led to a maximum of 22 participants and the decision for single group design. To aid in accounting for changes in fatigue, physical, or emotional health over the study session, the SF-36 was administered and no significant differences were found in any of the health categories over the 12-week session. Future research should add an in-person control group to directly compare whether online classes have equal efficacy to in-person ones.

During the study period regional COVID-19 mask mandates ended and an increase in cases affected older adults. This wave affected several of our participants and either caused them to miss classes or completely withdraw from participation (n=2). Additionally, the delay of physician appointments and late identification of conditions among older adults in Quebec contributed to some of our participants being diagnosed with ongoing health conditions and withdrawing (n=2). Another participant left the study prematurely due to lack of enjoyment and the final participant did not attend any of the dance classes or respond to the research team's emails after pre-testing. In total, four participants withdrew from the study.

Additionally, while community-dwelling older adults are generally a heterogeneous population, our cohort had a large range of physical activity levels, which may limit interpretation of results as those with differing baseline activity levels may respond differently. Normative data collected by Loland and colleagues (26) found 185 women (m=74.8 ± 6.6 years) to have average PASE scores of 116.9, which is consistent with Washburn and colleagues (50) who demonstrated 134 women (m=66.4 ± 5.4 years) had average PASE scores of 123.9 ± 66.3. Comparatively, participants in this study were highly active with median PASE scores of 140.5 (IQR=40.75, m=142.0 ± 65.0). Due to our cohort's already high fitness levels, improvements in strength and balance are harder to achieve (29,44), thus some of our failure to report significance may be attributed to an insufficient overload. The elevated physical activity levels of the participants present a main constraint which future studies should address by using physical activity levels as a criterion for participant eligibility.

Finally, with regards to testing of dynamic balance, the difficulty and resulting apprehension of the SEBT could be a limitation. The SEBT was originally designed to be used in athletes, but has been validated and used for older adults (42). To overcome apprehension among our participants, a modification of lightly tapping into the center between every excursion was added. This modification has not been validated and may limit our ability to directly compare the results to other studies.

Practical Applications: Despite limitations, our results underscore the clinical significance of online dance classes as accessible and enjoyable - a novel approach to reduce risk of falls in older adults. The low-cost, and wide-reaching nature of online programs offer practical applications, particularly for women living in remote communities or balancing caregiver responsibilities. This avoids barriers such as transportation, lack of qualified instructors in the region or pandemic guidelines. This online program provides opportunity to exercise, be in a social environment and express themselves creatively from the comfort of their own homes.

Conclusion: Online dance classes represent a promising avenue for reducing the fall risk of older women by improving postural stability, dynamic balance and strength. By adapting these programs to a range of styles, such as traditional dances, this may aid in promoting inclusion and cultural diversity. By implementing this new and easily applicable fall prevention intervention, the risk of falls may be reduced, subsequently decreasing injuries as well as improving independence and quality of life of older women.

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