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The Effects of Combining Videogame Dancing and Pelvic Floor Training to Improve Dual-Task Gait and Cognition in Women with Mixed-Urinary Incontinence

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Abstract

Objective: Many women over 65 years of age suffer from mixed urinary incontinence (MUI) and executive function (EF) deficits. Both incontinence and EF declines increase fall risk. The current study assessed EF and dual-task gait after a multicomponent intervention that combined pelvic floor muscle (PFM) training and videogame dancing (VGD).

Materials and Methods: Baseline (Pre1), pretraining (Pre2), and post-training (Post) neuropsychological and dual-task gait assessments were completed by 23 women (mean age, 70.4 years) with MUI. During the dual-task, participants walked and performed an auditory *n*-back task. From Pre2 to Post, all women completed 12 weeks of combined PFM and VGD training.

Results: After training (Pre2 to Post), the number of errors in the Inhibition/Switch Stroop condition decreased significantly, the Trail Making Test difference score improved marginally, and the number of *n*-back errors during dual-task gait significantly decreased. A subgroup analysis based on continence improvements (pad test) revealed that only those subjects who improved in the pad test had significantly reduced numbers of *n*-back errors during dual-task gait.

Conclusions: The results of this study suggest that a multicomponent intervention can improve EFs and the dual-task gait of older women with MUI. Future research is needed to determine if the training-induced improvements in these factors reduce fall risk.

Introduction

Urinary incontinence (UI) is a common problem affecting more than 55% of women over 65 years of age. Although UI is a geriatric syndrome of diverse physiological and anatomical etiologies, recent findings suggest that cognitive deficits need to be considered as important contributor to this complex state. In fact, studies examining executive functions (EFs) (i.e., planning, coordinating, inhibiting) and different types of UI has demonstrated that women with mixed-UI (MUI) (a combination of stress- and urge-UI) exhibit greater EF declines than women with stress-UI or women who are continent.[1] In everyday divided attention situations, such as walking and talking, individuals with poorer EF have more difficulty managing the two tasks,[2] and it is well known that declines in EFs are related to increased fall risk.[3] A systematic review of fall risk and UI has demonstrated a clear association between UI and falls,[4] and recent work has supported associations between mobility limitations and urge and MUI.[5] As such, the increased risk of falls in individuals with UI and the reduced executive control specific to women with MUI may put this population at high risk for falls and further physical and cognitive declines. A greater understanding of MUI and its association to mobility and cognition, as well as tailored interventions that target these factors, could have a major impact on healthcare systems.

The relationship between walking and UI has been understudied. Recent work has demonstrated that the speed and

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rhythmicity of gait are altered in continent women when there is a strong desire to void.[6] Their study suggests that an interaction may exist between bladder control and control of gait. Maintenance of a regular walking pattern in older adults requires divided attention skills.[7] Individuals who have to invest their attention to their bladder may lack attention resources to devote to other tasks (i.e., walking).

Although large proportions of older women have some form of UI, the prevalence rates for MUI are highest in women over 65 years of age.[8] The gold standard for treating UI is pelvic floor muscle (PFM) training, and this type of training is effective but specific to incontinence outcomes.[9] Given that recent evidence suggests that women with MUI not only have bladder control issues but also demonstrate EF declines,[1] PFM training may only address part of the problem. With the availability of game consoles (i.e., the Nintendo® [Redmond, WA] Wii™), many new intervention studies are utilizing games involving balance, dancing, etc., to promote virtual reality rehabilitation in a playful and accessible manner.[10–13] Furthermore, there are strong indications that videogame interventions are also able to influence EFs.[7] Pilot work, with residents in nursing homes, that compared an intervention group with a combination of videogame dancing (VGD) with strength and balance training to a control group with strength–balance training only demonstrated significant improvements in dual-task voluntary step execution and in dual-task gait specific to the intervention group.[14,15]

The purpose of the current pilot study was to assess the potential benefits of a multicomponent PFM and VGD intervention on standard neuropsychological tests and the dual-task gait of women over the age of 65 years with MUI. Given the motor and cognitive components of the PFM and VGD training, we hypothesized that this combined training would improve neuropsychological measures of EF and facilitate walking in a divided attention situation.

Materials and Methods

Participants

Twenty-four community-dwelling women over the age of 65 years were recruited through newspaper advertisements and senior organizations. All met inclusion criteria for MUI according to the urogenital distress inventory questionnaire (affirmative answer to questions 3 and 4), had a Mini Mental State Exam score of 24 and above, and were able to walk without assistance. All were informed of the details of the study and gave written consent. One participant was unable to complete the full protocol because of an ankle injury unrelated to the research project. On average, the 23 remaining participants were 70.4 ($\pm$3.6) years old, had a Mini Mental State Exam score of 28.5 ($\pm$1.5), and had a level of education of college or higher (university). The study received ethical approval from the ''Institut universitaire de gériatrie de Montréal'' Ethics Committee.

Procedure

There were three test phases in the current study: baseline (Pre1), pretraining (Pre2), and post-training (Post). At all three time points, neuropsychological, UI, and physical and dual-task walking outcomes were measured. From Pre1 to Pre2, there was a 2-week wait period prior to starting training to control for test–retest improvements unrelated to the intervention. From Pre2 to Post, all the participants completed a 12-week VGD program (see Elliot et al.[16]). In groups of eight the participants had a weekly 60-minute session with a trained physiotherapist. The session included an education period on incontinence-related topics (10 minutes) and static pelvic floor training in the lying, sitting, and standing positions (30 minutes) but also had the added component of functional PFM training using a freeware dance game program, ''StepMania'' (www.stepmania.com), projected on a screen in front of the participants (20 minutes). Across the training sessions, the cognitive and physical demands of the dance program increased such that all participants started by following arrows on the screen (up, down, left, right) one foot at a time (beginner; weeks 1–4) and then continued to include both feet and different dance steps for each foot (intermediate; weeks 5–8), and the last stage combined the intermediate step level with a signal (red dot) to add PFM contractions (expert; weeks 9–12). All participants were also given 20 minutes of static PFM exercises to do on their own 5 days a week. An extensive discussion of the intervention program progression and the results specific to improvements in several incontinence and adherence measures are reported elsewhere.[16]

Neuropsychological measures of EFs

Neuropsychological tests of EFs included the modified Stroop task (Reading, Color Denomination, Inhibition, and Inhibition/Switch conditions)[17] and the Trail Making Test (TMT) Parts A & B.[18] The last two conditions of the modified Stroop task (Inhibition and Inhibition/Switch) measure inhibition and flexibility. These conditions were included to test changes in EFs across time and to assess if improvements in EFs were specific to the training phase (Pre2 to Post). The TMT was chosen as it has correlated with changes in dual-task walk measures in previous studies,[19] and the difference between Trails B and Trails A has been used as an indicator of EF abilities.[20] For both the modified Stroop test and the TMT difference score (Trails B – A), a reduction in the time to complete that is specific to the training phase would suggest that the combined training may also benefit cognition. For the modified Stroop task, we also quantified the number of errors committed in order to evaluate if there was a training specific reduction in errors.

UI measures

The UI battery was extensive and is described in detail elsewhere.[16] All participants also completed a modified pad test, which measured the amount of urine leaked (in mL) by weighing a sanitary pad before and after physical tests (including dual-task walking). A 50 percent reduction in the amount of urine leaked during the pad test from Pre2 to Post was considered clinically significant training-induced improvement in bladder control.

Dual-task walking

For the dual-task walk evaluation, participants had to complete three tasks: (1) 2-back task in a seated position (single-task cognitive), (2) walking at a self-selected pace in a quiet hallway (single-task gait), and (3) 2-back while walking (dual-task [gait and cognition]). These tasks were completed in an ABBA design in order to minimize fatigue and order effects. As such, all participants completed the tasks in the following order: 1–2–3–3–2–1. The number of steps and the distance the participant walked during each trial were recorded, in order to calculate walk speed (in m/second) and cadence (in steps/minutes). Participants were filmed during the middle (5-m) portion of all walking tasks in order to extract step length (in cm) and stride time (in seconds) associated with single- and dual-task walking. Experimenters reviewed the video for each condition (single- and dual-task walking) and calculated step length from the heel of the left foot to the heel of the right foot during each step. Stride time was calculated from the initial contact of one foot to the next contact of the same foot. An experimenter also recorded the participants' answers to the 2-back task during single task (seated) and during walking (dual task).

In the 2-back task, the to-be-remembered stimuli were numbers (0–9). Participants were instructed to listen to a series of numbers and report the number they heard 2 numbers back. For example, if the participant heard "9–5–2–0…," when she heard 2, she would have to say 9 out loud, and when she heard 0, she would have to say 5 out loud. The numbers were recorded in a female voice, and sound files (wavfiles) and the lists were presented using E-prime2 software (Psychology Software Tools Inc., Sharpsburg, PA). The numbers were presented through wireless headphones (Acoustic Research Inc.). Six lists of 8 numbers were created for testing, and each list had a duration of 20 seconds, with a digit being presented every 2.5 seconds. For dual-task gait measures, we explored whether or not measures of speed (in m/seconds), cadence (in steps/minute), step length (in cm), stride time (in seconds), and the number of errors during the 2-back task were improved after training.

Statistical analyses

Absolute dual-task cost scores (DTCs) were computed for 2-back errors and all walking parameters. DTCs for 2-back errors were calculated as the number of dual-task errors minus the number of single-task errors, and the DTCs in walking parameters were calculated as single-task walking minus dual-task walking. In both cases, a higher score indicates greater DTCs. All outcome measures were subjected to separate repeated-measures analyses of variance (ANOVAs) with time (Pre1, Pre2, and Post) as the within-subjects factor. For all measures of interest (neuropsychological and dual-task walking [walking parameters and 2-back errors]), we expected significant improvements after training (from Pre2 to Post) and a nonsignificant improvement after the 2-week test–retest period with no intervention (from Pre1 to Pre2). Given the small sample size, Hedge's *g* effect sizes were computed for significant effects in the dual-task walking outcomes, where 0.2–0.3 indicates a small effect, around 0.5 indicates medium effect, and 0.8 and above indicates a large effect.[21,22]

Results

Neuropsychological measures

For the Reading and Color Denomination conditions of the modified Stroop task, reaction time measures did not change significantly over time (P values >0.585). The number of errors also did not change over time for the Reading condition ($P=0.166$), and the Color Denomination condition did demonstrate significant change across time ($P=0.003$) but did not change significantly between Pre2 and Post ($P=0.131$). Both the modified Stroop task (Inhibition and Inhibition/Switch conditions) and the TMT (difference score Trails B – A) reaction time measures demonstrated significant improvements across time (P values >0.016). The number of errors during the Modified Stroop task conditions also diminished over time (P values <0.022). Means and standard deviations for each measure are reported in Table 1. For the modified Stroop Inhibition condition, participants were faster at Pre2 ($P=0.002$) and Post ($P<0.001$) in comparison with baseline (Pre1) and showed significant improvements from Pre2 to Post ($P=0.030$). The number of errors in this condition declined significantly from baseline to Post ($P=0.015$) but did not change significantly between baseline and Pre2 ($P=0.095$) or Pre2 and Post ($P=0.228$). For the more difficult Inhibition/Switch condition of the modified Stroop task, participants were faster at Pre2 ($P=0.028$) and Post ($P=0.020$) in comparison with baseline

Table 1. Neuropsychological Measures

Neuropsychological measure	*Pre1 (baseline)*	*Pre2 (pretraining)*	*Post-training*	*Main effect of time* (P *value)*
Stroop Reading RT (seconds)	47.24 (9.40)	46.52 (9.45)	46.21 (8.29)	0.59
Stroop Color Denomination RT (seconds)	67.43 (16.59)	67.04 (20.61)	65.13 (12.56)	0.64
Stroop Inhibition RT (seconds)	122.19 (23.87)	111.40 (22.70)	105.59 (19.15)	0.001
Stroop Inhibition/Switch RT (seconds)	143.72 (34.42)	130.40 (22.17)	133.98 (26.88)	0.02
Stroop Reading errors	0.35 (0.94)	0.09 (0.42)	0.09 (0.29)	0.17
Stroop Color Denomination errors	1.96 (2.21)	1.22 (1.88)	0.83 (1.30)	0.003
Stroop Inhibition errors	3.44 (3.73)	2.61 (2.97)	2.09 (2.43)	0.03
Stroop Inhibition/Switch errors	6.09 (7.22)	5.45 (5.69)	3.74 (4.88)	0.02
Trails (B – A) difference (seconds)	1.34 (0.68)	−0.58 (0.12)	−0.51 (0.15)	0.001

Data are mean (standard deviation) values.
RT, reaction time.

Table 2. Dual-Task Cost Scores in Walk Parameters

DTC measure (units)	*Pre1 (baseline)*	*Pre2 (pretraining)*	*Post-training*	*Main effect of time (P value)*
Speed (m/second)	0.13 (0.10)	0.15 (0.12)	0.14 (0.11)	0.86
Cadence (steps/minute)	11.55 (11.80)	8.18 (15.44)	12.72 (14.68)	0.40
Step length (cm)	−0.005 (0.06)	0.041 (0.10)	−0.10 (0.80)	0.09
Stride time (seconds)	−0.05 (0.10)	−0.03 (0.07)	−0.03 (0.05)	0.58

Data are mean (standard deviation) values.
DTC, dual-task cost score.

but did not show significant improvements from Pre2 to Post ($P=0.375$). The number of errors declined significantly from baseline to Post ($P=0.002$) and from Pre2 to Post ($P=0.025$) but did not change significantly from baseline to Pre2 ($P=0.508$).

All participants also demonstrated improved TMT difference scores, such that participants were faster at Pre2 ($P<0.001$) and Post ($P<0.001$) in comparison with baseline and showed marginal improvements from Pre2 to Post ($P=0.055$).

Dual-task performance: Gait and cognitive parameters

The DTC for each walk parameter was subjected to a repeated-measure ANOVA with time (Pre1, Pre2, and Post) as the within-subjects factor. None of the walk parameters demonstrated a significant change over time (Table 2).

For the cognitive parameters, a DTC for the number of 2-back errors was calculated. The ANOVA revealed a main effect of time ($F_{1,22}=3.667$, $P=0.034$). Planned comparisons among the three time points (Pre1, Pre2, and Post) demonstrated that DTCs in 2-back errors were not significantly different between Pre1 and Pre2 ($P=0.138$) but that DTCs were significantly reduced between Pre2 and Post ($P=0.022$, $g=0.87$) (Fig. 1). In addition, we selected the dual-task component from the cost scores and evaluated changes across time. We found that the entire sample demonstrates significant reductions in total 2-back errors, during dual-task performance, across time ($F_{1,\ 22}=6.01$, $P=0.005$). Planned comparisons demonstrate that 2-back errors during dual-task are significantly reduced at Pre2 ($P=0.025$) and Post ($P=0.003$) in comparison with Pre1 (Fig. 2).

Subgroup analysis based on pad test improvements

Within the current dataset, we decided to explore which participants demonstrated clinically significant improvements on their pad test after training (from Pre2 to Post). There were 13 individuals who demonstrated a clinically significant improvement in their pad test after training (improvers) and 10 individuals who did not (non-improvers). Using repeated-measures ANOVA, we evaluated changes in DTC errors across time (Pre1, Pre2, and Post) in each group (improvers/non-improvers). The non-improvers did not demonstrate any significant change across time in their DTCs ($P=0.719$), whereas improvers did ($P=0.026$). Within the improver group, planned comparisons revealed that the change in DTCs was only significant between Pre2 and Post ($P=0.043$, $g=1.08$). We also reexamined the cognitive dual-task performance (total 2-back errors) across time, with repeated-measures ANOVAs in each group. There was a main effect of time in the improvers ($F_{1,12}=7.18$, $P=0.004$) and not in the non-improvers ($P=0.184$) (Fig. 3). Within the improver group, planned comparisons for the changes across time revealed that the total number of 2-back errors declined significantly from Pre1 to Post ($P=0.002$; see Fig. 3A). Effect size computations revealed a medium effect size ($g=0.63$) for this comparison. All other comparisons demonstrated a reduction in the number of errors across time that did not reach significance (between

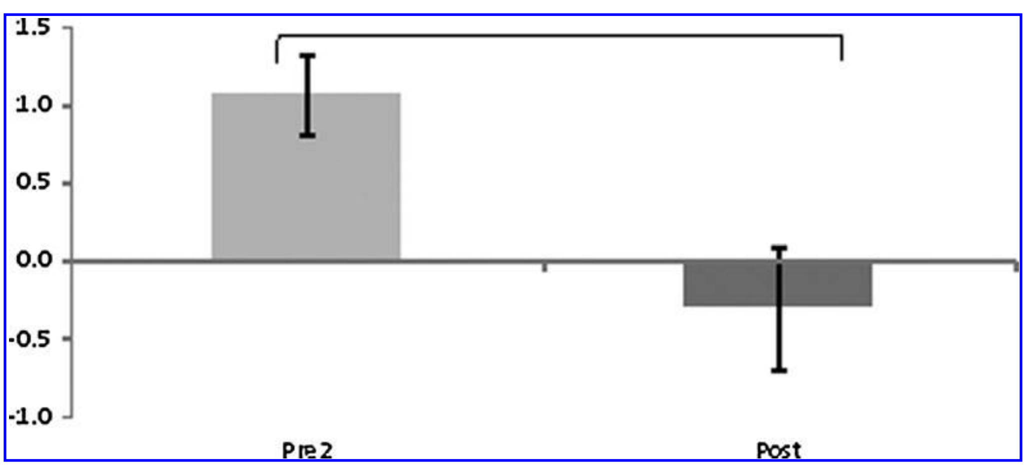

FIG. 1. Change in dual-task cost 2-back errors from pretraining (Pre2) to post-training (Post).

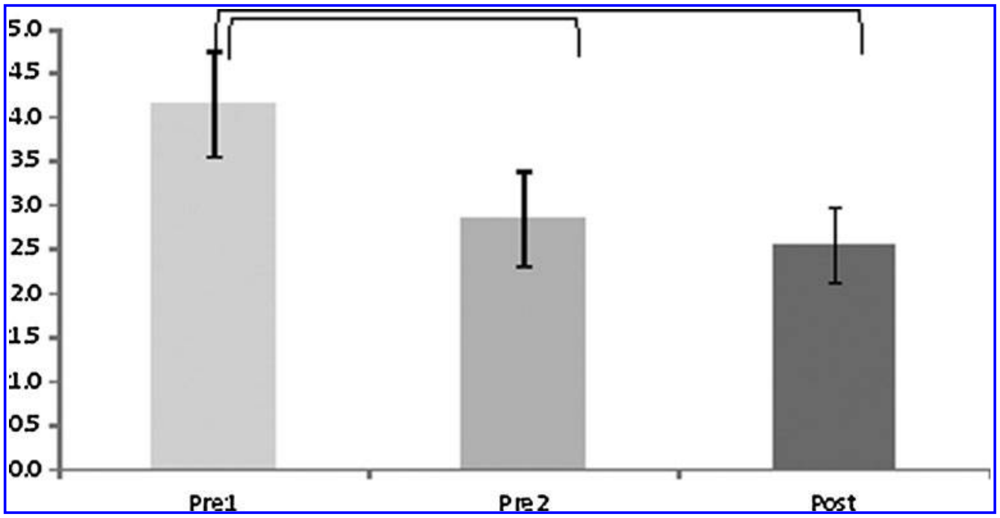

FIG. 2. Total number of 2-back errors during dual-task, across time (baseline [Pre1], pretraining [Pre2], and post-training [Post]).

Pre1 and Pre2 [$P = 0.071$, $g = 0.32$] and between Pre2 and Post [$P = 0.098$, $g = 0.36$]).

Discussion

The current pilot study is the first combined PFM training and VGD to treat older women with MUI. One of the study's goals was to explore the potential benefits of this multi-component PFM and VGD training on standard neuropsychological tests and the dual-task gait of women over the age of 65 years with MUI. Elliot et al.[16] have already demonstrated training-induced reductions in symptoms associated with UI and improved quality of life in this sample of women. In addition to the benefits observed in UI, the current study provides support for improvement on selected measures of EF (modified Stroop task and TMT) and on cognitive *n*-back performance during dual-task walking.

Neuropsychological measures

The pattern of results in the chosen neuropsychological measures generally demonstrates improvements over time. However, only specific measures demonstrate improvements from pretraining to Post. In the Inhibition condition, the participants were responding faster at each time point (i.e., baseline > Pre2 > Post), and therefore we cannot argue training-specific gains. However, it is still noteworthy that there are significant gains in speed between Pre2 and Post given the average age of our participants (70 years old) and the 3-month time interval between assessments. In the Inhibition/Switch condition, the number of errors did not change between baseline and Pre2, but errors were reduced significantly after training. The TMT difference scores also demonstrated a reduced time to complete across time with marginal improvements between Pre2 and Post. These neuropsychological findings need to be interpreted with caution, but the reaction time improvement in the Inhibition condition and the reduction in errors in the Inhibition/Switch condition only after training do suggest that the use of a combined PFM and VGD training to improve select EFs in a sample of women particularly ''at risk'' for cognitive declines may be effective, and further research is warranted.

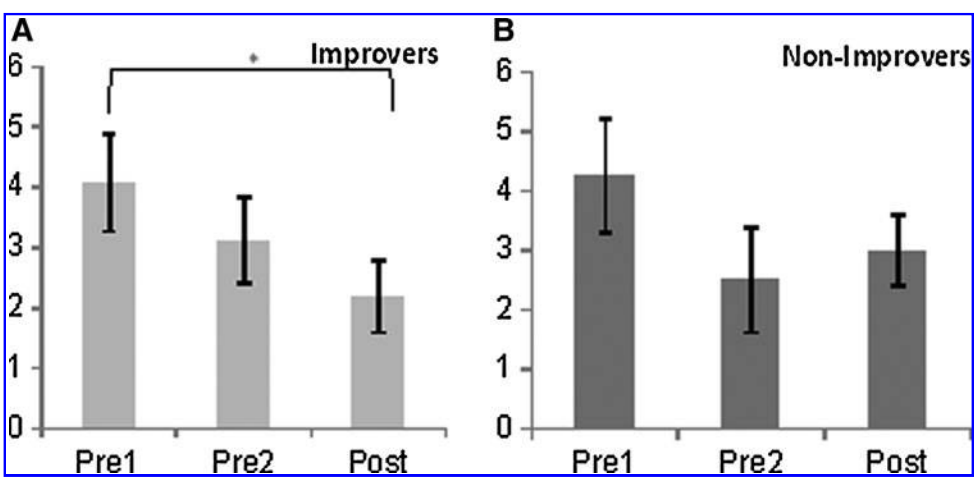

FIG. 3. Total number of dual-task 2-back errors across time for the pad test **(A)** improvers and **(B)** non-improvers.

Dual-task performance

Although none of the walking measures changed significantly over time, it is interesting that we found significant improvements after training in the number of errors produced during the 2-back task while walking. The VGD training involves attention and switching, as participants have to follow a screen with instructions where to step and with which foot or feet, as well as attending to the signal for a PFM contraction (in the last stage of training). As such, this type of training may have facilitated dual-task walking by improving cognitive processes of attention and switching, thereby resulting in an improved ability to perform a cognitive task while walking. In a group of women particularly at risk for cognitive declines, a training that improves cognitive abilities during gait has the potential to reduce the fall risk in this population.

In addition, in the subgroup analysis based on the pad test results, those who demonstrated clinically significant improvements on their pad test also demonstrate reduced cognitive dual-task costs and improved dual-task performance after combined PFM and VGD training. Although the sample size is small, the large and medium effect sizes (for DTCs and dual-task performance, respectively) suggest that the combined training has the potential to improve not only measures of UI but also cognitive performance during gait.

Limitations of the study and future research

This pilot study was primarily designed to assess the impact of combined PFM and VGD training on measures of incontinence in a sample of elderly women with MUI. As such, the study was not designed to assess if this type of training reduced fall risk. However, results suggest that cognitive processes both in neuropsychological measures and in dual-task gait benefit from this type of training, and given the important relationship between reduced EF and falls,[3] it is possible that these improvements could result in reduced fall risk. In addition, it is important to note that the focus of this study was women and that all were well educated; thus it is not possible to generalize these results to all individuals with continence issues. Future research studies should include a control group that receives the gold standard PFM training and an experimental group that receives the combined PFM/VGD training, as well as pre- and post-intervention falls assessment. This future study could complement the current results and further assess if the cognitive benefits of training are associated with reduced falls and fall risk in older women with MUI.

Conclusions

Taken together, this pilot study demonstrates that a sample of women with MUI who completed 3 months of combined PFM and VGD training could benefit not only in incontinence measures[16] but also in measures of EF and dual-task gait. Further research is needed to replicate and clarify the specificity of these benefits to women with MUI who have already experienced a fall (versus other fallers) and to test whether or not these cognitive benefits translate into reduced fall risk.

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Author Disclosure Statement

No competing financial interests exist.

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