Original Article

# Effects of virtual dance exercise on skeletal muscle architecture and function of community dwelling older women

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## Abstract

**Objectives:** The aim of this study was to analyze the effects of virtual dance exercise on skeletal muscle architecture and function in community-dwelling older women. **Methods:** Forty-two moderately active older women participated in this study and chose to join either the control group (CG; n=20; 70.3 ± 5.6 years) or exercise group (EG; n=22; 69.3 ± 3.7 years). Participants in the CG maintained their lifestyle and those in the EG performed group dance exercise using Dance Central game for Xbox 360® and Kinect for 40 min, 3 times/week, for 12 weeks. The primary outcomes were: ankle plantar flexion and dorsiflexion peak torque (PT), medial gastrocnemius muscle thickness (MT), fascicle length (FL), and pennation angle (PA). The secondary outcomes were: lower limbs range of motion (ROM), calf circumference (CC), 6 m customary gait speed, and handgrip strength. Data were analyzed using an ANOVA mixed model test (p < 0.05). **Results:** EG participants improved plantar flexion PT at 60°/s (16.3%; $p<0.01$), MT (8.7%; $p<0.01$) and ankle dorsiflexion ROM (5.1%; p=0.04) when compared to baseline, and exhibited enhanced CC values compared to CG (1.7%; p=0.03). **Conclusions:** Virtual dance exercise can be recommended to increase muscle mass. Moreover, ankle plantar flexion strength and dorsiflexion ROM gains may contribute to improve functionality and fall avoidance in moderately active older women.

**Keywords:** Skeletal Muscle, Video Game, Ultrasound, Ageing, Dance Therapy

## Introduction

The aging process can lead to a reduction in muscle strength, mass and flexibility. This age-related decline in muscle mass and muscle performance is defined as sarcopenia[1-4]. Sarcopenic skeletal muscle is not only characterized by decreased muscle mass, but also adverse changes in fascicle length and pennation angle[5]. Several training protocols have been recommended to mitigate and/or reverse the deleterious effects of aging on muscle[6]. In addition, a wide range of exercise modes and physical activities can induce skeletal muscle adaptations in older adults[7,8]. For example, community-dwelling older women exhibited improved functional performance and increases in muscle thickness (MT; 15%), pennation angle (PA; 17%), and fascicle length (FL; 10%) of the medial gastrocnemius muscle following 8 weeks of ballroom dance (3 sessions per week)[8]. The social element and familiarity of dance are easily adapted for therapeutic exercise using a semi-immersive virtual game platform. Virtual games, also called exergaming, are emerging as a useful tool to increase physical activity or formal exercise programs[9]. The interactive and motivating characteristics of virtual games contribute to the high adherence among older adults engaged in this form of exercise[10-12].
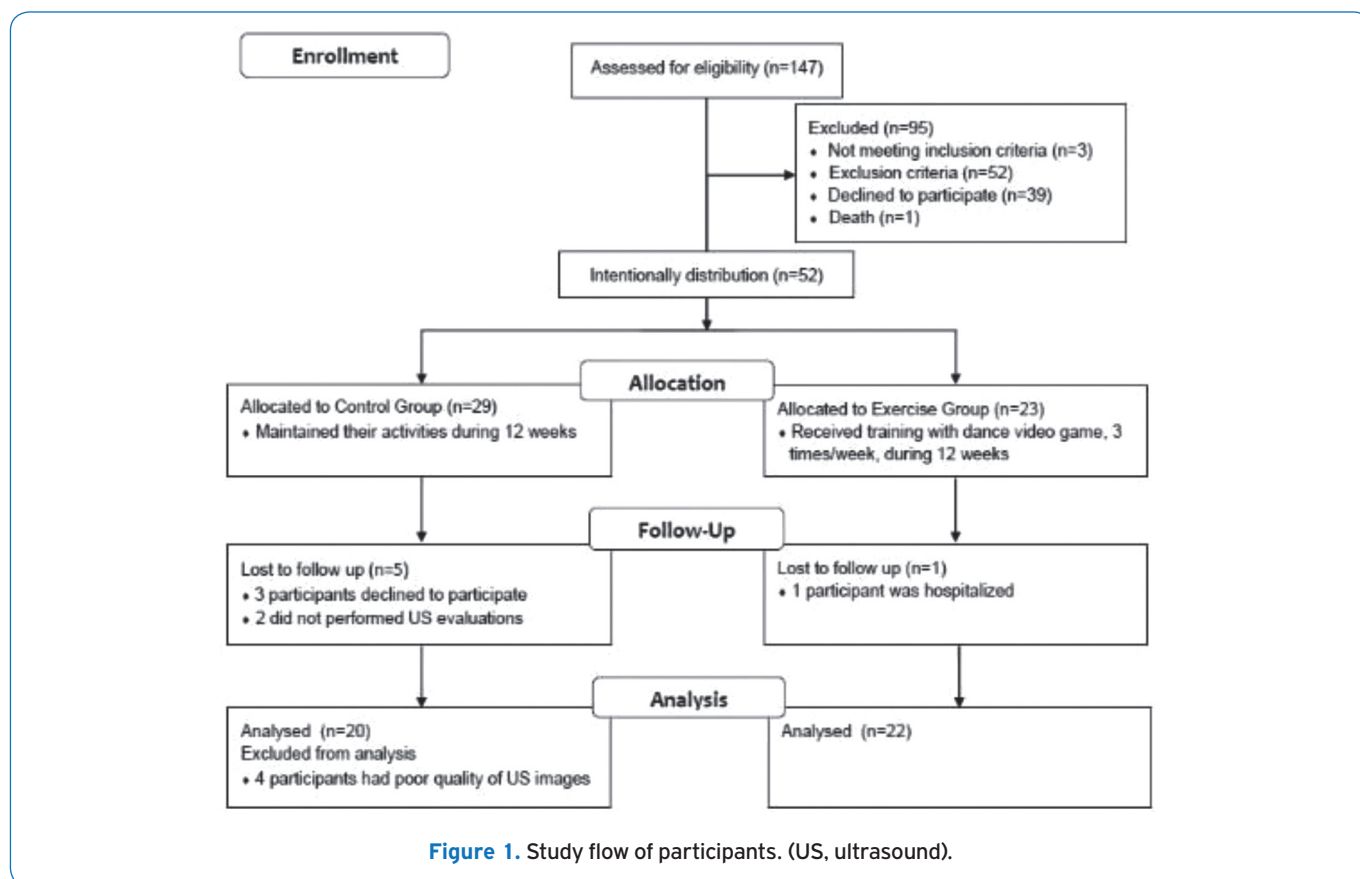
Virtual training has been previously shown to yield physiological adaptations and functional improvements.

**Figure 1.** Study flow of participants. (US, ultrasound).

Published findings include improvements in mobility[11,12], balance[13-15], muscle endurance and power[11], hip maximum voluntary contraction (MVC), and rate of force development (RFD)[11,14,16,17]. Moreover, a previous study has reported architecture and performance adaptations to ankle dorsiflexor and plantar flexor muscles following an exergame regimen in frail older adults[18]. Adequate range of motion (ROM) and muscle power at the ankle joint are associated with gait performance, balance and fall avoidance[2,19,20]. Consequently, age-related changes that affect ankle joint ROM and muscle performance are important determinants of functional independence in older adults.

Thus, considering the importance of ankle function, there is a need to develop and implement more attractive exercise training options for older adults. The objectives of the present study were to evaluate the effects of dance with video game exercise on functional performance and skeletal muscle architecture at the ankle joint, in a sample of community-dwelling older women.

## Methods

### Design

This was a longitudinal, non-randomized study, approved by the Research Ethics Committee of the Health Sciences Division of the Federal University of Parana (UFPR), Brazil, (CAAE: 36003814.2.0000.0102) and registered at Brazilian Register of Clinical Trials (ReBec) (RBR-8xkwyp). All participants signed the informed consent.

### Participants

Participant recruitment was completed through the dissemination of flyers, and verbal invitations to community groups and university programs that serve older adults within the city of Curitiba-PR and metropolitan region. The study investigators screened 147 older women interested in participating in the study, but 95 people did not meet the inclusion criteria and were excluded. Thus, 52 women chose to take part of control group (CG; n=29) or exercise group (EG; n=23). However, nine CG participants were excluded because: they did not complete baseline evaluations (n=3); they did not come for US evaluation (n=2); FL images were not clear and could not be analyzed using Image J (n=4). In addition, one EG participant dropped out due to hospitalization. Consequently, the study was completed by 42 participants (CG: n=20; EG: n=22). During 12 intervention weeks, EG participants completed exercise training with dance video game, 3 times/week, and CG participants maintained their lifestyle. Participant screening, enrollment, assignment, and attrition are summarized in Figure 1.

The study inclusion criteria comprised females over 65 years old who were physically independent according to Activities of Daily Living (ADL) and Instrumental Activities

of Daily Living (IADL)[21,22]. In addition, the participants were required to have good visual acuity with or without the use of corrective lenses (Snellen scores <2O/7O; International Classification of Diseases - ICD-1O)[23], and be classified as having low to moderate activity per the Adjusted Activity Score (AAS) (<74 score) of the Human Activity Profile (HAP)[24].

The exclusion criteria were: hip and knee impairments considering the Lequesne's Algofunctional Questionnaire[25] (scores higher than 7); ankle pain or dysfunction (Foot and Ankle Outcome Score - FAOS; scores lower than 75 in the domains, "*pain*" and/or "*difficulty in performing activity of daily living*"); an inability to properly follow commands[26] (Mini-Mental State Examination - MMSE scores <13); uncontrolled hypertension, diabetes or endocrine diseases.

*Outcomes*

The primary outcomes were ankle plantar flexion and dorsiflexion concentric isokinetic peak of torque (PT) and medial gastrocnemius muscle architecture (MT, PA and FL).

Concentric PT of the dominant limb was evaluated using a Biodex System 4 Dynamometer (Biodex Medical Systems, Shirley, New York)[27,28]. Limb dominance was determined by asking the participants the question, "Which leg would you use to kick a ball?"[27,28]. Participants walked in a 3O m straight corridor until reaching the target heart rate (HR) for warming-up (40% to 60% of HR reserve)[29], which lasted an average of 2 minutes. Then, they sat on the dynamometer chair in a slightly reclined position (back angle of 11O°), with the hip, and knee angles of the experimental leg set at 1OO°, and 3O°, respectively[30]. Other movements were minimized using non-elastic trunk, waist and thigh straps to stabilize the trunk and lower limb. The foot was secured to the footplate using a heel binding with an adjustable strap across the dorsum of the foot near the ankle joint, and the ankle joint was aligned with the axis of rotation of the dynamometer. Test protocol familiarization included participants performing 2-4 passive repetitions followed by 1 set of 4 submaximal continuous repetitions. Then, 1 set of 3 maximal continuous voluntary flexion-extension repetitions within a 3O° ROM (1O° dorsiflexion and 2O° plantar flexion) were completed[30]. The force-time curves were reviewed for analysis and the mean peak torque value was recorded for each testing condition. This process was done to evaluate ankle concentric strength, at 6O°/s and 18O°/s, with 2 minutes of rest between the tests[28]. All participants received the same verbal encouragement (i.e., "force up, force down, hard, hard", where "force up" referred to ankle dorsiflexion strength and "force down" referred to ankle plantar flexion strength) in order to attain the MVC at the target movement velocity for each trial[31,32].

A B-mode ultrasonography (US) imaging device (Logiq Book XP, General Eletric®) with a linear-array probe (5Omm long, 11 MHz, General Eletric®) was used to evaluate medial gastrocnemius MT, PA and FL. Participants were assessed in the prone position, with legs relaxed and their feet positioned outside the table with the ankle joint at 115°, which corresponds to the spontaneous resting angle of the tibiotalar joint[33]. Three images were each measured at a fixed depth of 4 cm at 20%, 30% and 40% of the distance from the lateral tibia condyle to the lateral fibular malleolus. The probe was positioned perpendicular to the dermal surface of the MG and coated with water-soluble transmission gel, which provided acoustic contact without depressing the dermal surface[34]. MT was defined as the mean distance between deep and superficial fascial planes, measured at five places along the ultrasound image[35]; PA was defined as the angle of insertion of muscle fiber fascicles into the deep fascial plane[33]; and FL was defined as the length of the fascicular path between the insertions of the fascicle into the superior and deep fascial planes. When the end of the fascicle extended off the acquired ultrasound image, FL was estimated by a trigonometric function according to Abellaneda et al.[36].

To ensure that the same recording position was used during the baseline and post 12-week assessments, dermal maps were developed on transparent sheets with reference points for skin marks (i.e. freckles and scars) and marks used to capture the images at the 20%, 30% and 40% distance locations. All US images analyses were performed using Image J software (Version 1.46r, National Institutes of Health, Bethesda, MD, USA).

The secondary outcomes were: range of motion (ROM), calf circumference, 6m customary gait speed test (GS), and handgrip strength (HS). ROM was assessed using a fleximeter (Sanny, Brazilian American Medical) for hip flexion/extension, knee flexion/extension, and ankle plantar flexion/dorsiflexion[37]. Three ROM measures were completed for each joint motion, without warm up, and the mean value was used for analysis. Calf circumference was measured as previously described by Cruz-Jentoft et al.[1] with measures <31 cm serving as a positive screening result for low muscle mass. The 6m customary gait speed test was performed on a straight walkway and timed with a stopwatch as the method described by Rogers et al.[38]. Customary gait speed was used to represent functional performance in this study, with gait speed values <1 m/s denoting poor physical performance[1]. Handgrip strength was assessed by a handheld dynamometer (SH5O01, Saehan Corp®) using a previously published protocol[39] with the mean peak force values used to characterize upper extremity strength. Strength was classified according to body mass index (BMI) and cut off values were used to determine participants with low relative strength values (≤17 kg when BMI ≤23 kg/m$^2$; ≤17.3 kg when 23.1 <BMI <26 kg/m$^2$; ≤18 kg when 26.1 <BMI <29 kg/m$^2$; ≤21 kg when BMI >29 kg/m$^2$)[1]. The calf circumference, gait speed, and handgrip strength were also the outcomes used for sarcopenia screening and staging[1].

The assessments were performed by trained physiotherapist or physical trainer professionals. Concentric PT and muscle architecture data were blindly analyzed by the same researcher, during the baseline and post-intervention weeks. Participants were classified as sarcopenic when they exhibited low muscle mass, with low muscle strength and/or low physical performance[1].

**Box 1.** Summary of the exercise progression using the Xbox 360® and Kinect® semi-immersive virtual game platform with activities from the Dance Central game.

| Exercise week | Music 1 | Music 2 | Music 3 | Music 4 | Music 5 | Music 6 | Exercise task elements |
|---|---|---|---|---|---|---|---|
| 1 | X | | | | | | Exercise progression included: increased exercise movement complexity, decreased base of support, increased body weight shifting, and increased frontal and lateral movements. |
| 2 | | X | | | | | |
| 3 | | | X | | | | |
| 4 | | | | X | | | |
| 5 | | | | | X | | |
| 6 | | | | | | X | |
| 7 | X | | | | | | Exercise performed over a foam pad and ambient light reduced. |
| 8 | | X | | | | | |
| 9 | | | X | | | | |
| 10 | | | | X | | | Exercise performed over a foam pad, ambient light reduced, and strobe and laser lights added. |
| 11 | | | | | X | | |
| 12 | | | | | | X | |

*Intervention protocol*

EG participants performed 40 min of virtual dance exercise as a group using the Xbox 360® system with a movement sensor (Kinect), 3 times/week, over a 12-week period. Six selections from the Dance Central game (i.e., *Funkytown, Galang' 05, Down, Brick House, Jungle Boogie, Days Go By*) were played, in a fixed sequence, at the "easy" level of difficulty. An external monitor and sound amplifiers were used to enable the semi-immersive exergame group training. Each exercise bout was preceded by a warm-up session. The warm-up included dance movements taught by the researcher using the Kinect "perform it" mode for 10 min in duration. Upon completion of the warm-up, the "dance battle" mode was played 4 times for a total exercise time of 20 min. All exercise bouts were followed by breathing and cool down exercises lasting 10 min.

The training progression incorporated recommendations for neuromotor training from the American College of Sports Medicine[6,40]. The exercise was progressed by changing the music to increase the movement complexity over the first 6 weeks of the regimen. The dance exercises started with basic movements performed during the first song and then progressed to include lateral displacements and jumps during the last song. Each song was played during the 3 sessions conducted each week. Upon reaching exercise week 7, all songs were played in the same order, but the exercise movements were performed over a polyurethane foam pad (5 cm of thickness, with a density of 33kg/m$^3$) and the ambient light was reduced. Strobe and laser lights were added to increase visual task demands from exercise week 10 to 12. The training progression is shown in Box 1.

Heart rate (HR) was assessed at the beginning and end of each session. Additionally, both HR and the rating of perceived exertion (RPE; using the Borg 6 -20 scale[41]) were monitored after the warm-up, and at the 10 min and 20 min time intervals during the intervention. The HR Reserve (HRR) method[29] (%HRR= ((HR achieved - HR rest)/HRR) x 100) was used for the calculation of exercise intensity with each HR check during exercise.

HR and RPE analyses were made considering only the last exercise session of each week. The cutoffs values for exercise intensity according to %HRR (BPM) and RPE (score) were, respectively: very light (BPM <30; score <9); light (BPM=30-39; score=9-11); moderate (BPM=40-59; score=12-13); vigorous (BPM=60-89; score=14-17); near maximal to maximal (BPM≥90; score≥18)[29]. All of the sessions were supervised by physiotherapists and physical trainers.

*Data analysis*

*A priori* power analysis (G*Power 3.1.9 Software) revealed that a total of 42 participants were needed to achieve 76% power for a two-group pre and posttest design (21 participants per group). The α-level was set at 0.05 and the effect size *f* was set at 0.80. The data were tested for normality distribution using the Shapiro Wilk test. Parametric data were presented as mean values (±SD) and non-parametric data as median values (minimum; maximum).

For sample baseline characteristics analysis, the independent Student t-test was used for height, weight, BMI and HAP, and the Mann-Whitney U test was used for non-parametric baseline variables. The possible exercise effects were analyzed using the analysis of variance (ANOVA) mixed model test with two factors, Group (CG and EG) and Time (Pre and Post), followed by post hoc Bonferroni, for comparison between groups for the parametric data. The variables that were significantly different between groups at baseline

**Table 1.** Baseline characteristics.

| | CG (n=20) | EG (n=22) | *p* |
|---|---|---|---|
| Age (years) | 68 (65-84) | 68 (65-79) | 0.87 |
| Weight (kg) | 69.4 ± 11.6 | 63.1 ± 9.3 | 0.06 |
| Height (m) | 1.6 ± 0.05 | 1.5 ± 0.07 a | 0.03 |
| BMI (kg/m²) | 28.2 ± 4.7 | 27.1 ± 3.6 | 0.4 |
| MMSE (score) | 28 (19-30) | 28 (21-30) | 0.6 |
| A-F Hip (score) | 0 (0-2) | 0 (0-6) | 0.66 |
| A-F Knee (score) | 0.25 (0-5) | 0 (0-5) | 0.96 |
| FAOS pain (score) | 100 (75-100) | 100 (91.7-100) a | 0.02 |
| FAOS ADL (score) | 100 (89.7-100) | 100 (97.05-100) | 0.53 |
| HAP (score) | 52.8 ± 14.1 | 55.8 ± 11.5 | 0.45 |
| Plantar flexion PT 60º/s | 44.36 ± 11.7 | 36.15 ± 9.9 a | 0.02 |
| Dorsiflexion PT 60º/s | 18.42 ± 3.7 | 17.72 ± 3.5 | 0.54 |
| Plantar flexion PT 180º/s | 32.66 ± 8.6 | 29.26 ± 9.7 | 0.24 |
| Dorsiflexion PT 180º/s | 16.64 ± 4.3 | 15.58 ± 2.4 | 0.34 |
| **Muscle thickness (cm)** | | | |
| 20% | 1.81 ± 0.23 | 1.85 ± 0.23 | 0.63 |
| 30% | 1.60 ± 0.26 | 1.61 ± 0.26 | 0.89 |
| 40% | 0.99 ± 0.29 | 1.04 ± 0.24 | 0.61 |
| **Pennation angle (º)** | | | |
| 20% | 26.47 ± 3.53 | 27.76 ± 3.46 | 0.24 |
| 30% | 25.25 ± 3.2 | 25.82 ± 4.18 | 0.63 |
| 40% | 21.51 ± 3.17 | 21.52 ± 4.17 | 0.99 |
| **Fascicle length (cm)** | | | |
| 20% | 4.18 ± 0.38 | 4.1 ± 0.54 | 0.60 |
| 30% | 4.00 ± 0.45 | 4.01 ± 0.48 | 0.87 |
| 40% | 3.51 ± 0.64 | 3.63 ± 0.69 | 0.56 |
| Hip flexion (º) | 73.11 ± 9.4 | 66.66 ± 8.54 a | 0.03 |
| Hip extension (º) | 15.64 ± 2.7 | 16.81 ± 3.83 | 0.2 |
| Knee flexion (º) | 122.02 ± 9.2 | 123.41 ± 9.4 | 0.64 |
| Ankle dorsiflexion (º) | 35.22 ± 5.6 | 34.05 ± 7.5 | 0.59 |
| Ankle plantar flexion (º) | 26.72 ± 5.1 | 27.94 ± 6.0 | 0.50 |
| Handgrip strength (Kg) | 22.83 ± 4 | 20.77 ± 3.6 | 0.08 |
| Gait speed (m/s) | 1.36 ± 0.2 | 1.32 ± 0.2 | 0.55 |
| Calf circumference (cm) | 36.87 ± 2.8 | 36.26 ± 2.1 | 0.42 |

*Results: mean ± SD; median (min-max). CG, Control Group; EG, Exercise Group; BMI, Body Mass Index; MMSE, Mini-Mental State Examination; A-F, Algofunctional Index of Lequesne; FAOS, Foot and Ankle Outcome Score; ADL, Activities of Daily Living; HAP, Human Activity Profile. a Different from CG baseline (p<0.05); independent Student test; U Mann Whitney test).*

(plantar flexion PT at 60º/s; hip flexion ROM) were analyzed through ANCOVA, with the pre-experimental period values inserted as co-variable.

The intragroup and between group effect sizes (ES) were also calculated using the *Cohen's d* equation for dependent (considering the Pearson correlation coefficient: *r*; $d=t_{dependent} \sqrt{2(1-r)/n}$), and independent sample ($d=t_{independent} \sqrt{n_1+n_2}/n_1*n_2$). Additionally, data from 18 GC volunteers at baseline and post 12 weeks were used to evaluate the intra-observer variability of the concentric PT, muscle architecture, ROM and calf circumference measures. This analysis

was performed by calculating the intra-rater intraclass correlation coefficients (ICC) and confidence intervals (95% CI). Statistical significance was set at *p*-values<0.05 for all statistical procedures, which were performed using SPSS ver. 22.0 (IBM, USA).

## Results

Excellent repeatability was observed for the majority of outcomes used in this study: plantar flexor PT at 60º/s

**Table 2.** Concentric ankle plantar and dorsiflexion peak of torque (Nm/s).

| | CG (n=20) | | | EG (n=22) | | | | |
|---|---|---|---|---|---|---|---|---|
| | Pre | Post | $p_{(within\ group)}$ | Pre | Post | $p_{(within\ group)}$ | $F_{(1,\ 40)}$ | $p_{(between\ groups)}$ |
| Plantar flexion PT 60º/s | 44.36 ± 11.7 | 47.34 ± 11.6 | 0.15 | 36.15 ± 9.9 | 42.04 ± 9.2 [a] | 0.001 | 0.012 | 0.91 |
| Δ | 3.0 ± 8.8 | | | 5.89 ± 7.4 | | | | |
| Dorsiflexion PT 60º/s | 18.42 ± 3.7 | 18.9 ± 3.3 | 0.56 | 17.72 ± 3.5 | 18.21 ± 3.8 | 0.50 | 0.002 | 0.97 |
| Δ | 0.44 ± 3.5 | | | 0.49 ± 3.3 | | | | |
| Plantar flexion PT 180º/s | 32.66 ± 8.6 | 32.88 ± 8.8 | 0.90 | 29.26 ± 9.7 | 31.31 ± 8.9 | 0.22 | 0.59 | 0.45 |
| Δ | 0.23 ± 6.9 | | | 2.05 ± 8.3 | | | | |
| Dorsiflexion PT 180º/s | 16.64 ± 4.3 | 15.46 ± 2.3 | 0.07 | 15.58 ± 2.4 | 16.0 ± 3.2 | 0.49 | 3.399 | 0.073 |
| Δ | - 1.18 ± 3.1 | | | 0.42 ± 2.41 | | | | |

Results: mean ± SD; CG, Control Group; EG, Exercise Group; PT, Peak of torque; Δ, Delta score (post test data minus pretest data). [a] Different from EG baseline.

**Table 3.** Medial gastrocnemius muscle architecture.

| | CG (n=20) | | | EG (n=22) | | | | |
|---|---|---|---|---|---|---|---|---|
| | Pre | Post | $p_{(within\ group)}$ | Pre | Post | $p_{(within\ group)}$ | $F_{(1,\ 40)}$ | $p_{(between\ groups)}$ |
| **Muscle thickness (cm)** | | | | | | | | |
| 20% | 1.81 ± 0.23 | 1.84 ± 0.23 | 0.47 | 1.85 ± 0.23 | 1.91 ± 0.36 | 0.11 | 0.36 | 0.55 |
| Δ | 0.03 ± 0.1 | | | 0.07 ± 0.24 | | | | |
| 30% | 1.60 ± 0.26 | 1.64 ± 0.24 | 0.10 | 1.61 ± 0.26 | 1.63 ± 0.27 | 0.49 | 0.55 | 0.46 |
| Δ | 0.04 ± 0.15 | | | 0.02 ± 0.06 | | | | |
| 40% | 0.99 ± 0.29 | 1.05 ± 0.3 | 0.02 | 1.04 ± 0.24 | 1.12 ± 0.28 [a] | 0.001 | 0.67 | 0.42 |
| Δ | 0.06 ± 0.13 | | | 0.09 ± 0.09 | | | | |
| **Pennation angle (º)** | | | | | | | | |
| 20% | 26.47 ± 3.53 | 26.69 ± 3.47 | 0.73 | 27.76 ± 3.46 | 27.74 ± 4.0 | 0.98 | 0,07 | 0,79 |
| Δ | 0.23 ± 2.58 | | | - 0.02 ± 3.12 | | | | |
| 30% | 25.25 ± 3.2 | 26.22 ± 3.85 | 0.08 | 25.82 ± 4.18 | 26.59 ± 4.55 | 0.14 | 0,06 | 0,80 |
| Δ | 0.97 ± 2.78 | | | 0.78 ± 2.15 | | | | |
| 40% | 21.51 ± 3.17 | 22.47 ± 3.59 | 0.12 | 21.52 ± 4.17 | 22.52 ± 3.77 | 0.09 | 0,001 | 0,97 |
| Δ | 0.96 ± 2.40 | | | 0.99 ± 2.91 | | | | |
| **Fascicle length (cm)** | | | | | | | | |
| 20% | 4.18 ± 0.38 | 4.2 ± 0.53 | 0.90 | 4.1 ± 0.54 | 4.08 ± 0.41 | 0.79 | 0,01 | 0,92 |
| Δ | - 0.01 ± 0.35 | | | - 0.02 ± 0.38 | | | | |
| 30% | 4.00 ± 0.45 | 4.01 ± 0.48 | 0.83 | 4.01 ± 0.48 | 3.97 ± 0.57 | 0.61 | 0,26 | 0,61 |
| Δ | 0.02 ± 0.34 | | | - 0.41 ± 0.39 | | | | |
| 40% | 3.51 ± 0.64 | 3.52 ± 0.69 | 0.91 | 3.63 ± 0.69 | 3.62 ± 0.7 | 0.90 | 0,03 | 0,87 |
| Δ | 0.01 ± 0.40 | | | - 0.01 ± 0.51 | | | | |

Results: mean ± SD; CG, Control Group; EG, Exercise Group; Δ, Delta score (post test data minus pretest data). [a] Different from EG baseline

**Table 4.** Hip, knee and ankle range of motion (ROM).

| | CG (n=18) | | | EG (n=22) | | | | |
|---|---|---|---|---|---|---|---|---|
| | Pre | Post | $p$ (within group) | Pre | Post | $p$ (within group) | $F_{(1, 38)}$ | $p$ (between groups) |
| Hip flexion (º) | 73.1 ± 9.4 | 72.3 ± 13.3 | 0.62 | 66.7 ± 8.5 | 68.0 ± 8.6 | 0.36 | 0.69 | 0.41 |
| Δ | -0.8 ± 7.4 | | | 1.3 ± 6.0 | | | | |
| Hip extension (º) | 15.6 ± 2.7 | 17.1 ± 5.3 | 0.43 | 16.8 ± 3.8 | 17.1 ± 3.8 | 0.35 | 1.50 | 0.23 |
| Δ | 1.4 ± 4.4 | | | 0.3 ± 2.4 | | | | |
| Knee flexion (º) | 122.0 ± 9.2 | 119.6 ± 10.1 | 0.07 | 123.4 ± 9.4 | 122.1 ± 9.3 | 0.28 | 0.42 | 0.52 |
| Δ | - 2.4 ± 5.5 | | | - 1.3 ± 5.5 | | | | |
| Ankle dorsiflexion (º) | 35.2 ± 5.6 | 35.4 ± 4.9 | 0.89 | 34.1 ± 7.5 | 36.0 ± 7.2 | 0.04 | 1.83 | 0.18 |
| Δ | 0.1 ± 3.2 | | | 1.8 ± 4.5 | | | | |
| Ankle plantar flexion (º) | 26.7 ± 5.1 | 25.9 ± 5.8 | 0.46 | 27.9 ± 6.0 | 27.4 ± 5.9 | 0.56 | 0.04 | 0.85 |
| Δ | - 0.9 ± 5.1 | | | - 0.6 ± 4.7 | | | | |
| Results: mean ± SD; CG, Control Group; EG, Exercise Group; Δ, Delta score (post test data minus pretest data). | | | | | | | | |

**Table 5.** Sarcopenia diagnostic criteria.

| | CG (n=20) | | | EG (n=22) | | | | |
|---|---|---|---|---|---|---|---|---|
| | Pre | Post | $p$ (within group) | Pre | Post | $p$ (within group) | $F_{(1, 40)}$ | $p$ (between groups) |
| Handgrip strength (Kg) | 22.83 ± 4 | 23.30 ± 4.6 | 0.27 | 20.77 ±3.6 | 20.26 ± 3.7 | 0.20 | 2.94 | 0.09 |
| Δ | 0.47 ± 1.89 | | | -0.52 ± 1.84 | | | | |
| Gait speed (m/s) | 1.36 ± 0.2 | 1.40 ± 0.2 | 0.24 | 1.32 ± 0.2 | 1.30 ± 0.1[a] | 0.45 | 1.93 | 1.17 |
| Δ | 0.04 ± 0.14 | | | -0.02 ± 0.14 | | | | |
| Calf circumference (cm) | 36.87 ± 2.8 | 36.72 ± 2.8 | 0.53 | 36.26 ± 2.1 | 36.87 ± 2.3 | 0.01 | 5.26 | 0.03[b] |
| Δ | -0.16 ± 1.07 | | | 0.61 ± 1.10 | | | | |
| Results: mean ± SD; CG, Control Group; EG, Exercise Group; Δ, Delta score (post test data minus pretest data). [a] Different from EG baseline; [b] Group vs Time interaction. | | | | | | | | |

(ICC=0.847) and 180º/s (ICC=0.815); muscle thickness at 20% (ICC=0.947); 30% (ICC=0.904) and 40% (ICC=0.962); pennation angle at 20% (ICC=0.838); 30% (ICC=0.831) and 40% (ICC=0.869); fascicle length at 20% (ICC=0.779); 30% (ICC=0.818) and 40% (ICC=0.905); hip flexion (ICC=0.883); knee flexion (ICC=0.911) and dorsiflexion ROM (ICC=0.895). Good repeatability was exhibited for the following study outcomes: dorsiflexion PT at 60º/s (ICC=0.721) and 180º/s (ICC=0.718); hip extension (ICC=0.635) and plantar flexion ROM (ICC=0.725).

The training intensity was classified as light-to-moderate, considering the % HRR and RPE values. Also, training intensity did not differ ($p$>0.05) when comparing the first (HR=51±24 BPM; RPE score=13±2), 6th (HR=39±14 BPM; RPE score=12± 2) and 12th (HR=40±18 BPM; RPE score=12±2) exercise weeks. Importantly, the investigators noted a high rate of training adherence among the participants (96%). Among the baseline characteristics, height ($p$=0.03), ankle pain scores ($p$=0.02), plantar flexion PT 60º/s ($p$=0.02) and hip flexion ROM ($p$=0.03) differed between groups. No significant difference was observed for the other characteristics (Table 1).

The effects of the intervention on strength, muscle architecture, ROM, and sarcopenia diagnosis are presented in Tables 2, 3, 4 and 5, respectively. The EG participants showed greater calf circumference improvement (1.68%) than the CG volunteers ($p$=0.03; d=0.71), and EG participants also had greater plantar flexion PT at 60º/s (16.29%; $p$<0.01; d=0.61) and muscle thickness at 40% (8.65%; $p$<0.01; d=0.30) after 12 exercise weeks, when compared to pre-training.

No study participant was diagnosed with sarcopenia as their handgrip strength, gait speed and calf circumference mean values were higher than 18 kg, 1 m/s, and 31 cm, respectively (Table 5).

## Discussion

To the best knowledge of the authors, this work is among the first studies to report the effects of dance training with virtual games on skeletal muscle architecture and function of moderately active community-dwelling older women. The main findings indicate that the training protocol, using light-to-moderate exercise intensity without the use of progressive resistance, was sufficient to induce muscular adaptations. These adaptations included improvements on calf circumference, ankle plantar flexion isokinetic torque, and gastrocnemius thickness at 40%. Other studies have evaluated, in an isolated manner, the effects of dance training[8] or visual computer feedback training[18], but not the combination of dance training using an exergame format. Moreover, previous studies assessed isometric strength, but not isokinetic strength. Moreover, the effects of exergames on plantar flexion strength have not been previously reported[16-18].

The development and maintenance of lower extremity strength remain an important therapeutic target with advancing age. Maintaining adequate ankle plantar flexor (i.e., the calf muscles) strength is critical since the loss of strength in this muscle group is related to slower gait speed, poor balance, and increased risk of falls[2,20,42]. In a classic study by Winegard and colleagues[43], ankle plantar flexion and dorsiflexion isometric strength of apparently healthy older women ($n$=11; initial age 69.5±6.4 years) and older men ($n$=11; initial age 73.5±7.5 years) were evaluated at baseline and then re-evaluated 12 years later. The authors observed more pronounced decrease in plantar flexion strength (24.8%) in comparison with dorsiflexion strength (3.3%) for the female group. These adverse changes were attributed, in part, to muscle architecture and morphology[43]. Winegard and colleagues[43] reported that the type II muscle fibers, which are innervated by larger motor neurons, are affected early during the aging process. This data suggests an average 2.1% annual decrease in plantar flexion strength. Considering the findings of the current study, the observed plantar flexion PT improvement of 16.3% was eight times higher than the potential annual reduction in torque. These data may indicate that only three months of dance exergaming contributed to increase ankle muscle strength similar to the magnitude of strength loss anticipated over one-decade of the aging process. The post-intervention improvement observed is in agreement with the literature regarding the positive effects on muscle strength after virtual games training when measured in other group muscles[11,14,16,17].

The increase in plantarflexion torque can be related to the gastrocnemius muscle mass (i.e., calf circumference and muscle thickness) improvement and the training progression. Even without the addition of external loads, participants had to dance on a foam surface with increased visual task demands. The literature indicates that training on unstable surfaces can increase muscle tension inducing proprioceptive and neural adaptations[44,45], thus providing greater lower limb neural activation and shorter time to activation onset. These adaptations could contribute to a faster muscle response and an enhanced ability to avoid falls in older adults[45-47].

Previous investigators have analyzed the effects of dance training on flexibility and assessed participant performance using tests such as the sit-and-reach test (either on the floor or on the chair)[42,43,45]. In this study, flexibility was evaluated using angular using fleximeter, an angular tool, to assess each joint's ROM. Although "ROM" is an element of "flexibility", the terms are not equivalent. Importantly, flexibility measures can involve more than one joint's ROM[48,49]. Thus, ROM and flexibility outcomes from multiple studies are difficult to compare given the varied measurement approaches employed by different investigators.

The effects of dance training on flexibility are still controversial, especially for the trunk and lower limbs[50]. Hui et al.[51] investigated the effects of 12 weeks of aerobic dance (2x/week, 50 min/session) and did not observe changes in flexibility. On the other hand, Holmerová et al.[52] provided 12 weeks of ballroom dancing for institutionalized seniors (1x/week, 75 min/session), and Janyacharoen et al.[53] provided six weeks of Thai dance for community elders (3x/week, 30 min/session), with both investigators reporting significant increases in post-intervention flexibility. The authors of the current study found no previous research studies reporting the effects of a dance training or exergaming on the ROM of older women.

The knee flexion, hip flexion, and hip extension ROM results are in agreement with the normal reference values for older adults[4,54], while ankle dorsiflexion was slightly above, and plantar flexor was lower than expected[4]. The lack of significant improvements in ankle ROM excursions might be related to training specificity. Although the exercise protocol was composed of dance movements performed over wide joint amplitudes, the end-ranges positions were not maintained for enough time to promote changes in viscoelastic tissue properties to increase ROM[55].

Among the muscular architecture parameters, an improvement in muscle thickness was observed with no further changes in the other parameters. These observations are in partial agreement with recently published findings. In a study of ballroom dance exercise (8 weeks (3x/week, 60 min) for community-dwelling older women, changes were reported in medial gastrocnemius architecture including increases of 15% for MT, 17% for PA, and 10% for FL[8]. On the other hand, neither a conventional strengthening regimen (2 sets, 10 repetitions, 75% of one repetition maximum (RM), 3 min recovery) nor a predominantly eccentric strengthening regimen (3 sets, 10 repetitions, 50% of 1 RM, 3 min recovery) over a 16-week period resulted in medial gastrocnemius adaptations of muscle thickness. Some studies have found that post-exercise muscle architecture adaptations vary based on spatial factors, which are biased towards regions under greater relative tension, i.e., proximal or distal regions. Post-exercise adaptations may be characterized by muscle hypertrophy as well as increases in both serial and parallel sarcomere number[56-58]. Previous

investigators have evaluated the medial gastrocnemius at 30% of the distance between the tibia lateral condyle and the fibula lateral malleolus, whereas the investigators in this study detected significant adaptations at the 40% location which could complicate direct comparisons[8,59].

The increase of 1.68% in calf circumference found in EG participants after the training period must be highlighted as this is a simple, inexpensive method that has been widely used to estimate muscle mass and screen sarcopenia in older population[1]. Nevertheless, this method presents biases. The tape measurement includes subcutaneous adipose tissue, and loss of skin elasticity contribute to errors of estimation in older people, which may confound sarcopenia screening procedures[1]. Therefore, it is important to consider other methods to complement the assessment of muscle mass for the sarcopenia diagnosis. Some studies have demonstrated that muscular architecture assessed through ultrasound imaging can be used for a more detailed evaluation of sarcopenia, while minimizing the confounding effect of subcutaneous fat, thus allowing for better skeletal muscle morphology analyses[60-63].

Notably, some investigators have established cut-off scores for sarcopenia screening by assessing muscle mass loss using ultrasound equipment[60-63]. Minetto et al.[61] propose the value of 1.3 cm for medial gastrocnemius muscle thickness (in its largest portion) for pre-frail institutionalized older adults. Additionally, investigators assessing the largest portion of the gastrocnemius muscle showed that muscle thickness and fascicle length values were significantly lower in sarcopenic community-dwelling older women (muscle thickness: 1.50 (1.16-1.69) cm; fascicle length: 3.46 cm (2.11-4.55 cm)) than in non-sarcopenic individuals (muscle thickness: 1.80 cm (1.12-2.56 cm); fascicle length: 4.07 cm (2.98-5.94 cm)) and have high sensitivity in the prediction of sarcopenia[63]. Although participants in the current study were not classified as sarcopenic according to EWGSOP criteria, the results observed at the 30% portion of the lower leg (which would be equivalent to the largest muscle portion) are similar to those reported by Kuyumcu et al.[63] for sarcopenic older women. Therefore, it can be speculated that more refined methods are required for muscle mass assessment and sarcopenia screening in older community-dwelling adults. Ultrasound can be accepted as a valid method to assess the effects of physical training on muscle architecture. Thus, it should be considered for wider adoption to provide a more detailed muscle tissue assessment in people at risk for sarcopenia.

The virtual dance exercise protocol used in this study featured a progression scheme that increased skeletal muscle mass assessed by calf circumference (1.68%) and by ultrasound at 40% of the distance from the lateral tibia condyle to the lateral fibular malleolus (8.65%), and ankle concentric plantarflexion PT (16.3%) of moderately active older women. The findings presented here suggest that moderate exercise intensity may be a feature of the exercise prescription used for virtual dance programs designed for active community-dwelling older women. It is important to highlight the detailed description, implementation, and progression of a dance exercise regimen with virtual games and the feasibility of group exercise for older people under the supervision of a health professional (e.g., Physical Trainers and/or Physiotherapists).

A lack of a fall risk assessment is a limitation of this study, so it is unknown if the post-exercise musculoskeletal improvements would be likely to decrease fall risk. The use of the calf circumference is also a limitation because this method presents biases such as subcutaneous adipose tissue impairing the estimation of muscle mass. Therefore, it is possible that sarcopenic individuals were not identified in our sample due to a false negative diagnostic classification. Other limitations of this work include absence of sample randomization and blinded evaluations, which could have avoided or minimized the observed baseline differences between groups. Additionally, the comparative effects of virtual dance exercise with and without the foam were not assessed after 6 weeks of training.

Additional study will be needed to better understand the efficacy and safety of the exergame protocol in older male participants. Also, while our findings suggest that muscular adaptations to virtual dance exercise may be greater in the distal regions of the medial gastrocnemius, follow up studies should incorporate additional muscle regions and a wider assortment of targeted muscle groups. Although post-exercise improvements in gastrocnemius muscle mass and ankle plantar flexion strength may improve functionality and help avoid falls, functional improvements were not noted in our participants. This may be a reflection of the participants' relatively high level of functioning upon study enrolment and the selection of outcomes used in this work.

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