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Effects of Dance/Movement Training vs. Aerobic Exercise Training on cognition, physical fitness and quality of life in older adults: a randomized controlled trial

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ABSTRACT

Introduction: It is generally accepted that physical activity promotes healthy aging. Recent studies suggest dance could also benefit cognition and physical health in seniors, but many styles and approaches of dance exist and rigorous designs for intervention studies are still scarce. The aim of this study was to compare the effects of Dance/Movement Training (DMT) to Aerobic Exercise Training (AET) on cognition, physical fitness and health-related quality of life in healthy inactive elderly. **Methods:** A single-center, randomized, parallel assignment, open label trial was conducted with sixty-two older adults (mean age = 67.48 ± 5.37 years) recruited from the community. Participants were randomly assigned to a 12-week (3x/week, 1hr/session) DMT program, AET program or control group. Cognitive functioning, physical fitness and health-related quality of life were assessed at baseline (T-0), and post-training (T-12 weeks). **Results:** Forty-one participants completed the study. Executive and non-executive composite scores showed a significant increase post-training ($F_{(1,37)}$=4.35, p=.04; $F_{(1,37)}$=7.01, p=.01). Cardiovascular fitness improvements were specific to the AET group ($F_{(2,38)}$=16.40, p<.001) while mobility improvements were not group-dependent (10m walk: $F_{(1,38)}$=11.67, p=.002; Timed up and go: $F_{(1,38)}$=22.07, p<.001). **Conclusions:** Results suggest that DMT may have a positive impact on cognition and physical functioning in older adults however further research is needed. This study could serve as a model for designing future RCTs with dance-related interventions. **Registration:** clinicaltrials.gov Identifier NCT02455258.

Keywords

Executive Functions, Cardiovascular Fitness, Prevention, Mobility, Quality of Life

INTRODUCTION

A growing body of research has emphasized the benefits of physical activity on cognition throughout life and during late age (Bherer L et al. 2013). More specifically, an inverse relationship has been established between the level of physical activity and cognitive decline (Larson EB et al. 2006), and longitudinal studies have shown that being physically active was associated with a lower risk of developing dementia (Yaffe K et al. 2001). A higher level of physical functioning abilities was also associated with greater processing speed and better executive functions (Desjardins-Crepeau L et al. 2014). It is proposed that being physically active improves cognition through cellular and molecular changes, structural and functional brain adaptations, and behavioural and socio-emotional modifications (Stillman CM et al. 2016).

Aerobic exercise training (AET) has often been studied in relation to executive functions in older populations. Many cross-sectional studies and randomized controlled trials (RCTs) found moderate to strong associations between aerobic fitness and executive functions (Berryman N et al. 2013). In addition, some studies have linked higher aerobic fitness to better performance on the general cognitive construct of executive functions using composite scores (Berryman N et al. 2013, Netz Y et al. 2010). However, due to its intensity, AET might not be the most preferred program for sedentary older adults who are not used to exercising.

In addition to the positive impact of AET on cognition in healthy (Colcombe S and Kramer AF 2003) and cognitively impaired older adults (Groot C et al. 2016), studies have also highlighted the benefits of other forms of exercise on cognition (Bherer L et al. 2013), namely resistance training (Liu-Ambrose T et al. 2012), gross motor skills training or a combination of AET and resistance training (Berryman N et al. 2014), coordination training (Voelcker-Rehage C et al. 2011, Voelcker-Rehage C and Niemann C 2013), or yoga (Gothe NP et al. 2014). For example, a review of the literature suggests that a coordination exercise program (e.g., balance, hand-eye/leg-arm coordination, spatial orientation, motor learning) could also have a beneficial effect on brain structures and functions (Voelcker-Rehage C and Niemann C 2013), even though it does not impact cardiorespiratory fitness. Accordingly, a study directly comparing the specific impact of this training program to an AET program over a period of 12 months shows similar improvement in executive control and perceptual speed performance (Voelcker-Rehage C et al. 2011).

Local community programs identify dance as one of the most preferred type of physical activity for sedentary older adults (Fan JX et al. 2013). As a result, interventions based on dance have also recently gained interest in the scientific community, as it offers a combination of physical, cognitive and social activities potentially useful for attenuating age-related decline. In a recent review, McNeely ME et al. (2015) report a positive effect of dance on executive functions and quality of life in older adults based on ten intervention studies involving different types of dance (e.g., salsa, ballroom, contemporary, etc.) from 8 weeks to 18 months. Forms of Dance/Movement Training (DMT), such as dance/movement therapy, designed to use movement and dance in order to promote physical, social, emotional and cognitive integration of the individual, have also been used in the literature with both clinical and healthy participants. A meta-analysis has shown that it promotes psychological outcomes (i.e., quality of life, well-being, mood and affect, body image) and reduces clinical symptoms related to depression, anxiety, and interpersonal competence (Koch S et al. 2014). It thus seems that dancing has the potential to be an affordable, accessible (Guzman-Garcia A et al. 2013), and an attractive exercise program to long-term sedentary older adults that can also be promising in reducing the burden of aging, but the specific impacts of DMT on strength, agility and cardiorespiratory health condition, or its use as continuous cognitive stimulation (Ballesteros S et al. 2015) remains understudied. Limits of past studies are, among other things (Predovan D et al. 2018), the lack of a structured intervention and, with the exception of a few studies, the absence of active control groups that would allow assessing dance interventions to more structured physical activity programs commonly used with older adult populations, like AET.

The present study compared the effects of a DMT program to an AET program on cognitive, physical and health-related quality of life (QoL) dimensions, using a structured RCT design. Given the reported effect of exercise and dance in previous studies, we hypothesized that participants in the DMT and AET groups would show improved cognition. Secondary hypotheses included increased improvement in health-related QoL in DMT compared to the AET and Control groups and an increase in cardiovascular fitness in the AET group as opposed to the other groups.

METHODOLOGY

Trial Design

A single-center, randomized, parallel assignment, open label control trial (Clinicaltrials.gov NCT02455258) with a three-arm design was completed from March 2015 to April 2016. All potential participants were screened over the phone with a general description of the project and a medical questionnaire to determine their eligibility. If participants met inclusion criteria, they were invited to complete a full geriatric assessment, a neuropsychological screening and pre-testing sessions (T-0). Pre-testing targeted several outcome domains: cognitive function, physical fitness, and health-related QoL. After T-0, participants were randomized into one of three groups (DMT, AET, CG). Following 12 weeks of training, participants underwent post-testing sessions (T-12 weeks) evaluating the same outcomes as pre-test. Evaluation days lasted maximum four hours and were scheduled within a two-week period (T-0, M=8.26, +/- 3.96 days before intervention; T-12, M=7.71, +/- 3.84 days after intervention). Assessments were completed over the course of two days and scheduled with consideration for potential cognitive and/or physical fatigue. The local Research Ethics Board of the geriatric institution where the study took place approved the project (CER IUGM 13-14-029), and written informed consent was obtained from all participants before data collection.

Participants

Inclusion criteria: Men and women aged 60 and over who were inactive (i.e., not meeting the American College of Sports Medicine physical activity guidelines to engage in 150 minutes of moderate intensity structured exercise per week), were targeted in this study.

In addition, they had not participated in another similar intervention study within the last year (i.e., had not been exposed to an AET or DMT program and/or had not been tested with a similar neuropsychological test battery). No mobility limitations were presented or any surgeries involving a general anaesthetic in the past year. Eligibility included non-smokers (within the last five years) and those who consume ≤2 standard measures of alcohol per day.

Exclusion criteria: A diagnostic of orthopaedic, neurological, cardiovascular, respiratory progressive somatic or psychiatric problems within the last six months or presented uncorrected auditory or visual limitations. Participants undergoing hormone therapy were excluded to avoid the interaction effects with prolonged physical activity in women. Participants with cognitive impairments as assessed with the Mini-Mental State Examination (MMSE) (Folstein M, Folstein, S., McHugh, P. 1975) (score of ≤ 24) were also excluded.

Once enrolled, participants were informed to refrain from changing their lifestyle behaviours (i.e., level of physical activity, diet, etc.) between T-0 and T-12. Recruitment was ongoing until the final cohort using advertisements placed in newspapers, on social media, in elevators, community centers, libraries and local businesses.

<u>Interventions</u>

Participants randomly assigned to either intervention group (DMT or AET) were enrolled in a training program with three 60-minute sessions per week. Both DMT and AET programs took place at the same geriatric institution research center in a gym facility dedicated to research. Participants were asked to attend at least 80% of the training sessions (i.e. could not miss more than 7 of the 36 sessions), otherwise they were excluded from the analyses.

Dance/Movement Training (DMT)

The DMT intervention used in this study was designed according to the standards of the American Dance Therapy Association (ADTA 2019) and adapted to the needs of the healthy older participants. An ADTA registered dance/movement therapist or a supervised trainee led the group training of 4-8 participants. Normally dance/movement therapy programs are quite flexible in nature, however, since this was a RCT, facilitators were asked to follow a common dance/movement therapy structure for each session (opening circle, warm up, development, and closure). Since the participants did not present with any health diagnoses to be resolved, the program did not follow a specific therapeutic treatment plan but rather, was comprised of expressive movement and guided gestures to expand participants' movement repertoire. Each facilitator was also given a list of themes pertinent to the healthy older adult to focus on in their intervention, such as lifestyle improvement, body awareness, relaxation, balance, self-care, socialization, rhythm and, enjoyment. Throughout the training program, props such as the Octaband©, the CoOper Blanket©, the Elastablast©, colorful scarves, exercise balls, TheraBands™ and tennis balls were used. Sessions were held in a space of approximately 4.5m x 10m. Music was not imposed as a part of this RCT, however, it was often incorporated. When used, music of differing styles was chosen based on the objectives of the movement, sometimes proposed by the group facilitator or the participants.

Aerobic Exercise Training (AET)

A certified kinesiologist supervised each session, which was comprised of a warm up, cardiovascular training on a seated recumbent bicycle and a cool down (adapted from Berryman N et al. (2014); see Supplemental Table 1 for a detailed protocol). The warm up and cool down were five minutes each, where participants used an ergometer of their choosing (bicycle, treadmill, elliptical). The cardiovascular training was tailored to the participant's maximal aerobic power (MAP) determined from the VO_2 peak test at T-0. The program was structured with 15-second bouts interval training (up to 110% of their MAP) twice a week mixed with continuous training (up to 70% of their MAP) once a week. Since the protocol demanded a high level of attention from the kinesiologist, a ratio of 2:1 (participants to trainer) was maintained, meaning the participants exercised in pairs.

Control Group (CG)

As a passive control group, CG participants were placed on a waiting list for the exercise group of their choosing (DMT or AET) and were offered to be a part of that group in the following cohort. While on the waiting list from T-0 to T-12, CG participants were asked to refrain from enrolling in any physical activity programs or changing their habitual lifestyle behaviours.

Outcomes

Initial Screening

Participants' risk in enrolling in this study was evaluated using the self-reported Physical Activity Readiness Questionnaire (PAR-Q+) as well as a comprehensive geriatric assessment. A certified geriatrician performed each medical evaluation during a 45- to 60-minute consultation. Various health components were assessed including, but not limited to, heart rate, blood pressure, current medical conditions and/or complaints in all physiological systems: cardiovascular, pulmonary, neurological, musculoskeletal, other (any condition that does not fit in the aforementioned categories), personal and family medical history, functional capacities, allergies, list of medications, a physical exam, and a frailty assessment. Participants were also screened for short-term memory, working memory and abstraction/reasoning (WAIS-4 Digit Span forwards and backwards and Similarities) (Wechsler D 2008), processing speed and visuo-constructive abilities (WAIS-3 Substitution) (Wechsler D 1997).

Primary Outcomes

Cognition

Graduate students in neuropsychology were trained by a certified neuropsychologist to administer the cognitive test battery with each participant in a quiet room. Executive functions were assessed using three tablet tasks (Dual-task, N-back, and Digit Stroop) based on previous studies (Logie RH et al. 2004, Miyake A et al. 2000). These tasks were administered on an iPad Air 16GB (9.7 inches) using Safari as the browser.

Firstly, the dual-task paradigm was adapted from previous studies (Bherer L et al. 2005, Bherer L et al. 2008, Lussier M et al. 2017a, Lussier M et al. 2017b, Lussier M et al. 2012) and consisted of performing two concurrent visual discrimination tasks, one with each hand. The paradigm involved two types of blocks. In the pure blocks, participants completed only one task at a time (single-pure trials, SP) and for each task they had to discriminate between three visual objects. Mixed-blocks were composed of trials presenting stimuli from only one of the two tasks (single-mixed trials, SM) or both at the same time (dual-mixed trials, DM). In all trials, participants had to answer as fast as possible. Reaction time (RT) and accuracy were recorded. As accuracy is generally high in this task (over 98.4%) the variable of interest is RT (in ms).

Secondly, the N-back task participants had to answer if a presented stimulus was the same or different than the one presented two positions before (reported as 2-back) (Owen AM et al. 2005). Participants also performed a 1-back task where they had to identify if a presented stimulus was the same as the one presented one position before. Stimuli were presented visually on the screen and audibly through headphones every three seconds. The variable of interest for this task is accuracy (percentage of correct responses).

Finally, the Digit Stroop task was also based on previous studies (de Paula J et al. 2014, Sedo M 2004) and was comprised of four different conditions: Reading, Counting, Inhibition, and Switching. During the Reading block, digits 1 to 6 were presented on the screen and the participants were instructed to identify it by pressing the corresponding button. During the counting block, a quantity of stars (from one to six) appeared on the screen, and participants had to say how many there were by pressing the correct button. In the Inhibition condition, a quantity of identical digits was present on the screen. The quantity differed from the digit (e.g., “2 2 2 2”). Participants were instructed to identify the quantity by pressing the corresponding button. In the Switching condition, participants had to identify the quantity unless a white border appeared on the screen, in which case they had to identify the digit. Stimuli were presented one at a time on the screen, and participants answered by pressing one of the six possible answer buttons as fast as possible. RTs and accuracy were recorded for all conditions. However, the variable of interest for this task is RT due to the high accuracy (over 96% for Reading, over 95% for Inhibition, and over 89% for Switching).

In addition to the Dual-Task, N-back and Digit Stroop, global cognition was measured using the paper-pencil Montreal Cognitive Assessment (MoCA; version 7.1 at T-0, 7.2 at T-12) (Nasreddine ZS et al. 2005).

Composite Scores

Two composite scores were created from all the cognitive tablet tasks, the first representing executive functions and the second, non-executive functions. The Z-scored values averaged in the executive composite score were: (1) 2-back accuracy (percentage of correct answers), (2) average SM trials’ RTs from the Dual-task, (3) average DM trials’ RTs from the Dual-task, (4) average RTs from the Stroop inhibition block, and (5) average RTs from the Stroop switching block. It is generally considered that these tasks mainly rely on executive processes. All included variables correlate with each other except DM RT and 2-back accuracy ($p=.12$), and overall, the items included have a strong degree of internal consistency (Cronbach's $\alpha = .83$).

The non-executive composite score was based on averaged Z-scores of the following items: (1) 1-back accuracy, (2) average SP trials' RTs from the Dual-task, and (3) average RTs from the Stroop reading block. It is generally considered that these tasks mainly rely on non-executive processes. The values included in this composite score also correlate with each other except 1-back and SP RT ($p =.16$), and they all have a moderate degree of internal consistency (Cronbach's $\alpha = .70$).

Secondary Outcomes

Physical Fitness

A graduate student under the supervision of a kinesiologist administered the tasks one-on-one with each participant. Physical fitness assessments targeted cardiovascular health by means of a VO_2 peak test using the procedure described in Berryman N et al. (2013), the Rockport One-Mile test (Kline GM et al. 1987) and an estimative equation (Jurca R et al. 2005). Due to a gas analysis malfunction during the study, the oxygen values of the VO_2 peak test could not be used. Instead, the MAP was calculated as the highest power (in Watts) reached during the test. If the participant was not able to finish the whole level, the amount completed was taken into account when calculating the MAP. Body composition (DXA) (Nana A et al. 2015), anthropometric measures, mobility (TUG) (Podsiadlo D and Richardson S 1991), walking speed (10m walk) (Graham JE et al. 2008), and handgrip strength (Abizanda P et al. 2012) were also assessed. Three trials were recorded per participant for the TUG and the 10m walk with a hand-held stopwatch. The fastest trial (in seconds) was used for statistical analysis. Similarly, three trials were recorded for each hand for the handgrip strength and the sum of the best scores for each hand was used for statistical analysis.

Health-Related QoL

Self-administered questionnaires measuring QoL (SF-12) (Ware J, Jr. et al. 1996), depression (Geriatric Depression Scale; GDS) (Yesavage JA et al. 1982), anxiety (State-Trait Anxiety Inventory; STAI) (Spielberger C 1983), lifestyle (Health Promoting Lifestyle Profile-2; HPLP2) (Walker SN et al. 1987), mental health (Mental Health Continuum-Short Form, MHC) (Lamers SM et al. 2011), nutrition (Short Dietary Screener Questionnaire; DSQ) (Institute NC 2016), sleep (Pittsburgh Sleep Quality Index; PSQI) (Buysse DJ et al. 1989), pain (Brief Pain Inventory; BPI) (McDonald DD et al. 2008, Poundja J et al. 2007), and social network (Lubben Social Network Scale-Revised; LSNS) (Lubben JE 1988) were used at T-0 and T-12. A package of these questionnaires was given to all participants to fill out during waiting times in the laboratory at evaluation sessions. Research assistants were available to respond to any questions if written instructions were unclear.

Randomization

Sequence Generation

A random sequence was generated using SPSS then individually altered one participant at a time until the groups were equivalent for gender, age and education level (within a 95%

confidence interval). A technique of stratified randomization was followed in order to aim for an equal proportion of completed participants among groups (DMT, AET, CG).

Allocation Concealment Mechanism

An open-label allocation concealment mechanism was used.

Implementation

The coordinator was responsible for assigning participants and information linking evaluations and training was kept confidential in a password-protected computer only accessible to the project coordinator and the principal investigator.

Blinding

Participants were aware of the two intervention groups available and knew which of the two groups they were assigned to. Evaluators who were responsible for administering the tests were blind to participants' assigned interventions and trainers/dance therapists were not involved in administering the pre-, post- or follow up evaluations except for the VO2max testing, which was performed by the certified kinesiologist who supervised the AET training.

Statistical Methods

All statistical analyses were performed using IBM SPSS Statistics software v20 for Windows (IBM, Inc., Chicago, IL). Data distribution was verified using the kurtosis and skewness of all variables. In order to decrease the impact of extreme outliers a ceiling value of 3 SD away from the mean was set (Tabachnick BG and Fidell LS 2013). Before performing analyses, all values were first transformed into standardized Z-scores by pooling the pre- and post- values from all participants for the calculation of the mean and SD, and variables favouring a lower score (e.g., reaction time, fat mass) were multiplied by -1 so that a higher value would reflect a better performance in all instances. Baseline group comparisons were performed using one-way ANOVAs or nonparametric statistics when applicable. If the assumption of sphericity was violated, Welch's ANOVA was used to detect for group differences. Since the results did not differ for most variables, only one-way ANOVA values are reported. In order to test the impact of the interventions, repeated measures ANOVAs were run on all scores (cognitive, physical and health-related QoL) using the group as a between-subjects variable and time as a within-subjects variable. The significance level was set to $p<.05$.

RESULTS

Participants

In total, 62 participants gave their consent and were randomized to one of the three groups: AET (n=21), DMT (n=23), and CG (n=18) with a total of 41 participants completing post-tests (see Figure 1 for overview).

Losses and Exclusions

In total 21 participants dropped out of the study (AET=6, DMT=11, CG=4; x^2= 3.35, $p<.19$), and there was no significant difference in baseline characteristics between them and those that finished the program. In each group, there were multiple reasons for losses, notably, the intervention not meeting participants expectations, medical reasons (not as a result of the intervention), family events and/or availability. Any exclusion after randomization was as a result of a new medical condition that was defined as an exclusion criterion or a surplus of absences.

[INSERT FIGURE 1 HERE]

Baseline Data

Table 1 presents initial screening and baseline assessment values for all participants that finished the 12-week intervention (DMT, AET or CG). Training compliance was calculated from attendance records. No significant differences between groups were found at baseline on initial screening measures nor any of the primary or secondary outcomes measures.

[INSERT TABLE 1 HERE]

Numbers Analyzed

During the DM block of the dual-task some participants did not respect the instructions and grouped their answers (9 participants at T-0, and 20 participants at T-12). For those situations, their RTs were replaced with the average RT in the DM block across all participants specific to the time of testing. One CG participant was dropped from all analyses involving tablet tasks because T-0 cognitive values were not registered due to a technical error (final N = 40 for cognitive values). Otherwise, the whole sample (N=41) was used except for the Rockport test (one CG participant missing), SF-12 (two CG participants missing), GDS (one participant per group missing), STAI-S (one CG participant missing), LSNS (one CG participant missing). The missing data listed above is due to incomplete information and has been found to be missing at random using Little's MCAR test. An imputation analysis was used to fill in missing data for all participants that started the trial. All statistical tests were performed both on variables with imputed values and original data and the pattern of significance was identical. Therefore, the values presented in this paper come from non-imputed data.

Outcomes and estimation (see Table 2 for selected variables and Supplemental Table 2 for remaining Z-score results)

[INSERT TABLE 2 HERE]

Primary Outcomes

Cognition

There was no time effect, group difference or interaction for the MoCA. The executive composite score showed a significant increase post-training ($F_{(1,37)}$ = 4.35, p = .04, η_p^2 = .11), but no group difference or interaction. The non-executive cognitive score also revealed a significant performance increase post-training ($F_{(1,37)}$ = 7.01, p = .01, η_p^2 = .16) without a group difference or interaction.

Secondary Outcomes

Physical Fitness

Appendicular lean body mass ($F_{(1,38)}$=4.70, p=.04, n_p^2=.11), 10m walking speed ($F_{(1,38)}$=11.67, p=.002, n_p^2=.24), Timed Up and Go ($F_{(1,38)}$=22.07, p<.001, n_p^2=.37) and Rockport time of completion ($F_{(1,37)}$=23.41, p<.001, n_p^2=.39) showed significant improvements post-training, but no group difference or interaction. Grip strength showed significant decline at post-training ($F_{(1,38)}$=4.50, p=.04, n_p^2=.11), and also no group difference or interaction. There was a significant time x group interaction in the estimated VO_2 max equation ($F_{(2,38)}$=5.34, p<.01, n_p^2=.22) and the MAP from the VO_2 peak test ($F_{(2,38)}$=16.40, p<.001, n_p^2=.46). The AET group was the only one to show an increase in the estimated VO_2 max equation ($F_{(1,14)}$=20.23, p<.01, n_p^2=.59) and the MAP ($F_{(1,14)}$ =29.90, p<.001, n_p^2=.68), while the other two groups did not change.

Health-Related QoL

State anxiety determined from the STAI revealed a group x time interaction ($F_{(2,37)}$= 5.01, p<.05, n_p^2=.21), with the CG having the only significant improvement ($F_{(1,12)}$=7.26, p<.02, n_p^2=.38). The global health lifestyle from the HPLP-2 also showed significant group x time interaction ($F_{(2,38)}$=6.78, p<.01, n_p^2=.26) with the CG showing the only significant increase ($F_{(1,13)}$=12.85, p<.00, n_p^2=.50). The global MHC score showed significant improvement post-training ($F_{(1,38)}$=6.37, p<.05, n_p^2=.14), and no group difference or interaction. All other scores showed no significant change.

DISCUSSION

The present study aimed at empirically comparing the effects of a 12-week DMT program to an AET program on cognition, physical fitness and health-related QoL in healthy inactive older adults by means of a RCT. Overall, only one of our three hypotheses was confirmed. First, results indicated both executive and non-executive functioning improvement over the 12-week intervention, however, this improvement was not specific to the training groups, since the CG also showed improvement at post-testing. Second, the AET group showed a significant increase in the MAP as well as in the estimated VO_2 max equation, which was not observed in the DMT and CG groups. Third, an improvement was seen in state-anxiety and the HPLP-2 for the CG group but overall, health-related QoL was maintained across all three groups, limiting our abilities to attribute any changes to one of the physical activity interventions proposed in this study. Although results show no significant group difference improvements for the 10m walking speed, according to Perera S et al. (2006) a substantial clinically relevant improvement was observed in the DMT group (Δ 0.16m/s, 95% CI: .017 - .295), while only small meaningful changes were observed in the AET (Δ 0.09m/s, 95% CI: .002 - .176) and CG (Δ 0.06m/s, 95% CI: -.053 - .165) groups.

The results of the present study match some other RCTs that have borderline or null results in the domain of alternative physical activity interventions on cognition in aging (Gothe NP et al. 2014, Merom D et al. 2016). However, some other dance-related intervention studies have been successful in showing positive results. For example, Hamacher D et al. (2015) assessed change in executive functions in older adults after a multi-style dance intervention and observed a positive impact, however, the study lacked methodological rigour by not using an RCT design. Furthermore, Bräuninger I (2012) reported a positive effect on QoL and used an RCT design, but the population sample combined young and old adults, which may bring many other important limitations to consider. Possible explanations for the discrepant results between the present study and past attempts could be due to the unknown dose-response needed for DMT programs in healthy inactive older adults. Furthermore, the physical intensity and memory components of this dance-related intervention should be explored and diligently measured in future studies. Moreover, the present study used standardized assessments often used for evaluating conventional physical activity exercise programs. Future studies may consider adding experimental assessments to explore more subtle changes that may not be captured here. Overall, the findings from this study provide empirical data to support future research that should concentrate on establishing the ideal volume of exercise needed to induce changes in cognition and aim to identify the biological mechanisms responsible for this effect.

Limitations

The generalizability of this study is limited by the relatively small sample size, and the unbalanced number of men included. In addition, physical and cognitive deficits are common in the aging population; however, selection criteria for this study required all participants to be physically and cognitively healthy for their age group. Thirdly, cross-contamination between training groups may have occurred and without strict monitoring we are unable to confirm that the three groups did not change their lifestyle habits over the 12 weeks. Therefore, the interpretation of these results should be made with caution.

Finally, another limitation of this study is the adaptation of the DMT program to the standards of an RCT. Due to the high degree of variation and improvisation used in a DMT program, the facilitators were asked to standardize elements of their intervention to ensure that all cohorts were exposed to a similar program. As a result, the impact of the DMT program used in the current study might be slightly different than other programs of its kind.

CONCLUSION

Dancing has the potential to be a promising and somewhat inexpensive type of intervention toward reducing the burden of aging. To the best of our knowledge, this is the first randomized controlled trial examining the effects of a DMT program with healthy inactive older adults on cognition, physical fitness and health-related QoL dimensions. This study could serve as a model for designing future RCTs with dance-related interventions.

Clinical Relevance

Future studies addressing the methodological challenges of putting a DMT program in a RCT design could lead to the development of multimodal physical activity programs tailored to seniors that contribute to their wellbeing and could influence the way in which health professionals present and discuss exercise with older adults.

OTHER INFORMATION

Registration

This study is a randomized control trial registered with ClinicalTrials.gov with the identification number NCT02455258.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Authors' Contributions

LB conceived and designed the study and wrote the grant application to the Quebec Ministry of Health and Social Services. AE contributed to the study design, coordinated the project and provide the first draft of the manuscript. AE, LB and TV actively contributed to manuscript writing and statistical analyses. LB and AE supervised the team of students and assistants that recruited and tested participants and carried out all interventions. TV participated in testing and writing the manuscript. All authors played a specific role in the study based on their expertise, either by providing advice, measurement tools and expertise. All authors read and approved the manuscript.

SUPPLEMENTAL MATERIAL

This document provides supplemental information on the AET protocol and the remaining Z-score results of variables registered in the RCT and not presented in the tables that appear in the manuscript.

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Table 1: Baseline characteristics of participants who finished post-testing (M ± SD)

Characteristics	**DMT (N=12)**	**AE (N=15)**	**CG (N=14)**	**F or x^2**	**p**
Age *(years)*	68.08 (7.59)	67.20 (4.20)	67.21 (4.12)	F= 0.11	0.89
% Female	66.67%	73.33%	85.71%	x^2=1.34	0.51
Education *(years)*	14.50 (3.12)	16.00 (4.47)	15.21 (4.02)	F= 0.48	0.62
% Right Handed or Ambidextrous	91.67%	100%	92.86%	x^2=1.23	0.54
% Francophone	91.67%	66.67%	78.57%	x^2= 2.44	0.30
Geriatric Evaluation					
Height (cm)	161.09 (8.40)	164.57 (6.88)	160.44 (8.98)	F= 1.09	0.35
Weight (kg)	73.64 (13.22)	77.65 (13.48)	66.31 (15.77)	F= 2.34	0.11
Cardiovascular risk factors *(n)*	0.91 (1.04)	0.85 (0.90)[1]	0.15 (0.38)	x^2= 8.43	0.21
Pulmonary risk factors *(n)*	0 (0)	0.21 (0.58)	0 (0)	x^2 = 3.62	0.46
Neurological/Neurocognitive risk factors *(n)*	0.18 (0.41)	0 (0)	0.78 (0.28)	x^2 = 2.80	0.25
Musculoskeletal Risk factors *(n)*	0.91 (0.83)	1.29 (0.73)	0.80 (0.79)[3]	x^2 = 2.81	0.59
Other risk factors *(n)*	0.80 (0.63)[1]	1.21 (0.43)	0.90 (0.57)[3]	x^2 = 4.97	0.29
% Family history of cognitive disorder	33.33% [3]	6.67% [3]	14.29% [1]	x^2 = 4.83	0.09
% Recreational drug use	0	6.67%	0	x^2 = 1.76	0.42
% Inability to perform ADLs or IADLs	0	0	0	-	-
% Taking Cardiac Medication	33.33%	60.00%	21.43%	x^2 = 4.91	0.09

% Taking Diabetic Medication	8.33%	6.67%	0%	x^2 = 1.15	0.56
% Taking Psychotropic Medication	8.33%	20.00%	7.14%	x^2 = 1.34	0.51
% With ≥ 1 fall in the last year	8.33%	0 [1]	0 [1]	x^2 = 2.34	0.31
Systolic Blood Pressure	136.64 (16.65)	136.57 (14.93)	137.15 (25.47)	F= 0	1.00
Diastolic Blood Pressure	78.64 (8.82)	80.29 (8.32)	77.39 (10.66)	F= 0.33	0.72
Resting Heart Rate	71.36 (7.75)	67.07 (10.31)	67.69 (9.89)	F= 0.71	0.50
Fried Frailty Criteria	0.27 (0.47)	0.29 (0.47)	0.23 (0.44)	x^2 = 0.11	0.95
MMSE	27.83 (1.53)	27.80 (1.42)	28.43 (1.45)	F= 0.81	0.45
General Health in account for Age (self reported on scale 1-5)	4.29 (0.81)	4.10 (0.71)	3.86 (0.66)	x^2 = 9.04	0.34
Hearing Capacity (self reported on scale 1-5)	4.13 (0.80)	3.37 (0.67)	3.71 (0.83)	x^2 = 9.46	0.31
Visual Capacity (self reported on scale 1-5)	4.17 (0.72)	3.57 (0.68)	4.07 (0.62)	x^2 = 9.72	0.29
WAIS-4 Similarities	23.33 (5.26)	25.27 (6.31)	24.07 (3.83)	F= 0.47	0.63
WAIS-4 Digit span	18.50 (3.71)	18.73 (5.91)	17.36 (2.44)	F= 0.41	0.67
WAIS-3 Substitution	59.83 (9.56)	56.67 (14.06)	65.29 (13.34)	F= 1.71	0.20
Total training compliance (%)	90.74%	91.30%			

Note. ADL= Activities of Daily Living; IADL= Instrumental Activities of Daily Living; MMSE= Mini-Mental State Examination; WAIS= Wechsler Adult Intelligence Scale

[n] number of participants missing data

*one participant per group is missing a geriatric evaluation in addition to missing data presented with [n]

Table 2: Selected pre-post Z-score results (M ± SD)

	DMT (n=12)		**AET (n=15)**		**CG (n=14)**		**time X group**		**time**	
	Pre	Post	Pre	Post	Pre	Post	F	p	F	p
Cognition										
Executive composite score	-.15 (0.75)	-.04 (0.81)	-.11 (0.88)	.10 (0.72)	.04 (0.80)	.15 (0.71)	.27	.78	4.35	**.04***
Non-Executive composite score	.02 (0.79)	.10 (0.68)	-.07 (0.89)	.10 (0.73)	-.29 (0.89)	.08 (0.77)	1.19	.32	7.01	**.01***
MOCA	.36 (1.07)	.04 (0.74)	.04 (1.18)	.18 (0.77)	-.12 (1.03)	-.46 (1.08)	.92	.41	1.04	.31
Physical										
BMI (kg/m^2)	-.07 (1.00)	-.10 (0.97)	-.17 (0.85)	-.10 (0.87)	.21 (1.19)	.22 (1.19)	2.44	.10	.59	.45
DEXA Appendicular lean body mass (kg)	.12 (0.96)	.16 (1.00)	.17 (1.18)	.20 (1.23)	-.34 (0.74)	-.29 (0.77)	.27	.77	4.70	**.04***
Equation estimated VO_2 max (ml/kg/min)	-.06 (1.06)	.08 (1.23)	-.12 (0.85)	.54 (0.85)[¥]	-.23 (1.00)	-.24 (0.98)	5.34	**.01***	8.56	**.01***

10-metre walking speed (m/s)	-.47 (0.95)	.10 (1.14)	-.01 (1.00)	.32 (0.70)	-.11 (0.96)	.10 (1.24)	.93	.4	11.67	**.00****
Timed Up and Go (s)	-.30 (1.33)	.14 (0.97)	-.21 (0.78)	.39 (0.77)	-.24 (1.05)	.17 (1.05)	.36	.7	22.07	**.00****
Maximal Aerobic Power (watts)	.22 (1.33)	.25 (1.23)	-.11 (0.88)	.43 (0.96)[¥]	-.38 (0.70)	-.37 (0.71)	16.4	**.00****	19.96	**.00****
Rockport Time (s)	-.37 (1.11)	-.05 (1.09)	-.21 (0.89)	.26 (1.01)	-.07 (0.95)	.30 (0.99)	.27	.76	23.41	**.00****
Health-Related QoL										
SF-12 Physical Component	-.25 (0.98)	.31 (0.53)	-.58 (1.45)	.23 (0.75)	.16 (0.76)	.27 (1.06)	.60	.55	3.7	.06
SF-12 Mental Component	.11 (1.22)	.17 (0.93)	-.23 (0.90)	.00 (0.88)	.04 (1.21)	-.04 (1.03)	.23	.80	.13	.72
STAI-State	.09 (0.86)	-.11 (1.25)	.13 (0.77)	-.03 (1.11)	-.46 (1.25)	.37 (0.61)[¥]	5.01	**.01***	1.06	.31
STAI-Trait	.07 (1.09)	.16 (1.09)	-.15 (0.85)	.00 (0.93)	-.03 (1.17)	-.01 (1.05)	.22	.81	1.15	.29
HPLP-2	.24 (1.10)	.24 (0.98)	-.10 (0.92)	-.38 (0.96)	-.15 (1.02)	.26 (1.03)[¥]	6.78	**.00****	.25	.62
MHC	.12 (0.96)	.25 (0.87)	-.25 (0.83)	.08 (0.71)	-.26 (1.42)	.13 (1.14)	.39	.68	6.37	**.02***
BPI- Pain Interference[§]	.38 (0.43)	-.24 (1.02)	-.43 (1.54)	-.03 (0.98)	.41 (0.36)	-.04 (0.98)	3.22	**.05***	1.55	.22
LSNS	.06 (0.94)	.02 (0.86)	.07 (0.83)	-.02 (0.68)	-.19 (1.18)	.06 (1.52)	1.13	.33	.2	.66

Note. SF-12 = Short Form Health Survey; STAI= State-Trait Anxiety Inventory; HPLP-2= Health Promoting Lifestyle Profile-2; MHC= Mental Health Continuum; BPI= Brief Pain Inventory; LSNS= Lubben Social Network Scale

¥ = A significant within-group time effect

§ = Due to the non-normal data distribution, non-parametric tests have been used and no significant group differences have been found

*$p < .05$, **$p < .01$

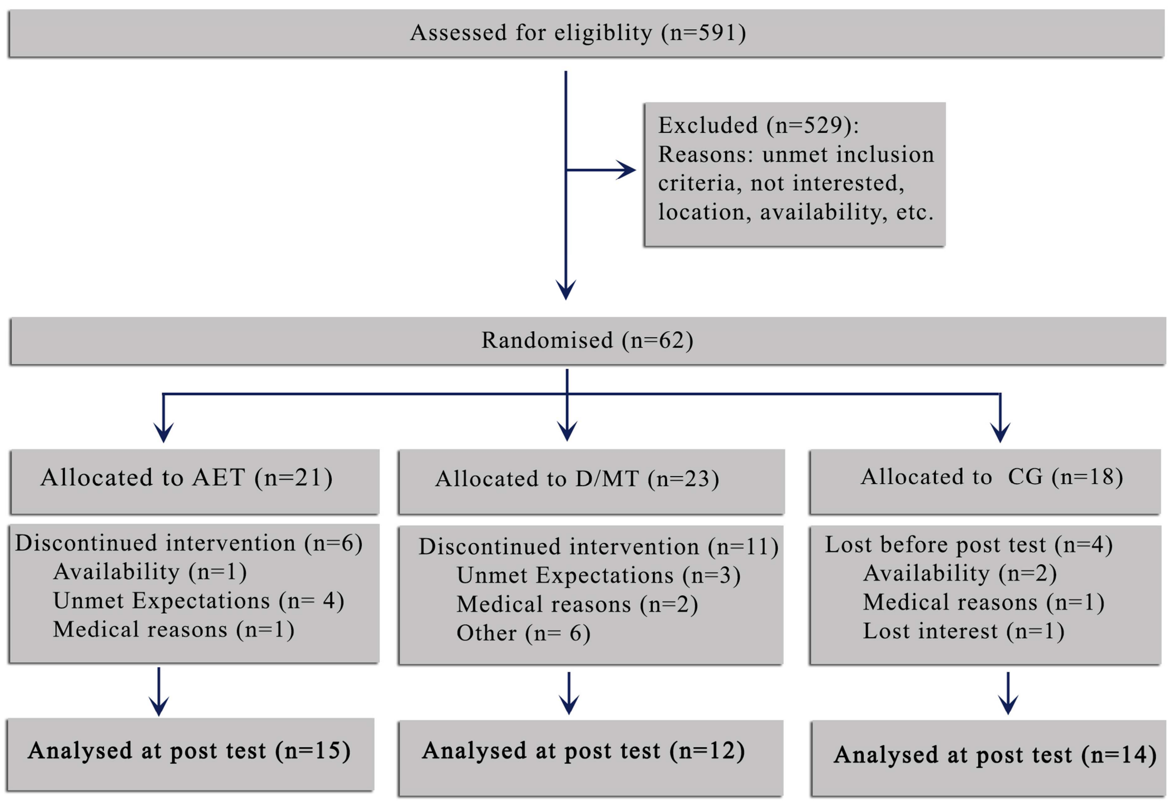

Figure 1: Participant Flow and Timeline

Conflict of Interest

The authors declare that they have no conflict of interest.