Brain Health in Older Latinos: Associations with Physical Activity Levels and the Impact of BAILAMOS™

BY

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DISSERTATION

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LIST OF ABBREVIATIONS

PA	Physical activity
LTPA	Leisure-time physical activity
MVPA	Moderate-to-vigorous physical activity
CRF	Cardiorespiratory fitness
RPE	Rate of perceived exertion
MET	Metabolic equivalent
US	United States
RCT	Randomized controlled trial
IRB	Institutional Review Board
UIC	University of Illinois at Chicago
CONSORT	Consolidated Standards of Reporting Trials
MMSE	Mini-Mental State Examination
EASY	Exercise Assessment and Screening for You
BMI	Body mass index
UDS	Uniform Data Set
TMT	Trail Making Test
CHAMPS	Community Healthy Activities Model Program for Seniors
ANOVA	Analysis of variance
IQR	Interquartile range
CI	Confidence interval
MCI	Mild cognitive impairment
ADRD	Alzheimer’s disease and related dementia

MRI	Magnetic resonance imaging
fMRI	Functional magnetic resonance imaging
DTI	Diffusion tensor imaging
FLAIR	Fluid-attenuated-inversion-recovery
BET	Brain Extraction Tool
EPI	Echo-planar imaging
BIANCA	Brain Intensity AbNormality Classification Algorithm
WM	White matter
WMV	White matter volume
WMI	White matter integrity
WMH	White matter hyperintensities
FA	Fractional anisotropy
AD	Axial diffusivity
RD	Radial diffusivity
MD	Medial diffusivity
ICV	Intracranial volume
FC	Functional connectivity
BOLD	Blood oxygenation level-dependent
DMN	Default mode network
FPN	Frontoparietal network
SAL	Salience network
FEN	Fronto-executive network
ECN	Executive-control network

LAN	Language network
ROI	Region of interest
CPM	Counts per minute

SUMMARY

Three complementary but different studies were conducted. Manuscript one was a pilot randomized controlled trial; manuscript two a cross-sectional study; and manuscript three a single-group pre- and post-design.

Manuscript 1 aimed to investigate the impact of a four-month dance program (BAILAMOS^{TM}) on self-reported and device-assessed PA and cognition, and whether changes in PA were associated with changes in cognition in older Latino adults. Participants were 57 cognitively intact older Latino adults randomized to either the BAILAMOS^{TM} dance program treatment group (n= 28) or the health education control group (n= 29). BAILAMOS^{TM} is a four-month, twice a week dance program with four Latin dance styles. Participants' engagement in physical activity (PA) (self-reported and device-assessed), estimated cardiorespiratory fitness (CRF), and cognition were tested at baseline and post-intervention. Participants in the BAILAMOS^{TM} group significantly decreased their engagement in light leisure-time PA. There were no statistically significant changes in other self-reported and device-assessed PA intensities, sedentary behavior, or estimated CRF. Although non-significant interactions were found, self-reported moderate PA, moderate-to-vigorous PA (MVPA), and leisure-time MVPA demonstrated moderate effect size increases among BAILAMOS^{TM} participants. Participants in the BAILAMOS^{TM} group did not demonstrate statistically significant improvements in cognitive domains relative to the health education group. However, there was a moderate effect size change in episodic memory when comparing BAILAMOS^{TM} and health education groups. Changes in cognitive domains were not significantly associated with changes in self-reported or device-assessed PA.

Manuscript 2 aimed to investigate the associations between self-reported PA engagement and white matter (WM) health (e.g., volume, integrity, and hyperintensities) in older Latino adults. Participants were 34 cognitively intact older Latinos of two different cohorts with similar recruitment efforts and magnetic resonance imaging (MRI) protocol. Participants self-reported demographic information, engagement in PA, and underwent MRI. Results showed that greater levels of self-reported leisure-time moderate-to-vigorous PA were significantly associated with greater global WM volume after controlling for intracranial volume (ICV), WM hyperintensities, and age. Self-reported PA was not significantly associated with WM integrity neither WM hyperintensities.

Manuscript 3 aimed to investigate the impact of the BAILAMOS™ dance program on self-reported and device-assessed PA, functional connectivity (FC) in three bain networks (DMN, FPN, and SAL), and cognition. Participants were 10 cognitively intact older Latino adults that took part in the BAILAMOS™ dance program. Participants' engagement in PA (self-reported and device-assessed), estimated CRF, cognition, and resting-state FC via MRI were tested at baseline and post-intervention. Results demonstrated a significant increase in self-reported moderate leisure-time PA. No statistically significant changes in cognitive domains or global cognition were found. FC within-FPN regions of interest significantly increased. Increases in moderate leisure-time PA were associated with increases in the FC within-FPN and decreases in FC between the supramarginal gyrus and the whole-brain. Increases in the FC within-FPN ROIs were associated with reductions in perceptual speed.

I. MANUSCRIPT 1

The Effects of the BAILAMOS™ Dance Program on Cognition and Physical Activity Levels of Older Latino Adults: A Pilot Study

A. Abstract

Introduction: Utilizing physical activity (PA) to reduce the risk factors of cognitive impairment among higher-risk groups such as older Latinos is warranted. Dancing is among the most preferred types of PA for Latino adults and older adults. We aimed to investigate the impact of a four-month dance program (BAILAMOS™) on self-reported and device-assessed PA and cognition, and whether changes in PA were associated with changes in cognition in older Latino adults. **Methods**: We randomized 57 cognitively intact older Latino adults to either the BAILAMOS™ dance program treatment group (n= 28) or the health education control group (n= 29). BAILAMOS™ is a four-month, twice a week dance program with four Latin dance styles. We assessed participants' engagement in PA (self-reported and device-assessed), estimated cardiorespiratory fitness (CRF), and cognition at baseline and post-intervention. Cognition scores were transformed to z-scores and combined into composite scores. We conducted a two-way ANCOVA controlling for attendance. Significance levels were set at $p < 0.05$. **Results:** Participants in the BAILAMOS™ group significantly decreased their engagement in light leisure-time PA. There were no statistically significant changes in other self-reported and device-assessed PA intensities, sedentary behavior, or estimated CRF. Although non-significant interactions were found, self-reported moderate PA, moderate-to-vigorous PA (MVPA), and leisure-time MVPA demonstrated moderate effect size increases among BAILAMOS™ participants. Participants in the BAILAMOS™ group did not show statistically significant improvements in cognitive domains relative to the health education group. However, there was a moderate effect size change in episodic memory when comparing BAILAMOS™ and health education groups. Changes in cognitive domains were not significantly associated with changes in self-reported or device-assessed PA. **Conclusions**: BAILAMOS™ has the potential to impact self-reported assessed PA engagement and episodic memory in older Latinos. In the future, dance programs should increase its length, dose, and intensity of PA delivered.

B. Introduction

The growth of the aging population is a phenomenon observed in the United States (US) and across the world. Between 2012 and 2050, the older population in the US is projected to be 83.7 million, compared to 43.1 million in 2012 (Ortman, Velkoff, & Hogan, 2014). The older adult population in the US is also becoming more racially and ethnically diverse. By 2050, older Latinos will account for 18.4% of older Americans, 11% higher than in 2012 (Ortman, Velkoff, & Hogan, 2014).

Older Latinos are at higher risk of cognitive impairment partially due to increased prevalence of risk factors for cognitive decline such as obesity, type 2 diabetes, and metabolic syndrome (Benjamin et al., 2017). Nonetheless, this scenario can be attenuated with the adoption of a healthy lifestyle, with physical activity (PA) being among the most effective strategies to reduce the risk of cognitive impairment (Piercy et al., 2018). Increasing PA levels is paramount to decreasing the risk of these chronic diseases. Nonetheless, estimates from the 2017 National Health Interview Survey (Clarke, Schiller, & Norris, 2017) showed that engagement in leisure-time PA (LTPA) is lower among Latino adults compared to non-Latinos whites. The trend is the same among older Latinos, who also participate in significantly less LTPA than other racial/ethnic groups (Keadle, McKinnon, Graubard, & Troiano, 2016). Therefore, utilizing PA to reduce the risk factors of cognitive impairment among higher-risk groups such as Latinos is warranted.

Preferred modes of PA have been shown to vary among different cultures, which makes culturally focused strategies and activities pivotal to increasing PA levels (Ickes & Sharma, 2012). Dancing is among the most preferred types of PA for Latino adults and older adults (Marquez et al., 2016; Mier, Medina, & Ory, 2007; Wilbur, Chandler, Dancy, & Lee, 2003). It is also an important form of socialization (Cromwell & Berg, 2006) and deemed as enjoyable (Melillo et al., 2001). Dancing is pleasurable and involves aerobic activity, music stimulation and cognitive, visuospatial, social, and emotional engagement (Hwang & Braun, 2017). Niemann, Godde, & Voelcker-Rehage (2016) referred to dance as a multimodal PA that addresses cardiovascular, coordinative, and cognitive demands while engaging in an attractive leisure activity for older adults. In addition to the aerobic requirements of PA, “dance comprises rhythmic motor coordination, balance, memory, emotions, affection, social interaction, acoustic stimulation, and musical experience" (Kattenstroth, Kalisch, Holt, Tegenthoff, & Dinse, 2013, p.2). Kattenstroth et al. (2013) mention that this unique combination of properties makes dance a potentially powerful interventional approach, as dance has been considered a potentially effective means to improve cognitive health among healthy older adults (Brown, Martinez, & Parsons, 2006; Niemann et al., 2016). Its effects on cognition might occur as a result of the multisensory demands, not just because of the cardiovascular requirements of PA (Thøgersen-Ntoumani, Papathomas, Foster, Quested, & Ntoumanis, 2018).

Research on the effects of dance on cognition has shown promising results in cross-sectional and longitudinal studies. A prospective study showed that participation in lifelong regular dancing was associated with a reduced risk of developing dementia (Verghese et al., 2003). Also, when compared to age-matched inactive controls, older adults with a lifelong experience with recreational dance revealed superior cognitive performance in attention and fluid intelligence attention (Kattenstroth, Kolankowska, Kalisch, & Dinse, 2010). Nonetheless, some studies did not demonstrate associations of social dancing with better cognition, perhaps because the matched older adults were engaging in other leisure PA (Verghese, 2006), or because of the use of the Mini-Mental Status Examination as the primary outcome (Alpert et al., 2009), which is a neuropsychological test not as sensitive to detecting cognitive differences in healthy older adults.

Based on preliminary evidence of cross-sectional and longitudinal studies, randomized controlled trials (RCTs) have utilized dance as an intervention to improve cognition. Dance interventions such as contemporary dance (Coubard et al., 2011), the Agilando™ dance program (Kattenstroth et al., 2013), adapted tango (Hackney et al., 2015), ballroom dance (Doi et al., 2017; Lazarou et al., 2017; Merom et al., 2016), Cha Cha Cha (Kim et al., 2011), a dance/movement training according to the standards of the American Dance Therapy Association (Esmail et al., 2020), and a mixture of dance styles (line dance, jazz, rock'n roll, Latin, and square) (Hamacher, Hamacher, Rehfeld, Hökelmann, & Schega, 2015) have revealed promising results improving a range of cognitive domains including episodic and working memory, attention, executive function, and global cognition.

To date, the RCTs that used dance as the primary mode of PA to increase PA levels and improve cognitive function in older adults were conduct abroad (e.g., France, Australia, South Korea, Germany), with a range of dance styles, and without the inclusion of ethnic/racial minority groups. Interestingly, only one RCT was based in the US (Hackney et al., 2015) and did not mention the inclusion of Latino participants, the largest ethnic minority with low levels of LTPA, and at-risk for cognitive impairment. Thus, promoting culturally relevant PA for a population at risk is warranted.

The present study aimed to investigate the impact of the four-month BAILAMOS™ dance program on self-reported and device-assessed PA and cognition and whether changes in PA were associated with changes in cognition in older Latino adults. We hypothesized that: (a) changes in self-reported and device-assessed PA would be significantly greater in the dance group compared to the control group; (b) changes in cognition (domain-specific and global) would be significantly greater in the dance group compared to the control group; and (c) changes in self-reported and device-assessed PA would be associated with changes in cognition (domain-specific and global) in the dance group only.

C. Methods

1. Study overview

We designed a pilot RCT randomizing participants to intervention or control group at the individual level. Participants were randomized and stratified by age and sex to a BAILAMOS™ treatment group or a health education control group in two different waves. The intervention took place at one community senior center in Chicago. The study was approved by the University of Illinois at Chicago Institutional Review Board (IRB) (Protocol # 2011-0763; Appendix A) and conducted in accordance with the Declaration of Helsinki with written informed consent obtained from all participants.

2. Participants

We conducted recruitment using established relationships of Dr. David X. Marquez with the Latino community in Chicago (e.g., senior centers, churches). Research staff conducted presentations at the senior center in which the intervention would take place, and at Roman Catholic churches in the vicinity of the senior center. The neighborhood has a large Latino population. Additionally, recruitment included flyers in senior housing facilities, word of mouth, presentations at health centers and clinics, and health fairs. We assessed 127 participants for eligibility and randomized 57 to either the BAILAMOS™ treatment group (n= 28) or the health education control group (n= 29) in two waves. Specifically, wave 1 had 30 participants ($n_{Treatment} = 15$; $n_{Control} = 15$), and wave 2 had 27 participants ($n_{Treatment} = 13$; $n_{Control} = 14$) (see CONSORT flow diagram in Figure 1).

Inclusion criteria were: (a) aged ≥ 55 years; (b) self-identification as Latino/ Hispanic; (c) self-reported ability to understand Spanish; (d) self-reported participation in less than two days per week of aerobic exercise; (e) at risk for disability (see below); (f) cognitively intact as evaluated by the modified version of the Mini-Mental State Examination (MMSE; Folstein,

Folstein, & McHugh, 1975) for telephone administration (Wilbur et al., 2012); (g) danced less than two times per month over the past 12 months; (h) willingness to be randomly assigned to either a treatment or control group; (i) no current plans to leave the U.S. for two consecutive weeks or more over the next twelve months.

At risk for disabilities was defined as one of the following: (a) diabetes (Al Snih et al., 2007); (b) underweight (body mass index [BMI] lower than 18.5; Al Snih et al., 2007); (c) overweight or obese (BMI greater than 25.0; Al Snih et al., 2007; Chen, Bermúdez, & Tucker, 2002); or (d) difficulty or change with any one of the following four tasks: (1) walking a long distance (four blocks or ½ mile), (2) climbing ten steps, (3) transferring from a bed or chair, (4) walking a short distance on a flat surface. Participants answered two questions for each task: “Have you had difficulty completing (task)” and “Have you changed the way you complete (task) or how often you do this, due to a health or physical condition?” Older adults with difficulty or change with any one of the four tasks were eligible for the study.

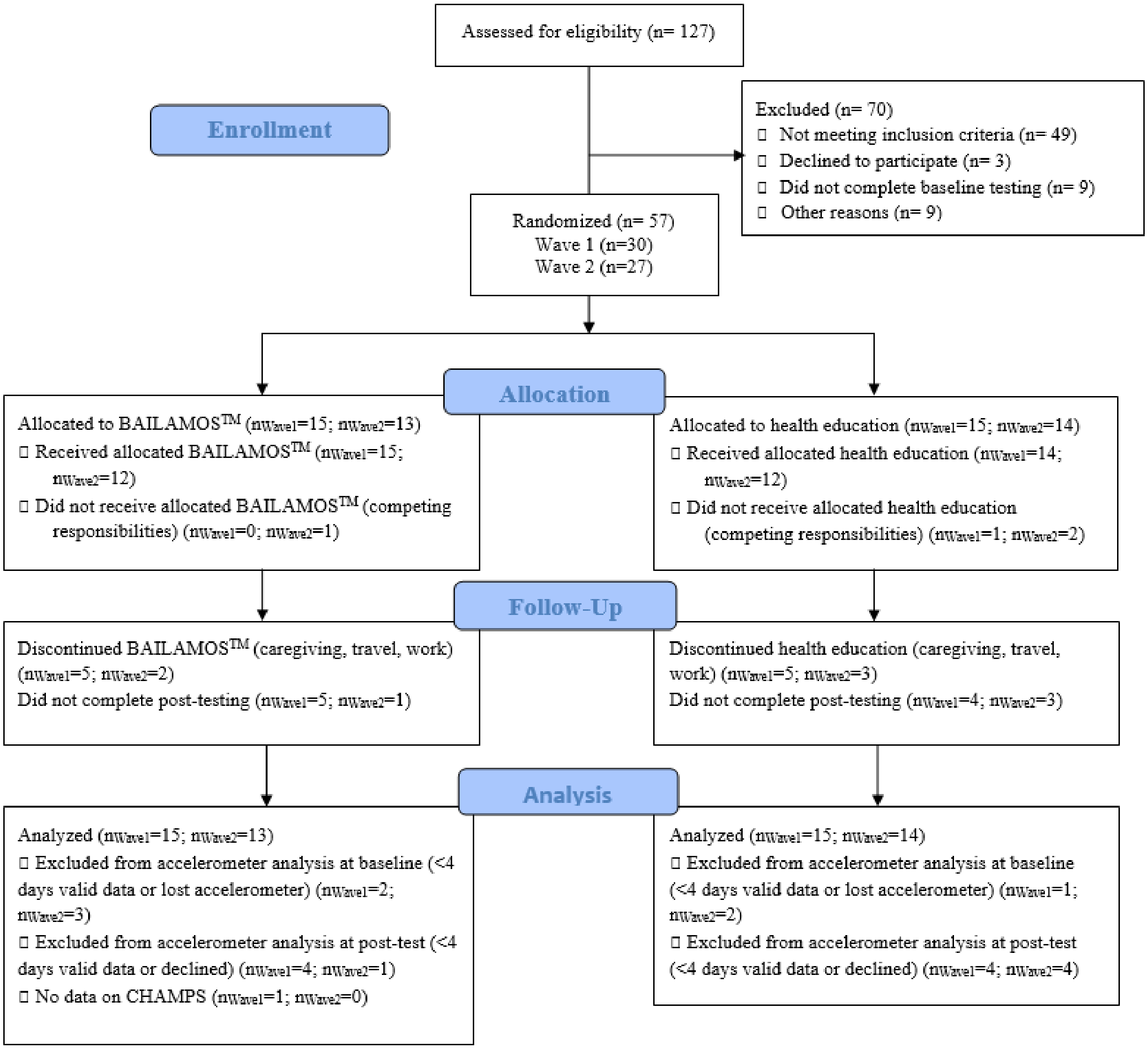

Figure 1. Participants CONSORT Flow Diagram.

Self-reported exclusion criteria included: (a) heart disease or heart failure; (b) uncontrolled type 2 diabetes; (c) pacemaker in situ; (d) stroke; (e) severe chronic lung disease; (f) fracture(s) in the last six months; (g) head injury; (h) chronic kidney disease; (i) frequent falls in the past year; and (j) use walking aids (cane, walker, or wheelchair). Besides, participants were screened with the Exercise Assessment and Screening for You (EASY) questionnaire (Resnick et al., 2008). This questionnaire provides recommendations on the need for physician evaluation and clearance before adopting PA (Chodzko-Zajko, Resnick, & Ory, 2012).

3. Measures

We collected data on demographic information, overall physical health, attendance at the intervention, class enjoyment, rate of perceived exertion (RPE) regarding the class, cognitive function, and self-reported and device-assessed physical activity.

a. Demographics, overall health, attendance, enjoyment, and perceived exertion

Demographic information included age, sex, education, income, marital status, country of origin, race, ethnicity, preferred language, years lived in the US, and number of children. Physical health measures included weight, height, BMI (kg/m2), and blood pressure (mm/Hg) while seated. Attendance was recorded at each class for both the BAILAMOS™ and health education groups. Participants graded their perceived exertion from 6 (no exertion) to 20 (maximal exertion) with the Borg Rating of Perceived Exertion (RPE) (Borg, 1982), and perceived enjoyment on a Likert scale from 1 to 7 (strongly disagree to strongly agree) after each class.

b. Cognition

We utilized a subsample of tests from the official Spanish version of measures in the Uniform Data Set (UDS) of the National Institute on Aging Alzheimer's Disease Center Program (Acevedo et al., 2009). Those tests assess cognitive domains that are subject to decline due to aging and shown to be influenced by PA (i.e., executive function, working memory, perceptual speed, episodic memory). We administered all neuropsychological tests at baseline and post-intervention for the BAILAMOS™ and health education groups.

Four neurocognitive tests measured executive function: (a) Trail Making Test (TMT; A and B) (Adjutant General's Office, 1944); (b) Stroop C (color task of the short form; Wilson et al., 2005) of the Stroop Neuropsychological Screening Test) (Trenerry, Crosson, DeBoe, & Leber, 1989) and the Stroop C-W (Color-Word task); (c) Word fluency test (Welsh et al., 1994), and (d) Symbol Digit Modalities Test (Smith, 1982). Working Memory was measured with the two parts (forward and backward) of the Digit Span test (Wechsler, 1987), and the Digit Ordering test (Cooper, Sagar, Jordan, Harvey, & Sullivan, 1991). The perceptual speed domain comprised of Trail Making Test, Stroop C, and Stroop C-W. The Word fluency (animals, fruits and vegetables) test measured semantic memory. Measures of episodic memory included the Logical Memory I (Immediate) and II (Delayed) (Wechsler, 1987). Global cognition comprised all of the above tests.

c. Physical Activity and Estimated Cardiorespiratory Fitness

We acquired self-reported physical activity data at baseline and post-intervention for the BAILAMOS™ and health education groups. Participants responded to the Community Healthy Activities Model Program for Seniors (CHAMPS) Physical Activity Questionnaire for Older Adults (Stewart et al., 2001). It assesses weekly frequency and duration of PA in four different lifestyle domains (leisure-time, household, occupational, and transportation) typically undertaken by older adults. The Spanish version of CHAMPS has been validated and employed with older Latino adults (Marquez et al., 2011; Rosario, Vázquez, Cruz, & Ortiz, 2008).

For device-assessed PA, participants wore a triaxial GT3X+ accelerometer (Actigraph, Pensacola, Florida) on their right hip for seven consecutive days, removing it for showering and swimming. Participants from each of the two study conditions wore the accelerometer for one week at baseline and post-intervention, respectively. Data collectors instructed the participants on the use of the accelerometer, and additional instructions with pictures were available in Spanish or English. Participants received an accelerometer log on which they were asked to record the hours worn each day. Data were included in the analysis if the participant wore the accelerometer for at least four days for more than 10 hours/day (Hart, Swartz, Cashin, & Strath, 2011). Those participants with less than four days with at least 10 hours of wear-time were excluded from the accelerometer data analysis. Data were processed with ActiLife version 6.13.3 software, with data converted to 60 seconds epochs. Non-wear time was defined as at least 60 consecutive minutes of 0 activity count. We categorized physical activity intensity according to Miller, Strath, Swartz, and Cashin's (2010) cut-points for older adults.

CRF was assessed with a previously validated regression equation (Jurca et al., 2005). It generated estimates of CRF in metabolic equivalents (METs) without exercise testing. The equation takes into account participants' sex, age, BMI, resting heart rate, and PA levels on a scale from 1 to 5 (see Jurca et al., 2005 for detailed scale). We used the following equation: sex × (2.77) – age × (0.10) – BMI × (0.17) − resting heart rate × (0.03) + PA score + 18.07 (Jurca et al., 2005).

4. <u>Procedures</u>

Procedures varied based on how participants were recruited. If recruited in-person, that potential participant consented to receive a call from a bilingual research staff member to be screened in a time of their preference. If potential participants learned about the study via word of mouth or flyers, they called our office to schedule a time for a trained research staff call back and perform the screening.

Eligible participants were scheduled for baseline testing. Data collection lasted one to two hours and was conducted by bilingual research staff. Wave 1 participants were tested at the senior center, whereas Wave 2 participants had their data collection held at the University of Illinois at Chicago Clinical Research Center of the Center for Clinical and Translational Science. Some participants declined to come to the University for their post-intervention testing; in that case, testing was conducted at the senior center. At baseline data collection, research staff explained the study and read the informed consent form to prospective participants. Questionnaires and neuropsychological tests were administered in the participant's preferred language (Spanish or English). Participants received a $10 gift card compensation for each baseline and post-intervention data collection.

Participants who were eligible and completed baseline data collection were assigned to either the BAILAMOS^{TM} or the health education group. We used Study360^{TM} software (Almedtrac, Inc) for randomization at the individual level and stratified by sex to try to ensure a similar proportion of men and women at each group. There was no allocation concealment for research staff and participants.

5. **Intervention**

Participants randomized to the dance intervention participated in the BAILAMOS^{TM} program. Details about the program have been previously reported (Marquez et al., 2014). The program is a four-month, twice a week dance program with four Latin dance styles ordered by difficulty level (Merengue, Cha Cha Cha, Bachata, and Salsa) and led by a trained professional instructor. Classes lasted one-hour each and aimed to offer light to moderate PA intensity. Classes were held at a senior center and were closed-off to control group participants and non-study participants. Dance sessions included warm-up and stretching, instructions of the respective dance style, and steps for singles and couples. Couples learned steps of both leaders and followers, and continually rotated partners. Twice a month, participants attended *fiestas de baile* (dance parties) in which they had time to practice the learned steps until that point.

The health education program for the control group was conducted by trained health educators of the University of Illinois Extension Program. The participants met as a group once a week for two hours over four-months at the study site, which allowed control group participants to equivalent social contact to that in the BAILAMOS™ group. Classes were taught in Spanish with Spanish-language materials. The topics covered in the program did not explicitly teach about PA, and included: stress, home safety, nutrition, dealing with chronic diseases (e.g., diabetes, cancer, osteoporosis), immunizations, healthy relationships, boosting the memory, and making the most of medical appointments.

6. <u>Statistical analysis</u>

Analyses were conducted in SPSS version 24 (Armonk, NY, IBM Corp). As a first step, we transformed all cognition score tests to z-scores, which we computed using the mean and standard deviation of baseline (Wilson et al., 2002). By averaging the z-scores converted from each test, we created composite scores (executive function, episodic memory, working memory, semantic memory, perceptual speed, and global cognition) (Wilson et al., 2002). Due to missing data at post-intervention data collection (neuropsychological tests and self-reported PA), we employed the sequential hot decking technique for imputing missing data (Rubin, 1989). We assumed missing data at random and used observed values from participants that responded to self-report PA and performed neuropsychological tests at both pre- and post-intervention. The imputation matched a recipient (i.e., missing score) to a donor (i.e., observed score) with similar demographic characteristics. We then transferred the donor's value to the recipient (Lavrakas, 2008). As this technique is indicated for use in self-reported data, we did not employ it for missing accelerometer data. Therefore, for accelerometer data, we only included in the analysis of those participants with valid data at both baseline and post-intervention. It resulted in an accelerometer analytic sample of N = 36 ($n_{Control}$ = 18, $n_{Intervention}$ = 18). The analysis for cognitive measures and estimated CRF included N = 57 participants ($n_{Control}$ = 29, $n_{Intervention}$ = 28), and N = 56 participants for self-reported PA ($n_{Control}$ = 29, $n_{Intervention}$ = 27) (one participant had missing self-reported PA data at baseline and post-testing).

We conducted two-way ANOVA with two factors (treatment [BAILAMOS™] and control [health education]) and two time-points (baseline and post-intervention) while controlling for intervention attendance. The central limit theorem assumed normal distribution of the data, and homogeneity of variances was checked with Levene's test. We also conducted Pearson correlations to test whether changes in self-reported and device-assessed PA levels were associated with changes in cognition. We computed 95% confidence intervals and Cohen's *d* effect size for each analysis. Significance levels were set at $p < 0.05$. We did not calculate sample size *a priori*. However, a *post-hoc* sample size calculation utilizing G*Power revealed that to detect a moderate effect size in a two-way ANOVA with within-between interaction, we would need 34 participants to achieve 80% of statistical power. Therefore, our sample size was adequate.

D. Results

1. Demographics, attendance, enjoyment, perceived exertion, and descriptive data

Participants were 65.2±6.5 years old, the majority were females (83.9%), married (60.3%), obese (30.8±6.0 kg/m^2), immigrated to the US from Mexico (77.2%) when they were 25.1±12.4 years old, and had been living in the US for 34.2±14.3 years at the time of data collection. They spent from 0 to 17 years in school (6.9±4.0), self-reported low-income (73.2%), and considered Spanish their preferred language (100%) (Table 1). The demographic characteristics by group assignment are shown in Table 1. The average self-reported RPE ranged from 6 to 20 (10.66±3.20) over the 32 classes of the BAILAMOS™. The average perception of enjoyment during classes ranged from 4 to 7 (6.66±0.88). The average attendance in the BAILAMOS™ program was 67.93±28.91%, and 61.68±38.03% in the health education program. One participant never attended the BAILAMOS™ program and three participants never attended the health education program.

TABLE I

DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS IN THE BAILAMOS^{TM} AND HEALTH EDUCATION GROUPS.

Demographic characteristics	BAILAMOS^{TM} M (SD) or % (n = 28)	Health education M (SD) or % (n = 29)
Age	64.8 (6.0)	66.4 (7.0)
Female	85.7	82.1
Marital status (Married)	57.1	64.3
BMI	30.1 (5.4)	31.6 (6.6)
Years of education	7.4 (4.0)	6.4 (4.0)
Income (Low)	78.6	67.9
Number of children	4.0 (2.0)	4.8 (2.5)
Country of origin (Mexico)	78.6	75.8
Years lived in the U.S.	33.2 (19.1)[a]	33.0 (18.6)[b]
Age of immigration	35.6 (14.0)[c]	32.8 (14.7)[d]
Spanish preferred language	100	100

[a] n = 26.
[b] n = 28.
[c] n = 22.
[d] n = 27.

We observed that both BAILAMOS^{TM} and health education groups presented high levels of engagement in PA both by self-reported and device-assessed PA measures (Table 2).

2. Physical activity and cognition

Participants in the BAILAMOS™ group significantly decreased their engagement in light leisure-time PA ($F(1,53) = 4.49$, $p = 0.039$, $d = -0.66$) compared to participants in the health education group (Table 2). We observed a main effect for time in self-reported moderate-to-vigorous PA (MVPA) ($F(1,53) = 6.33$, 95%CI = 23.02 - 203.74; $p = 0.015$) and leisure-time MVPA ($F(1,54) = 4.67$, 95%CI = 6.30 – 167.31; $p = 0.035$) (Table 2). Although non-significant interactions were found, self-reported moderate PA, MVPA, and leisure-time MVPA demonstrated moderate effect size increases of 0.40, 0.37, and 0.39, respectively (Table 2). There were no statistically significant changes in the other self-reported and device-assessed PA intensities, sedentary behavior, or estimated CRF after participating in the BAILAMOS™ or health education programs.

TABLE II

SELF-REPORTED AND DEVICE-ASSESSED PHYSICAL ACTIVITY LEVELS AND ESTIMATED CARDIORESPIRATORY FITNESS PRE- AND POST-BAILAMOS^{TM} AND HEALTH EDUCATION PROGRAM.

Self-reported PA (min/week)	**Dance**		**Health Education**		**Between-group differences**		
	Pre Mean (SD) (n = 27)	Post Mean (SD) (n = 27)	Pre Mean (SD) (n = 29)	Post Mean (SD) (n = 29)	Estimated difference (95% CI)	*p*	*d*
Light PA	633.33 (352.08)	672.22 (355.14)	584.48 (382.65)	628.45 (426.40)	-5.08 (-104.91, 94.76)	0.886	-0.01
Light Leisure PA	365.55 (266.33)	300.56 (200.92)	220.86 (161.10)	297.93 (216.43)	-142.06 (-198.03, -86.09)	0.039*	-0.66
Moderate PA	255.55 (342.80)	366.67 (334.33)	301.55 (325.54)	291.72 (200.03)	120.95 (41.05, 222.01)	0.120	0.40
Moderate Leisure PA	230.00 (335.13)	300.56 (286.31)	228.10 (255.33)	266.90 (162.27)	31.75 (-56.49, 119.99)	0.638	0.12
MVPA	310.55[a] (380.77)	495.56[a] (421.14)	343.93[a] (348.64)	387.32[a] (292.89)	141.62 (46.44, 236.79)	0.130	0.39
Leisure MVPA	285.00[a] (371.27)	432.22[a] (393.73)	265.86[a] (279.58)	292.24[a] (242.49)	120.84 (35.56, 228.82)	0.139	0.37
Total PA	943.89 (543.16)	1048.33 (585.39)	923.79 (555.90)	969.83 (668.99)	58.40 (-96.47, 213.27)	0.830	0.10
Total Leisure PA	650.55 (472.53)	771.66 (500.76)	486.72 (379.89)	588.10 (405.05)	19.73 (-126.13, 165.59)	0.923	0.04
Estimated CRF	5.96 (1.87)	5.94 (2.37)	5.41 (2.36)	5.73 (2.30)	-0.33 (-1.07, 0.41)	0.245	-0.14
Device-assessed PA (min/day)	(n = 18)	(n = 18)	(n = 18)	(n = 18)	Estimated difference (95% CI)	*p*	*d*
Sedentary Time	535.35 (98.17)	554.68 (76.21)	537.81 (80.03)	520.33 (107.77)	36.81 (-6.93, 66.67)	0.103	0.23
Light PA	258.81 (48.41)	259.34 (40.86)	265.12 (76.95)	278.75 (96.42)	-13.10 (-35.75, 9.55)	0.538	-0.18
Moderate PA	36.03 (26.01)	38.61 (28.25)	23.11 (15.16)	27.15 (29.45)	-1.46 (-9.74, 6.82)	0.944	-0.05
MVPA	36.07 (26.08)	38.67 (28.31)	23.33 (15.37)	27.36 (29.66)	-1.43 (-9.75, 6.89)	0.949	-0.05

* Statistically significant at $p < 0.05$.

[a] Main effect for time at $p < 0.05$

Note: All models are controlled for attendance.

Participants in the BAILAMOS™ group did not demonstrate statistically significant improvements in cognitive domains relative to health education group (Table 3). We did observe main effect for group in executive function ($F(1,54) = 6.39$, 95%CI = 0.04 - 0.36; $p = 0.014$) as well as in perceptual speed ($F(1,54) = 4.77$, 95%CI = 0.01 - 0.34; $p = 0.033$) (Table 3). Also, we found a main effect for time in semantic memory ($F(1,54) = 4.04$, 95%CI = 0.00 - 0.32; $p = 0.049$) and global cognition ($F(1,54) = 6.99$, 95%CI = 0.02 - 0.18; $p = 0.011$) (Table 3). Although statistically significant interactions were not observed, there was a moderate effect size change in episodic memory when comparing BAILAMOS™ and health education groups ($M_{diff} = 0.41$; 95% CI = 0.14 - 0.67; $d = 0.40$; Table 3) and a small effect size change in global cognition ($M_{diff} = 0.11$; 95% CI = -0.01 - 0.20; $d = 0.29$; Table 3).

Changes in cognitive domains were significantly associated with changes in self-reported or device-assessed PA in the BAILAMOS™ group. Changes in global cognition were negatively associated with changes in self-reported leisure-time MVPA (r = -0.45, $p = 0.020$). Significant associations between changes in PA and cognitive domains were observed in the health education group. Changes in global cognition were positively associated with changes in self-reported moderate PA (r = 0.48, $p = 0.009$), leisure-time moderate PA (r = 0.55, $p = 0.002$), and negatively associated with device-assessed MVPA (r = -0.71, $p = 0.001$). Changes in semantic memory were negatively associate with changes in device-assessed MVPA (r = -0.48, $p = 0.044$). Changes in episodic memory were positively correlated with changes in self-reported moderate PA (r = 0.56, $p = 0.001$), leisure-time moderate PA (r = 0.45, $p = 0.014$), and MVPA (r = 0.51, $p = 0.005$).

TABLE III

COGNITIVE DOMAINS PRE- AND POST-BAILAMOS™ AND HEALTH EDUCATION.

Cognitive domain	**BAILAMOS™**		**Health Education**		**Between-group differences**		
	Pre-intervention Mean (SD) (n=28)	Post-intervention Mean (SD) (n=28)	Pre-intervention Mean (SD) (n=29)	Post-intervention Mean (SD) (n=29)	Estimated difference (95% CI)	*p*	*d*
Executive Function	0.09[b] (0.34)	0.12[b] (0.32)	-0.09[b] (0.31)	-0.09[b] (0.34)	0.03 (-0.05, 0.11)	0.856	0.09
Working Memory	-0.06 (0.69)	-0.07 (0.58)	0.06 (0.81)	-0.01 (0.72)	-0.07 (-0.12, 0.24)	0.632	0.08
Episodic Memory	-0.13[a] (0.83)	0.48[a] (0.95)	0.13[a] (1.07)	0.33[a] (1.16)	0.41 (0.14, 0.67)	0.059	0.40
Semantic Memory	0.11[a] (0.94)	0.29[a] (0.78)	-0.10[a] (0.77)	0.05[a] (0.69)	0.02 (-0.24, 0.29)	0.880	0.03
Perceptual Speed	0.42[b] (1.62)	0.26[b] (1.73)	-0.41[b] (1.62)	-0.73[b] (1.86)	0.03 (-0.28, 0.60)	0.821	0.09
Global Cognition	0.01[a] (0.35)	0.13[a] (0.34)	-0.01[a] (0.37)	0.00[a] (0.42)	0.11 (-0.01, 0.20)	0.168	0.29

[a] Main effect for time at $p < 0.05$.
[b] Main effect for group at $p < 0.05$.
Note: All models are controlled for attendance.

E. <u>Discussion</u>

The present study aimed to investigate the impact of the four-month BAILAMOS™ dance program on self-reported and device-assessed PA and cognition and identify whether changes in PA levels were associated with changes in cognition in older Latino adults. Hypotheses one and two were partially supported, while hypothesis three was not supported. We did observe a trend of increased moderate PA, MVPA, leisure-time MVPA, and improved episodic memory after participation in the BAILAMOS™ program compared to health education. These PA intensities along with episodic memory demonstrated moderate effect size increases, which, combined with their respective 95% confidence interval for the estimated differences between groups, suggest that participants in the BAILAMOS™ had a meaningful increase in PA engagement and episodic memory compared to health education participants. Conversely, we found that health education participants increased their engagement in self-reported leisure light PA significantly, and no significant increases in device-assessed PA or estimated CRF were observed in BAILAMOS™ participants. These results add to the diverging literature of the effects of PA and exercise on cognitive function in healthy older adults. It also adds specifically to the literature on the effects of dancing on cognitive function in relatively healthy older adults.

Few studies have revealed improved CRF as a result of dance interventions (Cruz-Ferreira, Marmeleira, Formigo, Gomes, & Fernandes, 2015; Douka, Zilidou, Lilou, & Manou, 2019; Hopkins, Murrah, Hoeger, & Rhodes, 1990; Hui, Chui, & Woo, 2009; Janyacharoen, Laophosri, Kanpittaya, Auvichayapat, & Sawanyawisuth, 2013), but these studies did not have increased PA levels as a primary outcome. A systematic review aiming to examine the benefits of dance on older adults' physical health demonstrated that regardless of its style, dancing improved aspects of functional fitness in older adults (Hwang & Braun, 2017). Our results do not converge with the previously mentioned studies since we did not observe changes in estimated CRF. This might be due to two main reasons. First, dance interventions previously employed aerobic dance (Hopkins et al., 1990), cross step (Hui et al., 2009), Thai dance (Janyacharoen et al., 2013), creative dance (Cruz-Ferreira et al., 2015), and Greek dance (Douka et al., 2019). The dance styles we adopted might demand different PA intensities compared to previous studies which potentially yield distinct effects on CRF. Second, in learning new dance styles, there is a ramping up of skill and movement, such that the beginning classes of new styles have less movement as participants are trying to learn the new steps.

A systematic review aiming to investigate the role of dance on promoting PA recommends that culturally relevant dance should be encouraged, especially among groups at risk for inactivity, including racial/ethnic minority groups (Jain & Brown, 2001). One of our primary outcomes was to increase PA engagement. We observed a trend of increased engagement in moderate PA, MVPA, and leisure MVPA after participating in the BAILAMOS™ dance program with moderate effect sizes. Conversely, health education participants increased light leisure-time PA engagement while BAILAMOS™ decreased. We have two main hypotheses for these results. First, BAILAMOS™ participants replaced light leisure-time PA with MVPA. Also, they were encouraged to engage in MVPA outside the intervention. This can be inferred due to the moderate effect size increase favoring BAILAMOS™ participants in MVPA intensities. Second, the fact we offered health-related knowledge to participants in the health education control group (e.g., nutrition, coping with chronic diseases) might lead to indirect promotion of behavior change regarding PA behavior. Also, we observed that health education participants self-reported less engagement in leisure-time light PA, and device-assessed moderate and MVPA at baseline. We did perform randomization so it is unclear the reasons for such difference.

Although changes in PA levels were not associated with changes in episodic memory, we observed that episodic memory improved for both groups, though the improvement was more pronounced in the BAILAMOS™ group due to positive moderate effect size. From this preliminary data, it appears that participation of older Latinos in a setting in which they are actively engaged in learning new health information may benefit their episodic memory. This result is promising and warrants further investigation in future studies. As for improvements in episodic memory of BAILAMOS™ group participants, previous RCTs also demonstrated improvements in episodic memory after participation in dance intervention programs (Doi et al., 2017; Kattenstroth et al., 2013; Kim et al., 2011; Lazarou et al., 2017).

A RCT in Germany with healthy older adults (70.4 ± 1.6 years old) compared the effects of the six-month Agilando™ dance program (1 hour/week) on cognition relative to a control group (Kattenstroth et al., 2013). The authors observed that participants in the Agilando™ group demonstrated significant improvements in one of the subtests of episodic memory (list recall test of the Repeatable Battery of Neuropsychological Status) compared to the control group. Similarly, Kim et al. (2011) investigated the effects of a six-month dance program (2x/week for 60min) based on Cha-Cha-Cha in Korean older adults (68.2 ± 4.4 years old) with metabolic syndrome. Older adults that participated in the dance program showed significant improvement in a measure of episodic memory (word list delayed recall) compared to a control group. Neither study provided specific information about the control group. We assume that their control group participants carried out their usual activities of daily life and were an assessment-only group.

Two other studies focused on older adults with mild cognitive impairment (MCI). Doi et al. (2017) randomized older adults (75.8 ± 4.3 years) to either a 40 week (1x/week for 60 min) dance program based on ballroom dance (e.g., salsa, rumba, waltz, tango), a music program, or a health education program. The authors found that participants in the dance group showed significant improvements in episodic memory and global cognition compared to the other two groups. Lazarou et al. (2017) proposed a 10-month international ballroom dance program (2x/week for 60 min, including tango, waltz, salsa, foxtrot, and other styles) for older Greek adults with MCI (66.9 ± 10.1 years). Compared to a control group, participants in the dance group improved their performance on the two measures of episodic memory (Rivermead Behavioral Memory Test story direct and delayed recall). The authors did not specify whether the control group participants were an assessment-only group or were active controls.

Evidence showing the improvement of episodic memory in healthy older adults and those with MCI potentially impacts older adults' lives because of episodic memory importance in late-life cognition. Disruptions in memory are among the main six cognitive domains commonly disturbed with dementia (Gold & Budson, 2008). Furthermore, declines on episodic memory are associated with a range of other dementia-related neurodegenerative and cerebrovascular pathologies (Wilson, Leurgans, Boyle, Schneider, & Bennett, 2010; Wilson et al., 2013).

We observed a small effect size on global cognition favoring BAILAMOS^{TM} participants. Although not statistically significant, it is a promising improvement that warrants further investigation. Other dance interventions found that participants improved their performance in global cognition compared to control participants (Doi et al., 2017; Lazarou et al., 2017). Furthermore, other cognitive domains such as executive function, language, perceptual speed, and attention are essential for late-life cognition and are disrupted with dementia (Gold & Budson, 2008). Despite some evidence on the benefits of dance for better cognitive function (i.e., domain-specific and global) and reduced risk for dementia from cross-sectional and longitudinal research, data from RCTs are shown to be largely inconsistent (Meng et al., 2019).

In a study with healthy Australian older adults, participants took part in an eight-month ballroom dance program (2x/week for 60 min) or a walking group (Merom et al., 2016). Participants did not show greater changes in executive function, learning, and memory in the dance group compared to the walking condition. Merom et al. (2016) pointed out some possible reasons for the null results. First, participants were already highly active at baseline, with more than a third of participants engaging in more than 2.5hours/week in leisure PA. Second, the dance intervention supposedly provided low PA intensity and dose, and half of the participants had previous experience with dance.

These explanations overlap with some of our hypotheses for our null results, especially within the cognitive domains of executive function, perceptual speed, and semantic memory. We also observed that participants were already highly active at baseline measurement. We hypothesize that our PA screening measure was not sensitive enough to capure participants' actual PA levels. With that, there was not much room to increase PA levels, which consequently migh affect the impact of PA on cognition. What is more, considering participants' RPE, we hypothesize that the BAILAMOS^{TM} offered more time of light PA intensity than moderate PA during classes. In addition, the four months length might not be enough to lead to measurable changes in cognitive function.

Other RCTs also did not demonstrate significant changes in cognition in healthy older adults after participating in dance interventions. In a cluster-randomized trial in France, physically inactive older adults (73.3 ± 6.5 years) participated in one of three programs (contemporary dance, fall prevention, or Tai Chi Chuan) during 5.7 months (1x/week for 60 min) (Coubard et al., 2011). Results showed that executive function did not improve in the dance group compared to others. Likewise, Canadian healthy physically inactive older adults (67.5 ± 5.4 years) were randomized into a dance training (designed following standards of the American Dance Therapy Association), aerobic training, or wait-list group (Esmail et al., 2020). It was observed a within-group improvement in scores of executive function and non-executive function (e.g., task switching, perceptual speed) in the three groups, but changes in dance therapy or aerobic training groups were not significantly different from changes in the wait-list group. Lastly, another study had German older adults (63 to 80 years old) participating in either a ballroom dance or aerobic and resistance training program for six months (2x/week for 90 min) (Rehfeld et al., 2018). Results revealed that both improved attention and spatial memory, but did not reveal changes in processing speed, semantic, working, and episodic memory.

It is to be noted that RCTs with dance interventions demonstrate an array of distinct characteristics. Programs proposed a variety of different dance styles, each one with different physical and cognitive requirements. Each program had different doses of PA, ranging from 10 to 40 weeks, once to three times a week, from 45 min to 90 min per session. PA intensity was not always assessed during the interventions, and some studies acknowledged the possibility of offering more light than moderate PA for participants (Merom et al., 2016; Voss et al., 2019), which we hypothesize was also the case of BAILAMOS™ program. Furthermore, a range of different control groups were used as comparison groups, from assessment-only groups to control groups receiving aerobic and resistance training. Other RCTs also had control groups receiving health education or similar programs that might have fostered behaviors that led to improvements on cognition (Coubard et al., 2011; Esmail et al., 2020; Hackney et al., 2015; Merom et al., 2016; Rehfeld et al., 2018; Voss et al., 2019). Also, our health education participants might be benefited from being in an active learning environment with knowledge about health-related topics. This is supported by the significant associations between changes in self-reported PA and changes in semantinc memory, episodic memory, and global cognition. Conversely, it was not supported by associations with device-assessed PA.

The success of exercise intervention improving cognition depends on both the effectiveness of the interventions delivering the recommended volume and intensity of PA and the behavior of participants in the control group (Kelly et al., 2014). They suggest that confounders associated with relevant behaviors for cognition adopted by control group participants may help to explain the divergence between RCTs, cross-sectional, and longitudinal studies. This seems to be the case of the present and previous studies.

The results of the present study should be considered in light of several limitations. First, the length of BAILAMOS™ and the weekly PA dose might not be sufficient to cause measurable changes in cognitive function. However, once a month, we encouraged participants to engage in MVPA outside the intervention. Second, we did not have an assessment-only control group. We chose to offer a health education program that could benefit participants that are systematically not targeted by public health efforts. We believe that was an ethical choice, although we acknowledge that promoting health behavior to the control group potentially influenced the results of our intervention. Third, as the BAILAMOS™ group and health education classes took part within the same community, sample contamination was possible since we could not control participants' contact with their peers outside the intervention environment. Fourth, the low educational levels of our sample might have impacted the results of neuropsychological tests. Nonetheless, having participants with low educational attainment and Spanish as preferred language is a strength since these characteristics are marked characteristics of the older Latino population in the U.S.

Futures studies investigating the effects of dance on cognition should take into account several factors we observed in our dance program and previous research. Participants' inclusion and exclusion criteria should screen participants for their engagement in PA and experience with dance. More precise screening tools should be utilized, such as validated self-reported PA instruments instead of asking participants whether they engage in less than 150min/week of MVPA. This might be more effective in screening out participants that are already physically active. Future dance interventions should also consider delivering a dose of PA that matches the current PA guidelines for older adults, measuring PA intensity during the classes, and encouraging and providing resources to participants engage in PA outside the intervention. What is more, although a threshold at which cognitive changes occur is yet to be defined, we suggest that future studies should propose interventions with a duration of at least six months.

F. References

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II. MANUSCRIPT 2

Association of Physical Activity Levels and Brain White Matter in Older Latino Adults

A. Abstract

Introduction: Brain white matter (WM) is pivotal for cognitive functioning and a healthy brain. Physical activity (PA) is a modifiable factor for improved brain health. The relationship between PA and WM shows equivocal but potentially beneficial results of greater levels of engagement in PA. This study aimed to investigate the associations between self-reported PA engagement and WM health (e.g., volume, integrity, and hyperintensities) in older Latino adults. **Methods:** This cross-sectional study recruited 34 cognitively intact older Latinos in two different cohorts. Participants self-reported demographic information, as well as their engagement in PA, and underwent magnetic resonance imaging (MRI). For this study, we used high-resolution three-dimensional T1- and T2- weighted images and diffusion tensor imaging acquired via MRI. BIANCA (FSL software) was utilized for the hyperintensities quantification. We performed a series of linear regression models to examine the associations between WM volume, integrity, and hyperintensities volume with self-reported PA levels. We hierarchically added covariates. Significance levels were set at $p < 0.05$. **Results:** Greater levels of self-reported leisure-time moderate-to-vigorous PA were significantly associated with greater total WM volume ($\beta = 0.132$, SE = 0.091, $p < 0.05$) after controlling for intracranial volume (ICV), WM hyperintensities, and age ($F(4,29) = 26.958$, $p = <0.001$). More than ten years of education was significantly associated with lower WM hyperintensities volume ($\beta = -0.552$, SE = 0.271, $p < 0.05$) after controlling for ICV and age ($F(3, 30) = 3.33$, $p < 0.01$). Self-reported PA was not significantly associated with WM integrity or WM hyperintensities. **Conclusion:** Greater engagement in leisure-time moderate-to-vigorous PA was associated with a general measure of WM health in older Latinos adults. Future studies should focus on region-specific measures of WM and utilize device-assessed PA measurements.

B. Introduction

The older adult population in the United States (US) and around the world is growing rapidly. According to the US Census Bureau, the decade of 2030 will come with significant population changes (United States Census Bureau, 2018). Older adults will outnumber children for the first time, and they are becoming more racially and ethnically diverse. Between 2017 and 2040, the older non-Latino white population is projected to increase by 36% compared to 188% of the older Latino population (Administration on Aging, 2018). Importantly, race and ethnicity are noteworthy demographic risk factors for Alzheimer's disease and related dementia (ADRD)

(Matthews et al., 2019). Among a nationally representative sample of Medicare beneficiaries, Latinos older than 65 years had the second-most cases of ADRD among the racial/ethnic groups (African Americans were first) (Matthews et al., 2019).

Older Latinos are at higher risk of cognitive impairment due to increased prevalence of risk factors for cognitive decline such as obesity, type 2 diabetes, and metabolic syndrome (Benjamin et al., 2017). Previous studies have demonstrated that Latinos are 1.5 times more likely than age-equivalent non-Latino whites to develop ADRD, and less likely to be diagnosed until later stages of the disease (Alzheimer's Association, 2019; Cooper, Tandy, Balamurali, & Livingston, 2010). Nonetheless, the adoption of healthy lifestyles can potentially attenuate the increased risk factor, with physical activity (PA) being a central behavior. Physical activity is effective in reducing obesity, type 2 diabetes, and metabolic syndrome (Piercy et al., 2018); and a key modifiable factor for improved brain health (Hillman, Erickson, & Kramer, 2008; Jochem et al., 2017). Specifically, evidence suggests that PA helps to maintain cognitive function and reduce the risk of cognitive decline and ADRD (Beckett, Ardern, & Rotondi, 2015; Bherer, Erickson, & Liu-Ambrose, 2013; Blondell, Hammersley-Mather, & Veerman, 2014; Gallaway et al., 2017; Mortimer & Stern, 2019; Sofi et al., 2010; Yaffe, Barnes, Nevitt, Lui, & Covinsky, 2001; Yaffe et al., 2009).

The effects of PA on cognitive functioning can be understood with a conceptual model of mechanisms of PA at multiple levels of analysis (Stillman, Cohen, Lehman, & Erickson, 2016). This conceptual model (Figure 1) states that PA can influence cognitive functioning through downstream effects. Physical activity induces changes to molecular and cellular pathways, which initiate changes to macroscopic properties of the brain (i.e., brain structure and function), which in turn influences cognitive functioning directly or moderated by behavioral and socioemotional changes. Stillman et al. (2016) pointed out that previous literature has primarily focused on the molecular and cellular levels, to the detriment of brain systems and behavior. For this study, we are specifically interested in white matter (WM) volume (WMV), WM integrity (WMI), and WM hyperintensities (WMH).

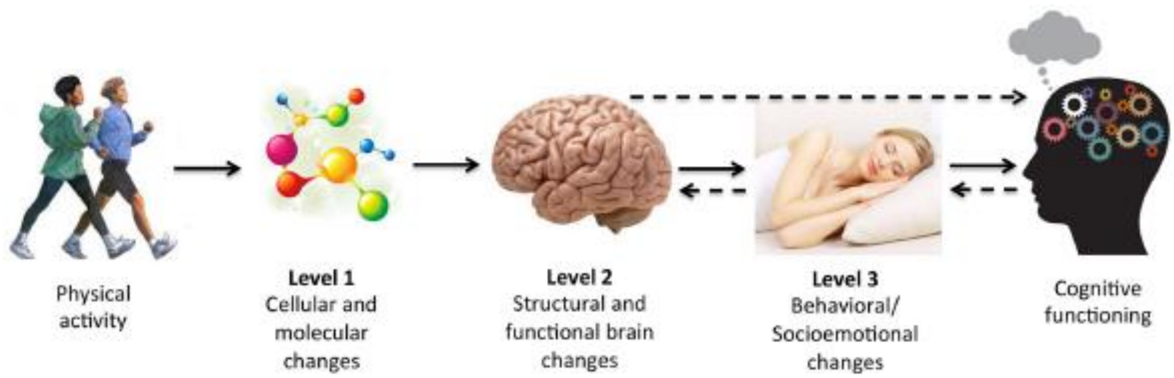

Figure 2. Conceptual model of the mechanisms of physical activity at multiple levels of analysis [extracted from Stillman et al. (2016)]

White matter is pivotal for cognitive functioning efficiency. White matter tracts enable the transfer of information within the brain, allowing for a rapid and efficient integrative capacity of neural systems necessary for high order cognitive operations (e.g., attention, memory, language, visuospatial skills, and executive function) (Filley & Fields, 2016). One of the fundamental mechanisms characterizing age-related cognitive decline is the disruption of axons and myelin in WM (Bennett & Madden, 2014; Burzynska et al., 2014; Madden et al., 2012; Raz & Rodrigue, 2006; Walhovd & Ka, 2014). Three primary measures of WM health (i.e., WMV, WMH, and WMI) have been widely used by researchers to demonstrate changes in WM both in normal aging and cognitive impairment. The most general form of measuring WM health is through global WMV, which represents roughly half of the total brain volume (Filley & Fields, 2016) and has accelerated decline starting at 60 years old (Walhovd et al., 2011). Global WMV includes measures of both integrity and injury, allowing for a sense of overall health via possible atrophic changes.

Another important measure of WM health relates to the presence of injuries (also known as leukoaraiosis), which are evident hyperintensities (Liu et al., 2016) or bright areas on magnetic resonance imaging (MRI) utilizing T2-weighted fluid-attenuated-inversion-recovery (FLAIR) (Debette & Markus, 2009; Torres, Strack, Fernandez, Tumey, & Hitchcock, 2015; Vesperman et al., 2018). The presence and progression of WMH are considered an indicator of cognitive decline (Kloppenborg & Geerlings, 2014), and its progression can be controlled addressing vascular risk factors (Dufouil et al., 2005). Considering that PA is widely accepted to improve cardiovascular health (Nystoriak & Bhatnagar, 2018; Pinckard, Baskin, & Stanford, 2019), greater PA levels could potentially be linked to lower levels of WMH or even slowing down its progression.

Alterations and subtle damage in WM can sign to degeneration of the tissue. The susceptibility to steep declines in WM is particularly high among older adults, with anterior regions showing greater degradation (Burzynska et al., 2017, 2010; Westlye et al., 2010). This degeneration is captured as decreased fractional anisotropy (FA) as measured with diffusion tensor imaging (DTI) acquired via MRI. As described by Burzynska et al. (2017), FA is a measure of the directional dependence of diffusion (Basser, 1995), reflecting fiber density, integrity, orientation and coherence within a voxel (Beaulieu, 2002). Reduced FA in aging has been linked to loss of axon and myelin integrity, signaling to reduced WMI (Burzynska et al., 2010). Improving WMI is essential to prevent declines in cognitive performance and keep older adults physically and cognitively independent (Burzynska et al., 2017). Accordingly, a recent systematic review and meta-analysis examining the relationship between physical fitness and activity and the WM of the aging brain demonstrated increased WMI among individuals that are more physically active and fit (Sexton et al., 2016).

To date, studies concerned with the relationship between PA and WM show equivocal results. Studies with overall PA (i.e., any body movement that leads to energy expenditure greater than at rest) have shown that higher levels are associated with greater WM global volume (Benedict et al., 2013; Gow et al., 2012), global integrity (Arnardottir et al., 2015; Gow et al., 2012; Tian et al., 2015), and less WMH (Burzynska et al., 2014). Greater levels of leisure-time PA (LTPA) or exercise have been associated with increased global WMI (Best et al., 2017; Smith et al., 2016; Wirth, Haase, Villeneuve, Vogel, & Jagust, 2014) and microstructural WMI (Gons, Laat, Norris, & Zwiers, 2013). Ho et al. (2011) categorized LTPA in quintiles and found that each increment in PA level was associated with a 2–2.5% greater WMV of the corona radiata and the parietal-occipital junction, after controlling for age, sex, and education.

One of the known benefits of being physically active is the improvement of cardiorespiratory fitness (CRF). Cardiorespiratory fitness is one component of physical fitness and is defined as “the ability to perform large-muscle, dynamic exercise, moderate-to-vigorous intensity exercise for prolonged periods” (p.72) (American College of Sports Medicine, 2014) Greater CRF levels have been associated with increased corpus callosum and frontal WMV (Erickson et al., 2007), microstructural integrity (Burzynska et al., 2014; Oberlin et al., 2016), and less WMH (Burzynska et al., 2014). Nonetheless, Sexton et al. (2016), in their systematic review and meta-analysis of the relationship between PA, CRF, and WM, showed small effects sizes in the associations of greater PA and CRF with greater WMV, reduced severity of WMH, and increased WMI. They also mentioned the existence of null findings and suggested cautious support to those associations.

Most of the evidence points to the benefits of increased PA levels on increased WMV, WMI, and reduced WMH. However, studies that included Latinos did not include a representative sample. This is an important gap that needs to be addressed, given the growth of the older Latino population, their increased prevalence of risk factors for cognitive decline (e.g., obesity, type 2 diabetes, and metabolic syndrome) (Benjamin et al., 2017), increased WMH volumes (Brickman et al., 2008; Wu et al., 2002; Zahodne et al., 2015), and increased likelihood of developing ADRD (Alzheimer's Association, 2019; Cooper et al., 2010). With that in mind, the present study aimed to investigate the associations between self-reported PA and WMV, WMI, and WMH in older Latinos. We hypothesized that greater levels of self-reported PA would be associated with greater WMV and WMI, and lower WMH.

C. **Methods**

1. **Study Design**

This study combined two cohort studies that have similar participants and neuroimaging protocols. Both studies were approved by the University of Illinois at Chicago (UIC) (Protocol # 2015-0497; Appendix B) and Rush University (FWA # 00000482; Appendix C) respective IRBs and conducted per the Declaration of Helsinki with written informed consent obtained from all participants. The first study was a pilot trial examining the impact of the BAILAMOS™ dance program on cognitive function, brain structure, and brain connectivity in older Latino adults (iBAILA). Participants of both intervention and control groups at baseline testing were included in this cross-sectional study. The second study refers to participants who self-identified as

Latino/Hispanic in a larger study of the brain aging and cardiovascular disease risk factors (Boots et al., 2019; Bronas et al., 2019; Karstens et al., 2019).

2. Participants and Procedures

Participants of both cohorts were community-dwelling older Latinos recruited via community outreach strategies in the Chicagoland area and Spanish speaking. Participants were recruited via community outreach strategies such as advertisements, flyers, and word of mouth. Individuals included in this study were screened according to the common inclusion criteria across the two cohorts including (a) age > 60 years; (b) self-reported Latino/Hispanic; (c) cognitively intact (score ≥ 14 in a modified version of the MMSE (Folstein et al., 1975) for telephone administration (Wilbur et al., 2012) for iBAILA, and a score ≥ 24 on the MMSE for the brain aging and cardiovascular disease risk factors study); and common exclusion criteria including (a) stroke within the past year; and (b) contraindications for MRI, including metallic implants. Additional criteria are outlined below.

Inclusion criteria that were particular to iBAILA encompassed information relevant to the dance intervention. Thus, they did not pertain to the brain aging and cardiovascular disease risk factors study. Bilingual staff screened interested individuals via phone. Inclusion criteria were (a) ability to speak Spanish; (b) participation in less than 150 minutes/week of aerobic exercise (c) danced < 2 times/month over the past 12 months; (d) willingness to be randomly assigned to treatment or control group; and (e) no plans to leave the U.S. for more than two weeks. Additionally, the EASY questionnaire (Resnick et al., 2008) was used to learn if physician consent was needed for program enrollment.

Participants deemed as eligible were scheduled for baseline testing. Bilingual research staff conducted data collection, which lasted one to two hours. Data collection occurred over two different sessions. Although all participants were either Spanish speaking or fluent in Spanish, we administered testing in Spanish or English, as requested by the participant. The first testing session included informed consent, demographic information questionnaires, and self-reported PA. During consenting, the staff member showed images of the MRI machine to make sure that participants understood the details about the MRI exam and agreed to participate in the study. Participants attended a second in-person session for MRI data acquisition at the UIC Advanced Imaging Center. Participants received a $50 gift card compensation after the data collection.

A detailed description of the two-stage screening process, inclusion criteria, and procedures of the brain aging and cardiovascular disease risk factors study are found elsewhere (Boots et al., 2019; Bronas et al., 2019; Karstens et al., 2019). Briefly, in addition to the common components described above, additional exclusion criteria consisted of (a) self-reported current or history of neurological conditions including Alzheimer's disease or any other form of dementia or mild cognitive impairment; (b) Parkinson's disease or any other movement or seizure disorder, (c) current or past history of Axis I or II disorders (e.g., depression or bipolar disorder); (d) a history of head injury or loss of consciousness, (e) a present or past substance abuse or dependence; (f) current psychotropic medication use. Individuals were not eligible for this study if they had received cognitive testing within the past year. For purposes of this study, only data on self-reported PA and DTI via MRI is being presented. Self-reported PA data were collected in a first visit, and MRI data acquisition occurred in a second visit at the UIC Advanced Imaging Center.

3. Measures

For both cohorts, we collected demographic data, self-reported PA, weight, and height. Brain imaging data utilized were WMV, WMI, and WMH acquired via MRI (see details below).

Demographic information included age, sex, education, race/ethnicity, and preferred language. Self-reported PA data were acquired through the Community Healthy Activities Model Program for Seniors (CHAMPS) Physical Activity Questionnaire for Older Adults (Stewart et al., 2001). It assesses weekly frequency and duration of physical activity in four different lifestyle domains (leisure time, household, occupational, and transportation physical activity) typically undertaken by older adults. The Spanish version of CHAMPS has been validated and employed with older Latino adults (Marquez et al., 2011; Rosario et al., 2008) We also collected self-reported data on weight (lb) and height (in). Those measures were then transformed (i.e., lb to kg, and in to cm) and used to calculate the body mass index (BMI = weight/height^2). BMI categories utilized were: less than 18.5 (underweight), 18.5–24.9 (normal weight), 25.0–29.9 (overweight), and 30.0 or more (obesity) (World Health Organization, 2000).

a. <u>Neuroimaging acquisition and processing</u>

Participants underwent neuroimaging at UIC's Center for Magnetic Resonance Research. Whole-brain images were acquired on a GE MR 750 Discovery 3T scanner (General Electric Health Care, Waukesha, WI) using an 8-channel head coil. Participants were instructed to remain still in a supine position on the scanner table. We provided earplugs to improve their comfort and positioned foam pads to minimize head movement. Sequences relevant for this data analysis were high-resolution three-dimensional T1- and T2- weighted images and diffusion MRI.

Diffusion MRI was acquired using a 2-D spin-echo EPI sequence (FOV=20mm; voxel size=0.78×0.78×3.0mm3; TR/TE=5,525/93.5ms; flip angle=90^o). Forty contiguous axial slices aligned to the AC-PC line were collected in 32 gradient directions with b=1400s/mm^2 and six baseline (b_0) images. Each subject's raw diffusion-weighted images volumes were aligned to the b_0 image using the FSL *eddy-correct* tool to correct for head motion and eddy current distortions.

The gradient table was adjusted accordingly. Non-brain tissue was removed from the DWIs using the Brain Extraction Tool (BET) (Smith, 2002) from the FSL package (Jenkinson, Beckmann, Behrens, Woolrich, & Smith, 2012) (http://fsl.fmrib.ox.ac.uk/fsl). Then FA was extracted from the diffusion tensor model, estimated on each voxel using *dtifit* from the FSL package.

In order to extract WMH data, T1-weighted image acquisition employed a Brain Volume (BRAVO) imaging sequence (field of view: FOV = 22mm; voxel size = 0.42×0.42×1.5mm3; 120 contiguous axial slices; TR/TE = 1200ms/5.3ms; flip angle = 13^{o}). A set of multi-slice T2-weighted fluid-attenuated inversion recovery (FLAIR) images were acquired using a two-dimensional PROPELLER sequence to improve robustness against motion (FOV=22cm, voxel size=0.35×0.35×3.0mm^3, 40 contiguous axial slices, TR/TI/TE=9500ms/2500ms/93.3ms, flip angle=142.35^{o}).

FSL software package was utilized for the WMH quantification. All images were pre-processed with brain extraction (using BET; Smith, 2002), and with intra-subject co-registration from FLAIR to T1 space (using FLIRT; Jenkinson & Smith, 2001) and from T1 to MNI152 standard space (using FNIRT; Andersson, Jenkinson, & Smith, 2010). Ten participants with high WMH load were manually and carefully segmented for WMH in FLAIR space as a training set. BIANCA (Brain Intensity AbNormality Classification Algorithm, part of FSL), a fully automated and supervised method for WMH detection, was then utilized for the remaining participants as well as for the manually segmented participants (Griffanti et al., 2016).

The following BIANCA default options were applied: no border (excluded voxels close to the lesion's edge), number of training points for WMH (i.e., 2000), and non-WMH (i.e., 10,000). The output images were post-processed by binarizing the WMH probability map with a threshold at 0.9, and by masking to exclude FLAIR image artifacts. Manual editing of the WMH mask was performed as needed visually. Finally, the WMH volumes were extracted with a minimum cluster size of 20.

4. Statistical analysis

Analyses were conducted in RStudio version 3.5.14 (RStudio Team, 2019) and FSL. Descriptive data are presented as mean, standard deviation, relative, and absolute frequency. Normal distribution was inspected with histograms and Kolmogorov-Smirnov test. We log-transformed WMH volume as it did not present normal distribution. All data were then transformed into z-scores. We capped outliers outside the Q1−1.5*IQR and Q3+1.5*IQR limits replacing those observations outside the lower limit with the value of the 5th percentile and those above the upper limit, with the value of 95th percentile. We performed multiple linear regression models to examine the associations between WMV, WMI, and WMH volumes with self-reported PA levels (leisure-time light PA, leisure-time moderate-to-vigorous PA (MVPA), total light PA, total MVPA, and total LTPA). For WMV analyses, we performed models for each independent variable (i.e., self-reported PA levels). The first model was unadjusted. We then sequentially added covariates (i.e., age, intracranial volume (ICV), WMH, sex, years of education, and BMI). For WMH analyses, we ran models for each independent variable (i.e., self-reported PA levels). The first model was fully unadjusted. We then sequentially added covariates (i.e., age, intracranial volume, sex, years of education, and BMI). Years of education was demonstrating significant associations with WMH within most of the model, we then decided to explore this variable as the independent variable. Therefore, we performed extra models with years of education as the independent variable and sequentially adding covariates (i.e., age, ICV, sex, and BMI). Models were performed utilizing the *lm* function in RStudio. Figures were generated with the *ggplot2* package (Wickham, 2011). Significance levels were set at $p < 0.05$. The analysis for WMI as measured by FA, was conducted utilizing the *randomize* tool on the FSL package. We conducted a series of multiple linear regression models. First, we performed fully unadjusted models; we then hierarchically added the following covariates: ratio WMH/ICV, age, years of education, sex, and BMI. The threshold was set at 95%. We did not conduct *a priori* sample size calculation. A *post-hoc* statistical power calculation utilizing G*Power showed that in order to achieve a small effect size with an 80% statistical power, the necessary sample size would be N = 55. Therefore, we acknowledge that results should be considered with caution due to our small sample size (N = 34).

D. <u>Results</u>

1. <u>Demographics and descriptive data</u>

Participants (N=34) were 66.6±6.4 years old, a majority were females (n = 55.9%), overweight (28.2±4.2 kg/m2), considered Spanish as their preferred language (88.2%), and spent from 3 to 25 years in school (9.9±5.0). Participants self-reported high levels of total LTPA, spending more time in MVPA than the 2018 Physical Activity Guidelines of 150min/week of MVPA.

TABLE IV
MEANS AND STANDARD DEVIATIONS OF SELF-REPORTED PHYSICAL ACTIVITY, GLOBAL WHITE MATTER VOLUME, AND WHITE MATTER HYPERINTENSITIES VOLUME.

Variables	*M*	*SD*
Light PA (min/week)	529.85	266.18
Leisure light PA (min/week)	318.97	233.91
Moderate PA (min/week)	246.62	236.23
Leisure moderate PA (min/week)	199.41	211.51
Vigorous PA (min/week)	90.00	166.42
MVPA (min/week)	336.62	334.84
Leisure MVPA (min/week)	289.41	309.04
Total PA (min/week)	866.47	517.49
Total leisure PA (min/week)	608.38	458.08
Global WMV (mm^3)	408261.61	54684.44
WMH volume (mm^3)	1932.20	1085.36

2. **Associations between white matter volume, hyperintensities, integrity and self-reported physical activity**

We observed that greater self-reported levels of leisure-time MVPA were significantly associated with greater total WMV (β = 0.132, SE = 0.091, $p < 0.05$) after controlling for ICV, WMH volume, and age (Model 1) ($F(4,29) = 26.958$, p = <0.001). We then hierarchically added the other three covariates (sex, years of education, and BMI). The model with all covariates (Model 4) accounted for an additional 0.2% (76.1%) of the variance in global WMV compared to Model 1 (75.9%) and showed a significant association between leisure-time MVPA and WMV (β = 0.179, SE = 0.096, $p < 0.05$). However, the additional 0.2% did not explain significantly more variance in WMV compared to Model 1 ($p = 0.379$). Figure 3 depicts the adjusted means of the linear regression of leisure-time MVPA on WMV (Model 1). We performed the same models capping outliers with the value of the 5th percentile and those above the upper limit, with the value of the 95th percentile. The results did not hold and self-reported levels of leisure-time MVPA were not associated with greater total WMV in all tested models. However, we chose to present the model with the outliers because five observations were not above the standard cut-off value of ±3 z-score. Nonetheless, we acknowledge the model should be interpreted with caution.

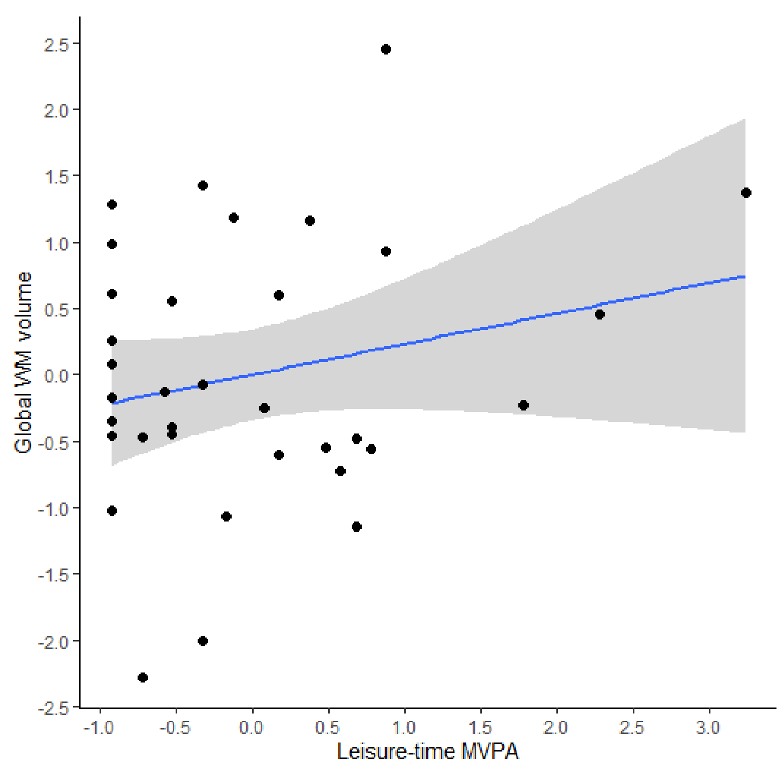

Figure 3. Adjusted means of the linear regression of leisure-time moderate-to-vigorous physical activity on global white matter volume (Model 1).

We did not find significant associations between self-reported PA levels and WMH. However, when not including self-reported PA levels in the model, we found that having more than ten years of education was significantly associated with lower WMH volume (Model 1) (β = -0.552, SE = 0.271, $p < 0.05$) after controlling for ICV and age ($F(3, 30) = 3.33$, $p < 0.01$). We then added hierarchically the other two covariates (sex and BMI). None of the models accounted for significantly more variance in WMH volume compared to Model 1 (17.5%) ($p > 0.05$). We performed the same models capping outliers ±1.5*IQR with the value of 5th and 95th percentile. The results held true after capping outliers. Therefore, we chose to present the model without capping outliers (Figure 4).

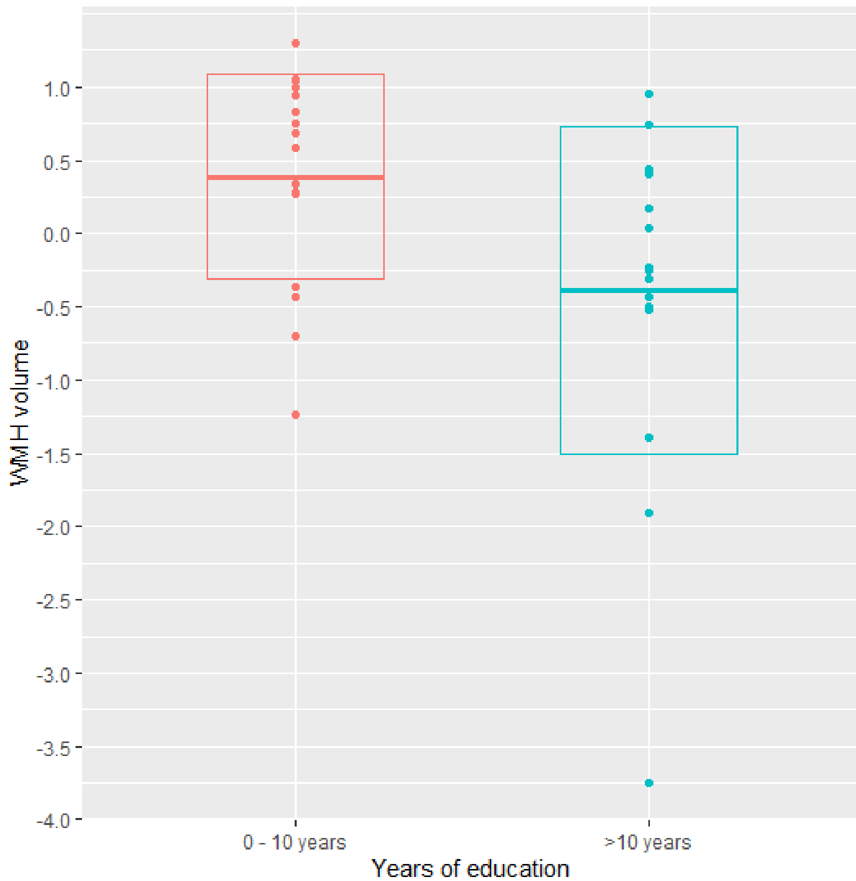

Figure 4. Adjusted means and standard deviation of the linear regression of years of school and white matter hyperintensities volume (Model 1).

We did not observe significant associations between self-reported PA levels and FA. We found that both unadjusted and full-adjusted models (i.e., age, ratio ICV/WMH, sex, years of education, and BMI) of all PA levels did not indicate any association with FA above the 95% threshold.

E. <u>Discussion</u>

This study aimed to investigate the associations between self-reported PA and global WMV, WMI, and WMH in older Latinos. We hypothesized that greater levels of self-reported PA would be associated with greater global WMV and WMI, and lower WMH. This hypothesis was partially supported. We found that greater levels of self-reported leisure-time MVPA were significantly associated with greater global WMV. Nonetheless, we did not observe significant associations between self-reported PA, WMI, and WMH. After conducting an exploratory analysis testing whether years of school was associated with WMH, we did find that having at least ten years of school was significantly associated with lower WMH volume.

Aging is the strongest risk factor in the loss of WMV and myelinated fibers (Marner, Nyengaard, Tang, & Pakkenberg, 2003), as well as WMI decline (Bennett & Madden, 2014), and WMH increases (de Leeuw et al., 2001). However, in a systematic review and meta-analysis of the relationship between PA, CRF, and WM (Sexton et al., 2016), the need to interpret results with caution was highlighted because this relationship is not yet well established. More studies of this nature are necessary for a more confident conclusion since associations of PA and CRF with WMV, WMI, and WMH have not been consistently reported (Sexton et al., 2016).

In the present study, we observed significant associations between self-reported leisure-time MVPA and global WMV when not excluding outliers. This result concurs with Sexton et al. (2016), who despite several null results, revealed that higher levels of PA and CRF were significantly associated with higher global WMV. Several studies are aligned with this finding. Benedict et al. (2013) classified older adults as very low, low, medium, and high active according to a self-reported measure of PA. They found that older adults in the medium and high active PA category had significantly greater global WMV. Adding further evidence, a population-based study in older adults from Iceland demonstrated that increased global WMV at baseline and five years later were associated with greater total PA at both time-points (Arnardottir et al., 2015). Similarly, another study found that being more physically active in the mid-life was associated with greater global WMV later in life (Rovio et al., 2010). However, the association was not significant after controlling for demographics and cardiovascular health covariates. Similarly, Gow et al. (2012) found that greater levels of PA in healthy older adults were positively associated with increased global WMV, but the association did not remain significant after adjustments for covariates.

Two main hypotheses of mechanisms of action explain the benefits of greater levels of PA on WM structure, the vascular and the neurobiological. The neurobiological mechanism of action is related to changes resulted from PA leading to increased growth of neurotrophic factors production and up-regulated molecular cascades, which contributes to neurogenesis and angiogenesis, consequently boosting brain and WM health (Stillman et al., 2016). The vascular hypothesis attributes the benefits of PA for brain health to positive effects on vascular risk factors also known to increase dementia risk (Kivipelto et al., 2001; Rovio et al., 2010).

Although we found that more time spent in leisure-time MVPA was significantly associated with greater global WMV, this result did not extend to other WM health metrics (i.e., WMH and WMI). These results concur with other previously reported null findings associating PA and WMH in cross-sectional studies with healthy older adults (Burzynska et al., 2014; Fleischman et al., 2015; Ho et al., 2011; Tian et al., 2014; Tseng, Gundapuneedi, Khan, & Levine, 2013; Willey et al., 2016; Zheng et al., 2012). Besides, longitudinal studies found that changes in PA were not associated with decreased WMH progression over three years (Moon et al., 2018), and five years of follow-up (Podewils et al., 2007).

On the other hand, other studies highlighted a significant relationship between PA and WMH. Burzynska et al. (2014) demonstrated that higher self-reported MVPA was associated with lower WMH volume, regardless of age, gender, and CRF. Gow et al. (2012) also found the self-reported PA at baseline was correlated with less WMH three years later. Similar results demonstrated that current PA levels significantly predicted lower WMH volumes (Wirth et al., 2014). It is important to note that participants in these studies were older and had higher educational attainment compared to participants in our study. Therefore, our sample might be too young to accrue as much damage to the WM, and consequently demonstrate a detectable pattern of associations between PA levels and WMH. Also, higher education attainment might reflect important differences in cognitive reserve, which may impact WM structure and health.

The role of educational attainment in WMH was demonstrated when exploring the associations between years of education and WMH. We found that having at least ten years of education was associated with lower WMH volume after controlling for age, sex, and BMI. This result might be explained by the concept of cognitive reserve, which suggests that intelligence or life experiences (e.g., educational or occupational attainments) might result in the form of reserve, shown as a set of skills that allows some people to cope with brain pathologies better than others (Scarmeas & Stern, 2011). Studies have shown that older adults with higher levels of education present delayed onset of cognitive impairment (Lenehan, Summers, Saunders, Summers, & Vickers, 2015), reduced risks of dementia (Brayne et al., 2010), reduced effects of brain infarcts on cognition (Farfel et al., 2013), and reduced association between WMH and cognition (Dufouil, Alperovitch, & Tzourio, 2003). Therefore, a higher educational level might exert influence decreasing WMH volumes and other brain pathologies (Fleischman et al., 2015).

Another measure of WM health that was not associated with PA in our study was WMI, as measured by FA. Previous studies with healthy older adults have demonstrated similar equivocal findings. Gons et al. (2013) found that being more physically active was negatively associated with other measures of WMI such as medial diffusivity (MD), axial diffusivity (AD), and radial diffusivity (RD) but was not positively associated with FA. Importantly, lower values of MD, AD, and RD and greater values of FA are estimates of better WMI. Similarly, Tian et al. (2014) classified healthy older adults in sedentary (i.e., less than 1,000 kcal/week in exercise, and less 2,719kcal/week in lifestyle PA), lifestyle active (i.e., more than 2,719 kcal/week in lifestyle PA and less than 1,000 kcal/week in exercise) and exercise active (i.e., more than 1,000 kcal/week in exercise). They found no difference in FA in several regions (superior longitudinal fasciculus, cingulate cortex, medial temporal lobe, and uncinate fasciculus) when comparing the three groups. However, participants in the exercise active group demonstrated lower MD than the sedentary group in the medial temporal lobe and cingulate cortex after controlling for age, sex, race, diabetes, and hypertension. Another study found that higher levels of PA was associated with greater global FA, but this association became non-significant after the inclusion of covariates in the model (Gow et al., 2012).

Equivocal results were also demonstrated in RCTs with exercise interventions. Fissler et al. (2017) showed that a short 10-week multimodal exercise program did not influence FA in older adults at risk of dementia. Whole-brain mean FA decreased while MD showed no significant change after a six-month aerobic exercise intervention in healthy sedentary older adults (Clark, Guadagni, Mazerolle, & Hill, 2019). Voss et al. (2014) did not observe significant increases in FA, AD, and RD in frontal, temporal, parietal, and occipital regions after a 12-moth aerobic training compared to stretching. Contrary to those results, WMI increased in older adults that participated in a six-month dance intervention compared to older adults in a six-month walking, walking + nutrition, and stretching and toning groups (Burzynska et al., 2017). Collectively, findings of cross-sectional, longitudinal studies and RCTs suggest that the associations of PA and WMI, and the effects of PA on WMI are elusive and subject to particularities of each study such as the metric of WMI, mode of PA (for RCTs), and type of PA measurement (i.e., self-reported or device-assessed).

Although our hypotheses were mainly not supported, investigating the association between WM health and PA levels in Latinos is warranted. Latinos have worse WM health compared to non-Latino whites counterparts (Brickman et al., 2008; Wu et al., 2002; Zahodne et al., 2015). In addition, a population-based study demonstrated that blood pressure and WM health share common genetic factors in Mexican Americans, the largest Latino subgroup in the U.S. (Kochunov et al., 2011). Genetic factors responsible for the elevation in arterial pulse pressure and systolic blood pressure were also responsible for declining WMI (Kochunov et al., 2011). Hence, considering it on the top of the well-known benefits of PA to prevent, treat, and control high blood pressure (MacDonald & Pescatello, 2019), it is even more urgent to understand the relationship between PA and WM health among Latinos. Therefore, future research can promote PA in Latinos to reduce the burden caused by vascular, cerebrovascular, and WM illnesses.

Despite some novel findings, this study has several limitations. First, our sample size might have prevented us from detecting statistically significant associations. Second, our measures of WMV, WMI, and WMH were limited to global measures, which limited our ability to investigate WM local health and structure. Third, we relied on self-reported PA measurement, which is subject to recall bias, overestimation of PA engagement, and social desirability bias. That might be related to participants self-reporting participation in more PA than advised by the 2018 Physical Activity Guidelines of 150min/week of MVPA. Additionally, a potential overestimated self-reported time spent in MVPA was due to CHAMPS scoring process. Fourth, we cannot imply any causal effects due to the cross-sectional design. Lastly, the brain aging and cardiovascular disease risk factors study and iBAILA cohorts, when considered individually, had distinct primary objectives.

Nevertheless, potential non-similarities between participants of both cohorts do not make them importantly different because of similar recruitment efforts.

Our study had important strengths. We focused entirely on older Latino adults, the fastest-growing minority group among older adults, and a populational segment that presents greater risk factors for cognitive decline compared to non-Latino whites. We also focused our recruitment efforts in low-income and low-educational attainment Latinos, which, unfortunately, is representative of the Latino population in the U.S. Future studies should further investigate measures of local WM health and structure, utilize additional measures of WMI other than FA, combine self-reported and device-assessed PA and CRF, account for cardiovascular and metabolic risk factors for WM health, and have larger sample sizes.

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III. MANUSCRIPT 3

The Impact of the BAILAMOS™ Dance Program on Brain Functional Connectivity and Cognition in Older Latino Adults

A. Abstract

Introduction: Older Latino adults are at higher risk of developing chronic diseases associated with cognitive impairment and engage in less leisure-time physical activity (PA). Dance is an appropriate and culturally relevant form of PA for this population. Resting-state functional connectivity (FC) is a putative biomarker for age-related cognitive decline. Studies investigating the impact of dance on brain networks' FC are scarce and did not include older Latinos. We aimed to investigate the impact of a four-month dance program (BAILAMOS™) on self-reported and device-assessed PA, FC in three bain networks (DMN, FPN, and SAL), and cognition. **Methods:** This was an exploratory single-group pre-post design. Ten cognitively intact older Latino adults participated in the four-month twice a week BAILAMOS™ dance program with four Latin dance styles. We assessed participants' engagement in PA (self-reported and device-assessed), estimated cardiorespiratory fitness, cognition (i.e., neuropsychological tests), and resting-state FC via magnetic resonance imaging at baseline and post-intervention. Self-reported PA data was not normally distributed. We first conducted the Wilcoxon Signed Ranked test for paired samples. For sensitivity analysis, we carried out dependent t-tests. As results were not different, we present data from the dependent t-tests. We also performed Pearson correlations to investigate whether changes in PA were correlated to changes in cognition and FC. Significance levels were set at $p < 0.05$. **Results:** We observed a significant increase of self-reported moderate leisure-time PA from pre- to post-intervention ($t(9) = 3.16$, $p = 0.011$, $d = 0.66$). We did not find statistically significant changes in cognition. FC within-FPN ROIs significantly increased pre- to post-intervention ($t(9) = 2.35$, $p = 0.043$, $d = 0.70$). The DMN ROIs showed a moderate effect size increase in the integration with other networks' ROIs ($t(9) = 1.96$, $p = 0.081$, $d = 0.64$) after participation in the BAILAMOSTM dance program. Increases in moderate leisure-time PA were associated with increases in the FC within-FPN (R = 0.70, $p = 0.022$) and decreases in FC between the supramarginal gyrus and the whole-brain (R = -0.75, $p = 0.012$). Increases in the FC within-FPN ROIs were associated with decreases in perceptual speed (R = -0.73, $p = 0.016$). **Conclusions:** The BAILAMOS™ showed promising increases within-FPN FC, which is a cognitive-control network related to adaptive control and flexibility. The FPN FC is associated with cognitive engagement of specific tasks and facilitate the learning of new tasks. Our results present dance as a potential form of avoiding loss of FC within- and between-networks that are associated with cognitive decline.

B. Introduction

Increasing physical activity (PA) levels is paramount to decreasing the risk of age-related chronic diseases (Booth, Roberts, & Laye, 2012). Older Latino adults have higher rates of risk factors for cognitive decline, such as obesity, type 2 diabetes, and metabolic syndrome compared to non-Latino whites (Benjamin et al., 2017). Older Latinos also engage in less leisure-time PA (LTPA) than other racial/ethnic groups (Keadle et al., 2016). Therefore, utilizing PA to reduce the risk factors of chronic diseases among higher-risk groups such as Latinos is warranted.

Cognitive decline due to aging most often affects the domains of attention, memory, and executive function (Hedden & Gabrieli, 2004). The process of aging in the brain that accompanies cognitive decline is heterogeneous, with dysfunctions in multiple brain systems (Lin et al., 2018). Within brain function, the use of resting-state functional connectivity (FC) is increasingly being utilized as a putative biomarker for age-related cognitive decline (Lin et al., 2018) and is a valuable measure of brain health because it correlates both with normal age-related decline in brain function and decline due to pathologies (Lin, Xing, & Han, 2018). Researchers have used resting-state FC to identify brain regions that are negatively affected by aging and, at the same time, are modifiable through PA (Suo et al., 2016; Voss et al., 2019; Voss, Erickson, et al., 2010).

Resting-state FC measures the correlations between regional fluctuations in blood oxygenation level-dependent (BOLD) signal fluctuations and aims to describe the relationship between neuronal activation patterns of anatomically distant, but functionally related, gray matter regions at rest (Nir, Hasson, Levy, Yeshurun, & Malach, 2006; Van Den Heuvel & Pol, 2010; Voss et al., 2016). Notably, dysfunctions due to cognitive decline are more accentuated in specific brain networks such as the default-mode-network (DMN) (Ferreira & Busatto, 2013; Jagust, 2013; Voss et al., 2016), frontoparietal network (FPN) (Ferreira & Busatto, 2013; Jagust, 2013; Voss et al., 2016), salience (SAL) (Onoda, Ishihara, & Yamaguchi, 2012; Voss et al., 2016), and fronto-executive network (FEN) (Huang, Fang, Li, & Chen, 2016; Voss et al., 2016).

A review of neuroimaging studies on PA in healthy older adults and those with mild cognitive impairment suggested that the DMN, FEN, and FPN are potential networks to be targeted by PA interventions (Huang et al., 2016). The literature presents mixed findings of the effects of PA on FC in specific networks. Literature has shown associations between higher cardiorespiratory fitness (CRF) levels and increased FC within DMN-regions (Voss, Erickson, et al., 2010; Voss et al., 2016), and PA maintenance over time with higher FC within DMN-regions (Boraxbekk, Salami, Wåhlin, & Nyberg, 2016). Randomized controlled trials have shown a positive impact of a multimodal PA and cognitive training intervention on FC within DMN-regions (Li et al., 2014) and an effect of resistance and flexibility training on increased FC within DMN and FPN-regions (Voss et al., 2010).

Engaging in PA is important; however, not all forms of PA are acceptable among older adults. A systematic review and meta-synthesis of studies on the acceptability of PA interventions in older adults showed that fun and enjoyment of social interaction were primary motivators to being physically active (Devereux-Fitzgerald, Powell, Dewhurst, & French, 2016). Interventions utilizing dance as a form of PA offers a combination of physical, cognitive, and social activities potentially effective for maintaining or improving cognition (Esmail et al., 2020; Predovan, Julien, Esmail, & Bherer, 2019). Although dance is considered an environmental and cognitive enriched type of PA (Kattenstroth et al., 2013), few studies investigating the impact of PA on cognition and brain network FC have utilized dance as the mode of PA.

Studies that have examined the effect of a dance intervention on cognition have reported improved overall cognition (concentration, attention, and non-verbal learning) (Kattenstroth et al., 2013), as well as within domains of cognitive flexibility (i.e., ability to adapt behaviors in response to changes in the environment) (Coubard et al., 2011), visuospatial learning (Merom et al., 2016), motor-cognitive dual-task performance while walking (Hamacher et al., 2015), and verbal short-term memory, long-term free recall and recognition (Rehfeld et al., 2018) compared to other forms of exercise or control groups. Voss et al. (2019) posit that although dance interventions might have insufficient intensity or duration to produce improvements in cognition associated with moderate-to-vigorous PA, the learning effects of a cognitively-demanding PA could lead to changes in FC. Some of the suggested networks are SAL, which is associated with updating learning skills that involve overriding habits (Corbetta & Shulman, 2002; Dosenbach, Fair, Cohen, Schlaggar, & Petersen, 2008), and the DMN, which includes essential pathways for spatial memory (Bubb, Kinnavane, & Aggleton, 2017). Moreover, we propose that learning dance could lead to changes in the FPN since the FPN is associated with the ability to coordinate behavior in a rapid, accurate, and flexible manner (Marek & Dosenbach, 2018).

Overall, studies investigating the impact of dance on brain networks' FC are scarce. Voss et al. (2019) found no changes in the DMN and SAL after a 24-week dance intervention compared to two groups who engaged in aerobic exercise and one control group. Conversely, participation in a 24–week traditional Greek dance program led to increased FC in the executive-control network ECN, DMN, and FPN (Zilidou et al., 2018). Other studies investigated the effects of a simulated dance exergame on whole-brain BOLD response and neural representations (Kirsch, Diersch, Sumanapala, & Cross, 2018), neural reorganization (Ji et al., 2018), and brain activity (Eggenberger, Wolf, Schumann, & de Bruin, 2016).

To date, few studies have proposed dance interventions to improve cognition and investigate its impact on FC in brain networks associated with aging and PA; and none of the studies focused on older Latino adults. Given that older Latinos are at higher risk of developing chronic diseases associated with cognitive impairment, engage in less leisure-time PA, and consider dance as an appropriate and culturally relevant form of PA (Marquez et al., 2016; Melillo et al., 2001; Mier et al., 2007; Wilbur et al., 2003), the present exploratory pilot study aimed to address this gap in the literature. We aimed to (a) investigate the impact of a four-month dance program (BAILAMOS^{TM}) on self-reported and device-assessed PA, estimated CRF, FC in DMN, FPN, SAL, and cognition; and (b) investigate whether changes in PA and estimated CRF as a result of the BAILAMOS^{TM} were associated with changes in FC in DMN, FPN, and SAL. We hypothesized that (a) FC within and between the DMN, FPN, and SAL regions would be significantly greater after participation in the BAILAMOS^{TM} program; (b) changes in self-reported and device-assessed PA and estimated CRF would be associated with changes in cognition and FC within and between the DMN, FPN, SAL areas; and (c) changes in cognition would be associated with changes in FC within and between the DMN, FPN, SAL areas.

C. Methods

1. Study design

This study was an exploratory single-group pre-post design. We utilized part of the dataset originated from the iBAILA study, a pilot trial examining the impact of the BAILAMOS^{TM} dance program on cognitive function, brain structure, and brain FC in older Latino adults. Participants were randomized to BAILAMOS^{TM} or a wait-list control group. For purposes of this study, data only from participants in the dance intervention was included (see detail in **Participants**). The study was approved by the UIC IRB (Appendix A) and conducted in accordance with the Declaration of Helsinki with written informed consent obtained from all participants.

2. Participants

We conducted recruitment using established relationships of Dr. David X. Marquez with the Latino community in Chicago (e.g., senior centers, churches). Research staff conducted presentations at the senior center in which the study took place, and at Roman Catholic churches in the vicinity of the senior center site. The majority of residents in the chosen neighborhood are Latinos. Additionally, recruitment included flyers in senior housing facilities, presentations at health centers and clinics, health fairs, and word of mouth. We assessed 162 participants for eligibility and randomized 22 to either the BAILAMOS^{TM} treatment group (n= 13) or a wait-list control group (n= 9). Due to high rates of attrition in the control group (60%), for purposes of this study, only data from participants in the dance intervention with MRI at pre- and post-intervention were included.

Inclusion criteria were: (a) aged 60 years or more; (b) self-identification as Latino/ Hispanic; (c) self-reported ability to understand Spanish; (d) self-reported participation in less than two days per week of aerobic exercise; (e) at risk for disability (see below); (f) cognitively intact as assessed by a modified version of the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) for telephone administration (Wilbur et al., 2012); (g) danced less than two times/month over the past 12 months; (h) willingness to be randomly assigned to treatment or wait-list control group; and (i) no current plans to leave the country for more than two consecutive weeks over the next year.

We defined at risk for disability as one of the following: (a) presence of diabetes (Al Snih et al., 2007); (b) underweight (body mass index [BMI] lower than 18.5) (Al Snih et al., 2007); (c) overweight or obese (BMI greater than 25.0) (Al Snih et al., 2007; Chen et al., 2002); or (d) difficulty or change with any one of the following four tasks: (1) walking a long distance (four blocks or half-mile), (2) climbing ten steps, (3) transferring from a bed or chair, (4) walking a short distance on a flat surface. Participants answered two questions for each task: "Have you had difficulty completing (task)" and "Have you changed the way you complete (task) or how often you do this, due to a health or physical condition?" Older adults with difficulty in any one of the four tasks were eligible for the study.

Self-reported exclusion criteria included: (a) uncontrolled cardiovascular disease or type 2 diabetes; (b) pacemaker or metallic implants (infusion pumps, metal prostheses, metallic-backed transdermal patches or metallic shrapnel); (c) claustrophobia that precludes MRI; (d) stroke within the past year; (e) healing or unhealed fracture(s); (f) hip or knee replacement within the past six months; (g) heart failure; (h) recurrent falls within the past year; (i) regular use of a walker or wheelchair; and (j) weigh more than 300 pounds (unable to fit into the MRI). We used the Exercise Assessment and Screening for You (EASY) questionnaire to detect conditions that could prevent exercise participation (Resnick et al., 2008) and learn whether physician evaluation and clearance was necessary before engaging in PA (Chodzko-Zajko et al., 2012).

3. Measures

We collected data on demographic information, rate of perceived exertion (RPE), class enjoyment, overall physical health, cognitive function, self-reported and device-assessed PA, estimated CRF, and functional resting-state MRI.

a. Demographics, overall health, rate of perceived exertion, and enjoyment

Demographic information included age, sex, education, income, marital status, country of origin, race, ethnicity, preferred language, years lived in the U.S., and number of children. Physical health measures included measurements of weight (Tronix 5002 Stand-on Scale or Seca 803

Flat Scale), height (Seca 216 Mechanical Stadiometer or Seca 213 Portable Stadiometer), and body mass index (BMI)(kg/m^2). At each class, we asked participants to grade their perceived rate of exertion from 6 (no exertion) to 20 (maximal exertion) with the Borg Rating of Perceived Exertion (RPE) (Borg, 1982) and to respond to a question about their perceived enjoyment on a Likert scale from 1 to 7 (strongly disagree to strongly agree).

b. Cognition

We utilized a subsample of tests from the official Spanish version of measures in the Uniform Data Set (UDS) of the National Institute on Aging Alzheimer's Disease Center Program (Acevedo et al., 2009). We administered all neuropsychological tests at baseline and post-intervention.

Four neuropsychological tests measured executive function: (1) Trail Making Test (TMT) A and B (Adjutant General's Office, 1944); (2) Stroop C (color task of the short form; Wilson et al., 2005) of the Stroop Neuropsychological Screening Test (Trenerry et al., 1989), and the Stroop C-W (color-word task); (3) Word fluency test (Welsh et al., 1994), and (4) Symbol Digit Modalities Test (Smith, 1982). The perceptual speed domain comprised of TMT A and B; Stroop C and Stroop C-W. Working Memory was measured with the two parts (forward and backward) of the Digit Span test (Wechsler, 1987), and the Digit Ordering test (Cooper, Sagar, Jordan, Harvey, & Sullivan, 1991; Wilson et al., 2005) The Word fluency test (fruits and vegetables) measured semantic memory. Measures of episodic memory included the Logical Memory I (Immediate) and II (Delayed) (Wechsler, 1987).

c. Physical Activity and cardiorespiratory fitness

Participants responded to the Community Healthy Activities Model Program for Seniors (CHAMPS) Physical Activity Questionnaire for Older Adults (Stewart et al., 2001). It assesses weekly frequency and duration of PA in four different lifestyle domains (leisure-time, household, occupational, and transportation) typically undertaken by older adults. The Spanish version of CHAMPS has been validated and employed with older Latino adults (Rosario et al., 2008).

Device-assessed PA was acquired with a triaxial GT3X+ accelerometer (Actigraph, Pensacola, Florida). Participants wore it for one week at baseline and post-intervention, respectively, on their non-dominant wrist for seven consecutive days, removing it for showering and swimming. The research staff members instructed participants about the use of the accelerometer and provided a handout with additional instructions and pictures in Spanish or English. Participants also received an accelerometer log to record the times they removed and put back the accelerometer. Data were included in the analysis if the participant wore the accelerometer for at least four days for more than 10 hours/day (Hart et al., 2011). Data were processed with ActiLife version 6.13.3 software after being converted to 60 seconds epochs. We defined non-wear time as at least 60 consecutive minutes of 0 activity counts. Average counts per minute (CPM) are reported as the main outcome for device-assessed PA.

We estimated CRF with Jurca's et al. (2005) regression equation, which estimates CRF in metabolic equivalents (METs) without exercise testing. The equation takes into account participants' sex, age, BMI, resting heart rate, and PA levels on a scale from 1 to 5 (see Jurca et al., 2005 for detailed scale). We used the following equation: sex × (2.77) – age × (0.10) – BMI × (0.17) − resting heart rate × (0.03) + PA score + 18.07.

d. <u>Neuroimaging data acquisition and processing</u>

Participants underwent neuroimaging at UIC's Center for Magnetic Resonance Research. Whole-brain images were acquired on a GE MR 750 Discovery 3T scanner (General Electric Health Care, Waukesha, WI) using an 8-channel head coil. Participants were instructed to remain still in a supine position on the scanner table. We provided earplugs to improve their comfort and positioned foam pads to minimize head movement. Sequences relevant for this data analysis was the high-resolution resting-state functional MR images acquired with a fast echo-planar imaging (EPI) sequence with the following parameters: repetition time (TR) = 2000 ms; echo time (TE) = 30 ms; flip angle = 90^{o}; FOV = 24 mm x 24 mm; acquisition matrix size 64 X 64 X 256; slice thickness = 4 mm; gap = 0 mm; 256 axial slices.

Functional connectomes were generated using the resting-state fMRI toolbox, CONN (http://www.nitrc.org/projects/conn) (Whitfield-Gabrieli & Nieto-Castanon, 2012). In brief, raw EPI images were realigned, co-registered, normalized, and smoothed before analyses. Confound effects from motion artifact, white matter, and cerebrospinal fluid were regressed out of the signal. Using 32 labels, functional brain networks (e.g., DMN, FPN, SAL, and Language) were derived using pairwise BOLD signal correlations, which were then converted to z-scores using Fisher's r-to-z transformation. The ROIs selected for the present study are displayed in Table V. The DMN, FPN, and SAL were selected due to evidence of the effects of aging and PA on these networks. The Language (LAN) network was selected as a control network because language processes are robust to brain aging and PA.

TABLE V
NETWORKS REGIONS OF INTEREST (ROIs) DERIVED FROM FUNCTIONAL CONNECTOMES GENERATED FROM RESTING-STATE FMRI TOOLBOX (CONN).

Network	Region of interest label (ROI)	Description of the anatomical region	MNI coordinates (x, y, z)
DMN	MPFC	Medial prefrontal cortex	1, 55, -3
DMN	LP_L	Left lateral parietal lobule	-39, -77, 33
DMN	LP_R	Right lateral parietal lobule	47, -67, 39
DMN	PCC	Precuneus	1, -61, 38
SAL	ACC	Anterior cingulate cortex	0, 22, 35
SAL	AInsula_L	Left anterior insula	-44, 13, 1
SAL	AInsula_R	Right anterior insula	47, 14, 0
SAL	RPFC_L	Left rostral prefrontal cortex	-32, 45, 27
SAL	RPFC_R	Right rostral prefrontal cortex	32, 46, 27
SAL	SMG_L	Left supramarginal gyrus	-60, -39, 31
SAL	SMG_R	Right supramarginal gyrus	62, -35, 32
FPN	LPFC_L	Left lateral prefrontal cortex	-43, 33, 28
FPN	LPFC_R	Right lateral prefrontal cortex	41, 38, 30
FPN	PPC_L	Left posterior parietal cortex	-46, -58, 49
FPN	PPC_R	Right posterior parietal cortex	41, 38, 30
LAN	IFG_L	Left inferior frontal gyrus	-51,26,2
LAN	IFG_R	Right inferior frontal gyrus	54,28,1
LAN	pSTG_L	Left posterior superior temporal gyrus	-57,-47,15
LAN	pSTG_R	Right posterior superior temporal gyrus	59,-42,13

4. <u>Procedures</u>

During recruitment efforts, individuals interested in participating in the study provided consent to be called by a research staff member at a later time to perform screening. Those individuals that learned about the study via word of mouth or flyers called our office to schedule a time for a trained research staff to call them back and perform the screening. Bilingual research staff members conducted the screening via phone.

Eligible participants were scheduled for baseline testing, which was performed by bilingual research staff. Data collection occurred over two different sessions. In the first visit, a research staff member administered the informed consent, questionnaires (demographic information and PA), and neuropsychological tests in Spanish or English, as requested by the participant. Participants also received the accelerometer to wear for the next seven days. The research staff member provided all information related to proper accelerometer use. Also, at this session, the staff member showed images of the MRI machine to make sure that participants understood the details about the MRI exam and agreed to participate in the study. This session took place at the Pilsen Satellite senior center. Participants attended a second in-person session for MRI data acquisition at the UIC Advanced Imaging Center. Participants received a $50 gift card compensation after the data collection. The same procedures (except informed consent and demographic questionnaires) were repeated for post-testing between two and four weeks after the end of the BAILAMOS™ program.

5. **Intervention**

Participants took part in the BAILAMOS™ program. Details about the program have been previously reported (Marquez et al., 2014). Briefly, the program is a four-month, twice a week for 60min dance program with four Latin dance styles (Merengue, Cha Cha Cha, Bachata, and Salsa) ordered by difficulty level. Classes aimed to offer light to moderate PA intensity. Dance sessions included warm-up and stretching, instructions of the respective dance style with steps for singles and couples, and cool down. Couples learned steps of both leaders and followers, and continually rotated partners. Twice a month, participants attended *fiestas de baile* (dance parties) in which they had time to practice the learned steps until that point. Attendance at each session was recorded. Adherence was calculated by the number of classes attended, divided by the number of classes conducted (32 total).

6. Statistical Analysis

All the analyses were conducted in RStudio version 3.5.14 (RStudio Team, 2019). To assess changes in the neuropsychological tests, we first converted the raw scores to z-scores utilizing baseline means and standard deviations (Wilson et al., 2002). Then we combined the z-scores into composite scores of executive function, episodic memory, working memory, and global cognition by averaging the z-scores from each test (Wilson et al., 2002). We checked for distribution of the data with the Shapiro-Wilk normality test. Due to the small sample size and the fact self-reported PA data was not normally distributed, we first opted to conduct the Wilcoxon Signed Ranked test for paired samples to examine changes in the outcome variables pre- and post-intervention. For sensitivity analysis, we carried out paired t-tests. As results were the same, we chose to present data from the paired t-tests and means and standard deviations. We conducted Pearson correlations to investigate whether changes in PA levels were correlated with changes in cognitive function and FC within and between ROIs in the DMN, FPN, SAL, and a network utilized as control, the language network (LAN). The scatter plots presented were produced using *ggplot2* package (Wickham, 2009). Significance levels were set at $p < 0.05$. We computed Cohen's d effect size with *effsize* package (Torchiano, 2019). We utilized the BrainNet Viewer (https://www.nitrc.org/projects/bnv/) (Xia, Wang, & He, 2013) to display figures of brain FC between ROIs. As the study was an exploratory pilot, we did not conduct *a priori* sample size calculation. However, a *post-hoc* power calculation showed that it would be necessary an N = 34 to detect a moderate effect size change with 80% statistical power. Therefore, results should be interpreted with this limitation in mind.

D. Results

1. Demographic information, attendance, perceived exertion, and enjoyment

Participants (N = 10) were 67.1±6.2 years old, a majority were females (n = 7), overweight (28.3±5.3 kg/m^2), immigrated to the US from Mexico (n = 9) or Guatemala (n = 1) when they were 25.1±12.4 years old, and had been living in the U.S. for 39.5±12.8 years at the time of data collection. They spent from 4 to 15 years in school (8.7±4.2), reported low (n=6) or medium (n=4) income, and most had never participated in structured PA before (n=7). The average attendance was 77±26.9%. One participant never attended the program, and one participant attended only three classes. Even not receiving the allocated intervention or attending 10% of the classes, those participants were included in the analysis. Self-reported RPE ranged from 8.5 to 11 (10.0±2.6) over the 32 classes of the BAILAMOS™. The average perception of enjoyment during classes ranged from 5.6 to 7.0 (6.6±0.7).

2. BAILAMOS™ effects on physical activity levels, estimated cardiorespiratory fitness, and cognition

After the four-month BAILAMOS™ dance program we found no significant increases in device-assessed PA, and estimated CRF (Table VI). We observed a significant increase of self-reported moderate LTPA ($t(9) = 3.16$, $p = 0.011$, $d = 0.66$). Participants increased more than two hours of time spent in moderate leisure-time PA (M_{diff} = 126.52 min/week, [95% CI = 36.03; 217.02]). Although statistically non-significant, we observed small and moderate effects sizes for self-reported light LTPA ($d = 0.23$), moderate PA ($d = 0.31$), leisure-time MVPA ($d = 0.32$), and total LTPA ($d = 0.31$).

TABLE VI

SELF-REPORTED AND DEVICE-ASSESSED PHYSICAL ACTIVITY PRE- AND POST-BAILAMOS™ .

Physical activity	Pre M (SD)	Post M (SD)	Mean difference (95%CI)	*p*	*d*
Device-assessed					
Steps	11304.92 (4228.32)	12614.85 (7053.13)	1309.93 (-1331.47; 3951.33)	0.291	0.11
Sum of vector magnitude	13564.14 (3274.16)	13765.39 (3078.331)	203.65 (-1867.69; 2274.99)	0.829	0.06
Self-reported (min/week)					
Light PA	433.50 (238.26)	403.33 (147.52)	-16.80 (-198.48; 164.88)	0.692	-0.14
Light leisure PA	184.50 (207.61)	228.00 (163.83)	43.50 (-112.69; 199.69)	0.544	0.23
Moderate PA	192.00 (258.82)	270.00 (196.85)	78.00 (-27.71; 183.71)	0.129	0.31
Moderate leisure PA	143.47 (186.01)	270.00 (196.85)	126.52 (36.03; 217.02)	0.011*	0.66
MVPA	238.50 (320.73)	292.50 (223.86)	54.00 (-70.23; 178.23)	0.351	0.17
Leisure MVPA	205.50 (208.98)	292.50 (223.85)	87.00 (-21.70; 135.70)	0.103	0.32
Total PA	672.00 (501.29)	701.32 (313.18)	29.32 (-224.24; 282.89)	0.799	0.06
Total leisure PA	390.00 (398.18)	507.00 (398.18)	117.00 (-63.67; 297.67)	0.177	0.31
CRF	5.33 (2.79)	5.51 (2.72)	0.18 (-0.35; 0.71)	0.465	0.06

*Statistically significant for $p<0.05$.

BAILAMOS^{TM} did not lead to statistically significant changes in cognitive domains or global cognition. However, we observed that participants showed a moderate effect size reduction in the perceptual speed domain (M_{diff} = -0.222, [95% CI = -0.592; 0.152], $t(9) = -1.34$, $p = 0.213$, $d = -0.5$).

3. BAILAMOS^{TM} effects on functional connectivity

We conducted four different analyses comparing the FC pre- and post- BAILAMOS^{TM} dance program. First, we compared the FC between each networks' ROIs and seeds across the whole-brain (Table VII). We display results for those ROIs with effect size above 0.5 (Figures 5, 6, and 7). Second, we compared the average FC within-ROIs for each network (Table VIII) and display results for the FPN (Figure 8). Third, we compared the average FC within-ROIs between each network (data not shown). Fourth, we created a ratio integration/segregation. This ratio was calculated with the average FC between-networks over the average FC within-networks ROIs. We compared the ratio for each network of interest at pre- and post-BAILAMOS^{TM} dance program (Table IX).

We did not observe statistically significant differences in the FC between the networks' ROIs and the whole-brain (Table VII). However, we found moderate effect of BAILAMOS^{TM} dance program in three ROIs, the right anterior insula (SAL) (M_{diff} = -0.0450, [95% CI = -0.1201; 0.0301], d = -0.54), left supramarginal gyrus (SMG) (SAL) (M_{diff} = -0.0435, [95% CI = -0.1035; 0.0165], d = -0.56), and left lateral prefrontal cortex (LPFC) (FPN) (M_{diff} = 0.0459, [95% CI = -0.0324; 0.1243], d = 0.52).

TABLE VII

REGIONS OF INTEREST FUNCTIONAL CONNECTIVITY X WHOLE-BRAIN PRE- AND POST-BAILAMOS^{TM}.

ROIs (Network) FC x Whole-brain	Pre M (SD)	Post M (SD)	Mean Diff (95% CI)	*p*	*d*
MPFC (DMN)	0.0015 (0.0931)	0.0198 (0.0610)	0.0183 (-0.0428; 0.0794)	0.515	0.22
LP_L (DMN)	0.0758 (0.0486)	0.0852 (0.0959)	0.0093 (-0.0542; 0.0729)	0.746	0.11
LP_R (DMN)	0.0906 (0.0662)	0.1153 (0.0778)	0.0247 (-0.0125; 0.0619)	0.167	0.33
PCC (DMN)	0.0621 (0.1054)	0.1061 (0.0931)	0.0439 (-0.0220; 0.1100)	0.166	0.44
ACC (SAL)	0.1646 (0.1486)	0.0585 (0.0767)	-0.0159 (-0.0723; 0.0404)	0.538	-0.23
AInsula_L (SAL)	0.2242 (0.0478)	0.1943 (0.0981)	-0.0299 (-0.0919; 0.0320)	0.302	-0.36
AInsula_R (SAL)	0.2103 (0.0570)	0.1653 (0.1001)	-0.0450 (-0.1201; 0.0301)	0.208	-0.54
RPFC_L (SAL)	0.2165 (0.0651)	0.1869 (0.0679)	-0.0296 (-0.0760; 0.0168)	0.183	-0.44
RPFC_R (SAL)	0.2101 (0.0775)	0.1817 (0.0950)	-0.0283 (-0.0856; 0.0289)	0.291	-0.32
SMG_L (SAL)	0.2206 (0.0666)	0.1771 (0.0854)	-0.0435 (-0.1035; 0.0165)	0.135	-0.56
SMG_R (SAL)	0.2159 (0.0546)	0.1774 (0.0969)	-0.0384 (-0.0985; 0.0216)	0.185	-0.45
LPFC_L (FPN)	0.1272 (0.1030)	0.1732 (0.0660)	0.0459 (-0.0324; 0.1243)	0.217	0.52
LPFC_R (FPN)	0.1616 (0.0700)	0.1500 (0.0674)	-0.0116 (-0.0529; 0.0297)	0.542	-0.16
PPC_L (FPN)	0.1189 (0.0962)	0.1395 (0.0553)	0.0206 (-0.0386; 0.0798)	0.452	0.24
PPC_R (FPN)	0.1711 (0.0642)	0.1682 (0.0761)	-0.0029 (-0.0642; 0.0584)	0.917	-0.04

We chose to display the three ROIs x Whole-brain FC with effect sizes above 0.5 (Table VII) in Figures 5, 6, and 7.

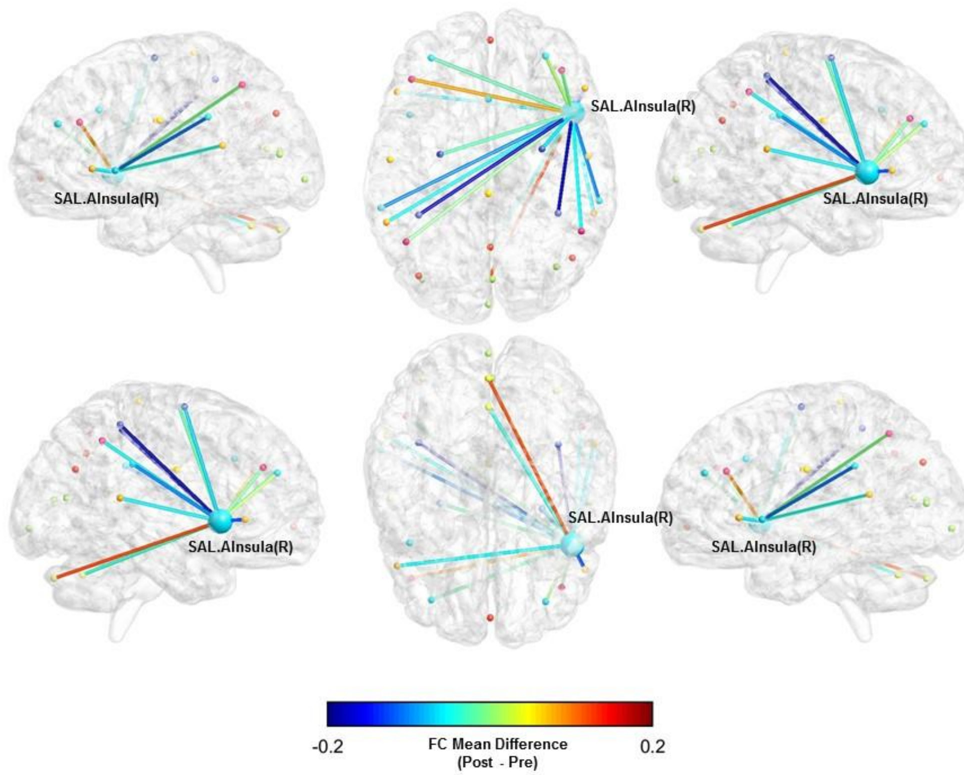

Figure 5. Functional connectivity mean difference between the right anterior insula (SAL) and whole-brain pre- and post-BAILAMOS^{TM}.

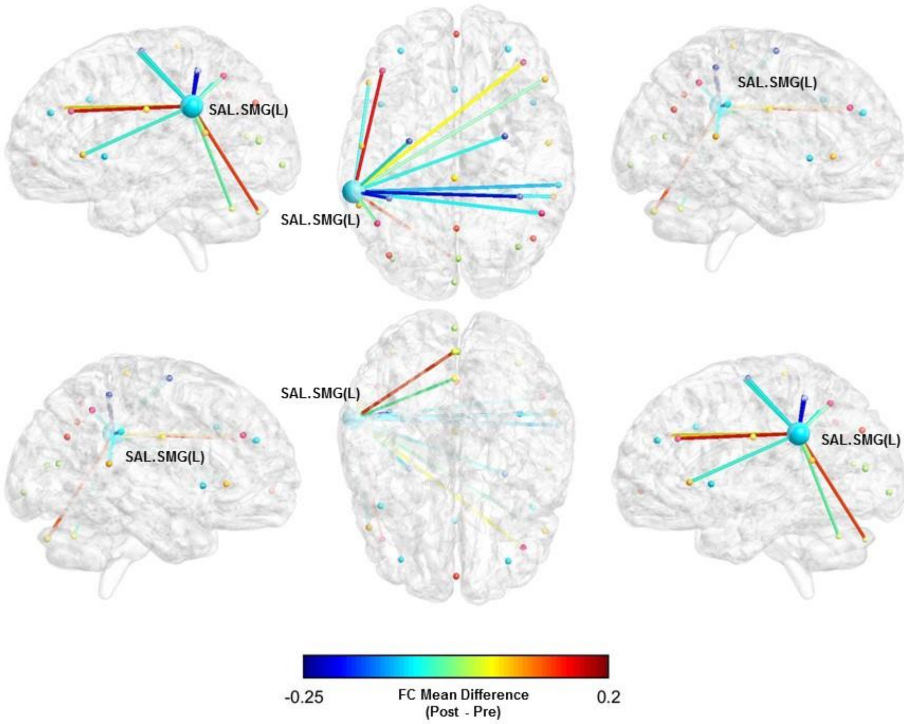

Figure 6. Functional connectivity mean difference between the left supramarginal gyrus (SAL) and whole-brain pre- and post-BAILAMOS^{TM}.

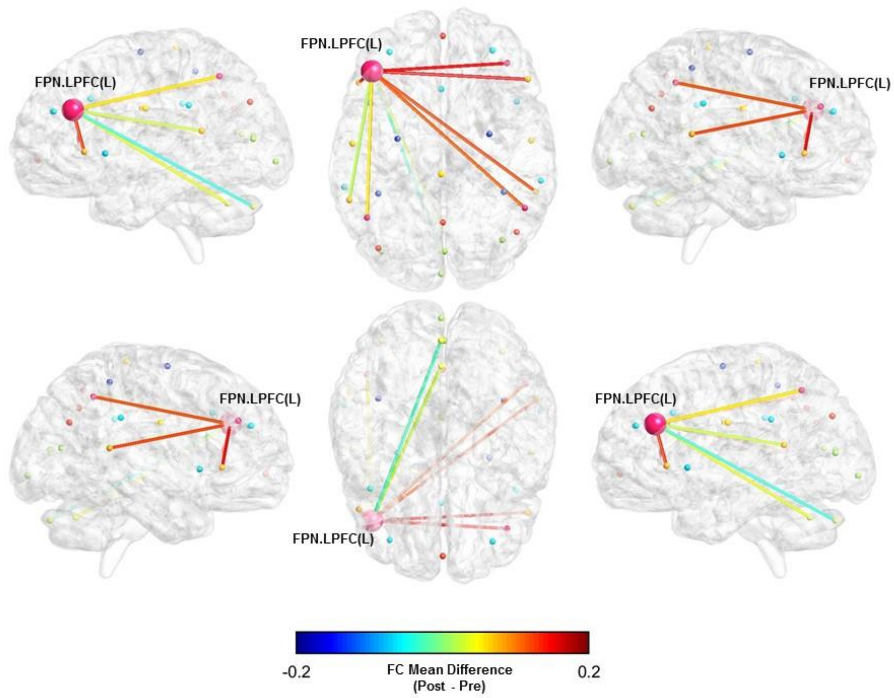

Figure 7. Functional connectivity mean difference between the left lateral prefrontal cortex (FPN) and whole-brain pre- and post-BAILAMOS™.

Averaging the FC within the ROIs of each network of interest, we found that within-network FC of the FPN increased significantly after participation in the BAILAMOS™ dance program ($t(9) = 2.35$, $p = 0.043$, $d = 0.70$) (Table VIII).

TABLE VIII
AVERAGE FUNCTIONAL CONNECTIVITY OF REGIONS OF INTEREST WITHIN-NETWORKS PRE- AND POST-BAILAMOS™.

FC of ROIs within-networks	Pre M (SD)	Post M (SD)	Mean Diff (95% CI)	*p*	*d*
DMN	0.5719 (0.2069)	0.5100 (0.1924)	-0.0618 (-0.1953; 0.0716)	0.321	-0.31
FPN	0.4923 (0.1530)	0.5955 (0.1341)	0.1013 (0.0037; 0.1988)	0.043*	0.70
SAL	0.5582 (0.1426)	0.5160 (0.1469)	-0.0422 (-0.1515; 0.0671)	0.405	-0.29
LAN	0.4886 (0.1139)	0.5280 (0.1437)	0.0394 (-0.0448; 0.1237)	0.318	0.29

*Statistically significant for p<0.05.

To explore which ROI was driving this significant increase, we explored the FC within the FPN ROIs. We noticed that although non-significant ($t(9) = 1.82$, $p = 0.101$, $d = 0.77$), an increase in FC between the left LPFC and the left posterior parietal cortex (PPC) was driving the average increase in the FPN (Figure 8). The other ROI-ROI FCs did not show significant changes and presented small effect sizes.

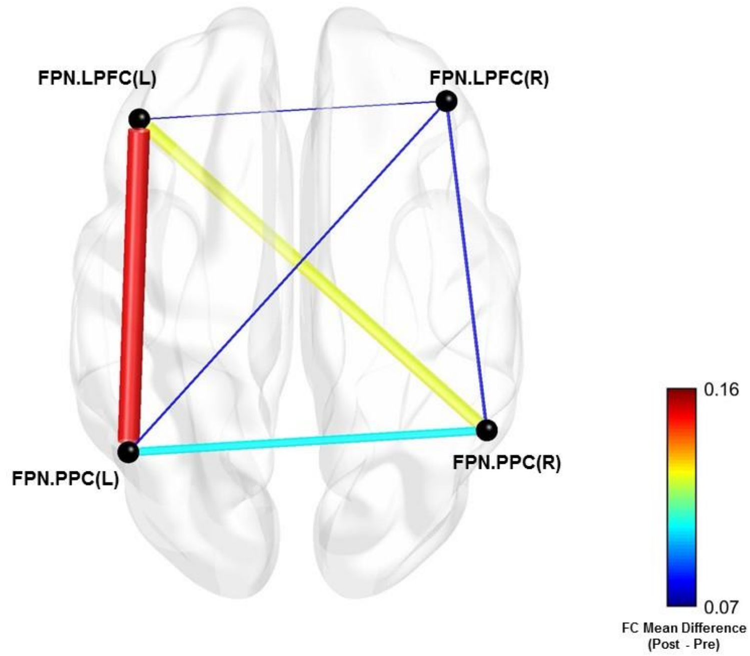

Figure 8. Mean difference between FPN regions of interest pairs pre- and post-BAILAMOS^{TM}.

Taking the average FC within the ROI-ROI pairs of each network, we calculated the FC of each network and calculated the average FC between each network as a whole. We did not observe significant changes nor moderate effect sizes in FC between networks pre- and post-BAILAMOS^{TM} (data not shown). We calculated a ratio integration/segregation of the three networks of interest and the network we used as control (Language). This ratio was calculated to demonstrate whether each network presented a trend to have stronger connectivity with other networks (i.e., integration) or to stronger connectivity within its own network (i.e., segregation) (Table IX). The results did not show statistical differences. However, there was a trend of the DMN ROIs integrating more with other networks' ROIs ($t(9) = 1.96$, $p = 0.081$, $d = 0.64$) after participation in the BAILAMOS^{TM} dance program. Moreover, the negative small effect size in the

FPN ratio integration/segregation (*d* = -0.28) aligns with increased FC within FPN ROIs previously observed in Table VIII.

TABLE IX.
RATIO INTEGRATION/SEGREGATION PRE- AND POST-BAILAMOS™.

Ratio integration/ segregation	Pre M (SD)	Post M (SD)	Mean Diff (95% CI)	*p*	*d*
DMN	0.1435 (0.1625)	0.2398 (0.1337)	0.0962 (-0.0145; 0.2070)	0.081	0.64
FPN	0.4150 (0.2682)	0.3477 (0.1645)	-0.0672 (-0.2360; 0.1016)	0.391	-0.28
SAL	0.1040 (0.1447)	0.1090 (0.2205)	0.0049 (-0.1073; 0.1172)	0.923	0.02
LAN	0.4276 (0.1260)	0.4163 (0.1950)	-0.0113 (-0.1511; 0.1285)	0.860	-0.06

4. Correlation between changes in physical activity, cognition, and functional connectivity

We performed correlations to investigate whether the changes in PA levels were correlated with changes in cognition and FC, and to test whether changes in cognition were correlated with changes in FC. This analysis was performed only for the self-reported PA (moderate leisure PA), cognition domain (perceptual speed), and FCs that demonstrated a statistically significant change or a moderate effect size in the previously reported results. We observed that changes in moderate leisure-time PA were negatively associated with changes in FC between the left supramarginal gyrus and whole-brain (R = -0.75, *p* = 0.012), and positively associated with FC within-FPN ROIs (R = 0.70, *p* = 0.022) (Figure 9). We also found that changes in perceptual speed were negatively associated with changes in the FC within-FPN ROIs (R = -0.73, *p* = 0.016) (Figure 9).

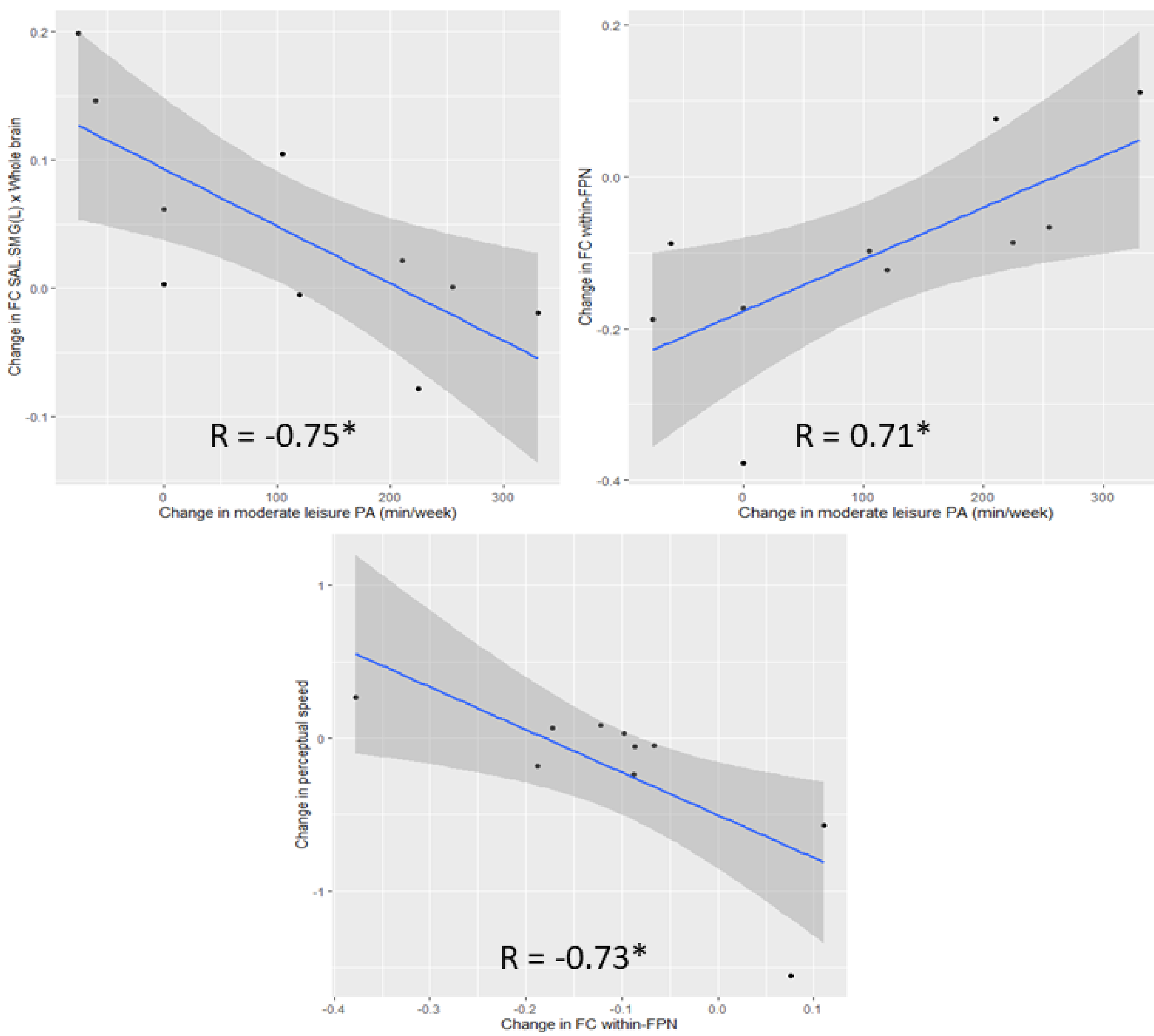

Figure 9. Correlation between changes in moderate leisure-time physical activity, functional connectivity, and perceptual speed.

E. Discussion

The present study aimed to investigate the impact of the BAILAMOS™ dance program on self-reported and device-assessed PA, CRF, FC in DMN, FPN, SAL, and cognition; and investigate whether changes in PA as a result of BAILAMOS™ dance program were associated with changes in FC in DMN, FPN, and SAL, and cognition. We hypothesized that (a) FC within and between the DMN, FPN, and SAL regions would be significantly greater after participation in the BAILAMOS™ program; (b) changes in self-reported and device-assessed PA and estimated CRF would be associated with changes in cognition and FC within and between the DMN, FPN, SAL areas; and (c) changes in cognition would be associated with changes in FC within and between the DMN, FPN, SAL areas.

Although not adequately powered, results partially supported our first hypothesis, since we did observe a significant increase in the FC within the FPN ROIs, and moderate magnitudes of FC change in whole-brain seed-based analysis in the right anterior insula (SAL), supramarginal gyrus (SAL), and lateral prefrontal cortex (FPN). Moreover, the DMN showed a moderate FC increase between its ROIs and other networks ROIs, suggesting a trend of increased integration with other brain networks. Nonetheless, we did not observe significant improvements in cognition, increases in the FC within-DMN and SAL networks, and FC between DMN, SAL, and FPN. Our second hypothesis was partially supported. We observed significant associations between increases in moderate leisure-time PA and increases in the FC within-FPN, increases in moderate leisure-time PA, and decreases in FC between the supramarginal gyrus and the whole-brain. The third hypothesis was also partially supported, showing that increases in the FC within-FPN ROIs were associated with decreases in perceptual speed.

We did not observe changes in CRF and device-assessed PA, and its associations with changes in FC. Although increased CRF resulted from exercise programs has been found to slow down aging-related impairment in the FC of associative networks (e.g., DMN, SAL) in resting-state fMRI (Porto et al., 2018; Voss et al., 2019, 2016), our study did not replicate these results. A possible explanation is that we utilized an estimated measure of CRF instead of a direct assessment of CRF and sum of vector magnitude for device-assessed PA. Also, the light-to-moderate PA intensity nature of the BAILAMOS™ might not be sufficient to result in device-assessed PA and CRF changes, and, in turn, changes in cognition. Voss et al. (2019) utilized dance in one of their intervention groups and pointed out "that the dance intervention group had insufficient intensity or duration to enhance benefits of cognitive enrichment" (p.84) associated with dance. They suggested that future work should reduce the time spent on instructions and increase the intensity of dance for changes in widespread functional networks.

Dancing is a complex task, involves aerobic exercise, music stimulation and cognitive, visuospatial, social, and emotional engagement (Hwang & Braun, 2017). It also involves stimuli from the instructor and the dance partner. The ability to perform complex tasks requires persistent control throughout the task, prevails against distraction, and at the same time, respond quickly to unpredictable demands that arise during task performance (Dosenbach et al., 2007). Dosenbach et al. (2007) suggested the FPN activation profile supports control initiation and provides flexibility by adjusting control in response to feedback in a top-down fashion. This profile aligns with tasks that are essential to individuals learning how to dance. While dancing, the participant initiates control of the dance steps based on the beats of the music and instructions from the instructor, which is followed by constant adjustments in response to feedback from the music, dance partner, and instructor.

The increased FC within-FPN observed in this study might signal the importance of an environmental and cognitive enriched type of PA, such as dance, to increase FC between FPN ROIs. Changes in FPN FC were previously demonstrated as a result of a range of different PA interventions. Hsu et al. (2017) found decreases in the FPN during a right finger tapping task after a six-month aerobic exercise program for older adults with subcortical ischemic vascular cognitive impairment. These changes were associated with improved mobility, which Hsu et al. (2017) mentioned concur with emerging evidence that less FC of large-scale networks may be advantageous within the context of mobility in older adults with cardiovascular diseases (Chuang et al., 2014). Another six-month aerobic exercise intervention led to gains in CRF, which was associated with greater activation of FPN areas (e.g., superior parietal gyrus) and better executive functioning (Colcombe et al., 2004). Also, Zilidou et al. (2018) found that a four-month traditional Greek dance program increased FC within-FPN ROIs, as well as brain betweenness centrality and participation coefficient, which are measures of integration to assess region's ability to link disparate parts (Reineberg & Banich, 2018).

The changes in FC within-FPN ROIs in our study add to the findings from previous studies involving PA and FPN FC. However, it is important to acknowledge that different types of PA were employed (e.g., aerobic exercise programs), and FC was measured differently. Hsu et al. (2017) measured FC while participants underwent a task-based fMRI with a finger-tapping motor task. Zilidou et al. (2018) utilized electroencephalogram and functional cartography techniques. Also, the FPN ROIs selected in our study were not derived from independent component analysis, but from functional connectomes using the resting-state fMRI toolbox CONN (Whitfield-Gabrieli & Nieto-Castanon, 2012). Although we used different approaches, we contribute to the scientific evidence that PA, specifically dance, has the potential to induce changes in the FPN FC.

We specifically observed that the FC between the left LPFC and the left PPC was driving the increase in the FC within-FPN ROIs. This result is consistent with studies that showed the activation profile of the dorsolateral prefrontal cortex (dlPFC), which is part of the LPFC, is similar to the inferior parietal lobule (IPL) activation profile (Dosenbach et al., 2006; Fincham, Carter, Van Veen, Stenger, & Anderson, 2002) which is part of the PPC. Moreover, another study suggested that FC between dlPFC and IPL is stronger than the FC between other FPN ROIs (Dosenbach et al., 2007), concurring with our results.

Contrary to increases in the FC within-FPN ROIs and FC between left LPFC and whole-brain, we also observed that two ROIs from the SAL network demonstrated FC reduction after participation in the BAILAMOS™ dance program. The SAL network, and specifically the bilateral insula, was previously shown to be affected by aging (Onoda et al., 2012; Voss et al., 2016). Onoda et al. (2012) demonstrated a negative correlation between age and bilateral insula and anterior cingulate cortex FC, which are SAL regions. Specifically, they found that disruptions of SAL FC were associated with significant declines in cognitive function. Conversely, previous studies reported increased FC in the SAL of older adults with mild dementia (Dosenbach et al., 2007; Zhou et al., 2010). Therefore, the role played by the SAL in age-related cognitive function decline still need to be further investigated.

The anterior insula is the primary hub of the SAL network. It receives convergent input from a range of sensory modalities, including auditory and visual systems, and simultaneous attention to multisensory stimuli (Menon, 2015; Nieuwenhuys, 2012). A primary function of the anterior insula in the SAL is the detection of behaviorally relevant stimuli (Menon, 2015). The multi-sensory and complex requirements of dancing matches with the primary functions of the anterior insula. However, it is unknown whether "exercise affects intrinsic, resting-state insula function, or if this effect is specific to task-related activation" (Mcfadden, Cornier, Melanson, Bechtell, & Tregellas, 2013, p.867).

Previous studies with overweight and obese adults have shown reductions of FC in the insula after acute exercise (Evero, Hackett, Clark, Phelan, & Hagobian, 2012) and after a six-month walking program (Cornier, Melanson, Salzberg, Bechtell, & Tregellas, 2012). Although, the literature shows mixed results for changes in the insula and SAL network FC after exercise interventions among older adults. Voss, et al. (2010) observed increased FC in the SAL after a 12-month aerobic exercise program. However, the results were not replicated in the six-month walking and dance interventions compared to a walking plus dietary supplement and control groups (Voss et al., 2019). It appears that previous studies did not converge to an agreement whether increases or reductions of the FC in SAL following exercise intervention are beneficial for cognition. Therefore, more studies are needed to detect a pattern of changes in SAL FC that promote benefits to older adults' cognition.

Interestingly, the FPN and SAL, which are cognitive-control networks, demonstrated opposite responses to the BAILAMOS™ dance program. This result suggests some alignment with the dual-network hypothesis between the FPN and SAL (Dosenbach et al., 2007). Based on differences in FC and activation profiles, Dosenbach et al. (2007) argue that the FPN and SAL support distinct functions. The FPN is related to adaptive control and the SAL to stable set maintenance of attentional control. They propose that the SAL network exert more stable cognitive-control and "contributes to the flexible control of human goal-directed behavior through the stable, across-trial implementation of task sets" (Dosenbach et al., 2007, p.11076). Meanwhile, the FPN is more adaptative, support control initiation, and provide flexibility by adjusting control in response to feedback. They found that the FPN and SAL were separated from each other as for their FCs, suggesting that they carry out dissociable control functions.

While the role of PA in increasing the FC within-DMN is more prominent in the literature (Boraxbekk et al., 2016; Li et al., 2014; Voss, Erickson, et al., 2010; Voss et al., 2016; Voss, Prakash, et al., 2010), we did not observe statistically significant changes as a result of the BAILAMOS™ dance program. This null result might be due to the short-intervention period, the light-to-moderate intensity PA that characterized BAILAMOS™, and lack of statistical power. However, we did notice moderate effect size changes in the DMN ratio integration/segregation, signaling to increased integration with ROIs of other networks. (Goldstone et al., 2016) mentioned that few studies focused on the FC between-networks (i.e., integration), with some evidence that FC between-networks is in general reduced with aging (Onoda et al., 2012; Tomasi & Volkow, 2012). Specifically, one study demonstrated a reduction in FC between areas of the DMN and SAL network (He et al., 2013). Conversely, other studies (Buckner, 2004; Cabeza, 2002; Dennis et al., 2008; Park & Reuter-Lorenz, 2009) proposed that increased FC between-network in older adults is a sign of over recruitment of brain regions during tasks as a compensatory mechanism to maintain or improve function. Goldstone et al. (2016) highlighted that it remains to be determined whether increased integration is a beneficial compensatory mechanism response to the usual age-related lowering of within-network FC or represents an interference to within-network FC.

Brier et al. (2012) assessed between-network FC in older adults in different stages of dementia and found significant decreases in FC between the DMN and other resting-state networks. Our results might present dance as a potential form of avoiding loss of FC between-networks that are associated with cognitive decline, specifically the integration of the DMN and other resting-state networks. Previous studies on PA and aging had not associated integration and segregation changes in FC as a result of PA. The results suggest that future research should further investigate the role of PA in promoting greater integration between resting-state networks.

We also did not observe statistically significant changes in cognition. This result does not converge with significant changes in cognition found in previous studies utilizing dance interventions (Coubard et al., 2011; Hamacher et al., 2015; Kattenstroth et al., 2013; Rehfeld et al., 2017). The lack of statistically significant results in cognition may have been partly due to the use of neuropsychological tests that were not sensitive enough to subtle changes over four months in cognitively healthy adults and partly due to the small sample size. As previously mentioned, light-to-moderate PA intensity during the dance program might be another factor that contributed to the null result. The literature has presented mixed results in studies with exercise interventions with a length of six months or less (Kramer & Colcombe, 2018; Northey, Cherbuin, Pumpa, Smee, & Rattray, 2018). These results suggest that longer exercise programs might be necessary to observe a more consistent effect of exercise in cognition.

Our results and interpretations must be considered in the context of several limitations. First, our small sample size limited the statistical power to observe the effects of the BAILAMOS™ dance program. Second, we adopted a single-group pre-post design without a control group. Although this type of design is acceptable for feasibility stages, results must be interpreted with caution. Third, only participants with complete observations at pre- and post-intervention data collection were included in the study; with that, potential non-random effects might be playing a role in our results. Fourth, networks' ROIs were selected *a priori* centered around an ROI-based examination of exercise effects on age-sensitive network disruptions. With that, we limited the exploration of the effects of dance in other ROIs that were not included in our *a priori* set of ROIs.

Despite these limitations, this is the first study investigating the effects of dance on cognition and FC in brain networks associated with aging in older Latino adults. Our results provide initial insights on the effects of a culturally relevant and enjoyable PA type on the brain health of a minority group at risk for dementia. Future studies should consider increasing the PA intensity throughout the dance program and propose a longer intervention period.

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APPENDICES
Appendix A

UNIVERSITY OF ILLINOIS
AT CHICAGO

Office for the Protection of Research Subjects (OPRS)
Office of the Vice Chancellor for Research (MC 672)
203 Administrative Office Building
1737 West Polk Street
Chicago, Illinois 60612-7227

Approval Notice
Amendment to Research Protocol and/or Consent Document – Expedited Review
UIC Amendment # 1

January 11, 2012

David Xavier Marquez, PhD
Department of Kinesiology and Nutrition
1919 W Taylor St., Room 632
M/C 994
Chicago, IL 60612
Phone: (312) 996-1209 / Fax: (312) 413-0319

RE: **Protocol # 2011-0763**
"BAILA-C: Bypassing Alzheimers, Increasing Latinos' Activity and Cognition"

Dear Dr. Marquez:

Members of Institutional Review Board (IRB) #3 have reviewed this amendment to your research and/or consent form under expedited procedures for minor changes to previously approved research allowed by Federal regulations [45 CFR 46.110(b)(2)]. The amendment to your research was determined to be acceptable and may now be implemented.

Please note the following information about your approved amendment:

Amendment Approval Date: January 10, 2012
Amendment:

Summary: UIC Amendment #1 dated November 21, 2011 (received 11/30/11) involves the following changes: 1) Addition of key research personnel (Giamila Fantuzzi, Shane Phillips, and Lynn Podraza). 2) Changing the research protocol to include participants who will also have cardiovascular outcomes assessed pre- and post-intervention, in addition to the previously approved physical activity, cognitive function, and physical function measures. The protocol was also revised to include that participants will have all testing done within the Clinical Research Center (CRC) at UIC. 3) Added Letter of Support from the Southwest Senior Center. 4) The UIC Midwest Roybal Center for Health Promotion and Translation Pilot grant was added as a funding source. 5) Changing fasting requirements from 8-12 hours to 4-8 hours. 6) Adding CRC members and Dr. Stamos to Appendix P Key Personnel. 7) Adding Dr. Tom Stamos as Medical Advisor. 8) Updating Inclusion criteria to include being post-menopausal and overweight; and adding Exclusion criteria including adverse reactions to nitroglycerin or ultrasound gel, and unwilling to not use erectile dysfunction pills 24 hours before and after testing. 9) Adding the storage of leftover blood samples to allow keeping them

Appendix A (Continued)

2011-0763 Page 2 of 3 January 11, 2012

in Dr. Fatuzzi's laboratory. 10) Revising recruitment materials that referenced the funding source to now include the Midwest Royal Center for Health Promotion and Translation.

Approved Subject Enrollment #: 100
Performance Sites: UIC
Sponsor: Alzheimer's Association, Midwest Roybal Center for Health Promotion
PAF#: Not available, 2011-04279
Grant/Contract No: Not available, 205469
Grant/Contract Title: Not available, BAILA-C: Bypassing Alzheimers, Increasing Latinos' Activity and Cognition

Research Protocol:

a) BAILA-C: Bypassing Alzheimers, Increasing Latinos' Activity and Cognition; Version 4, 01/05/2012

Recruiting Materials:

a) Flyer (English); Version 2, 12/21/2011
b) Newspaper Ad (English); Version 2, 12/21/2011
c) Physician Referral (English); Version 3, 12/21/2011
d) Flyer (Spanish); Version 2, 12/21/2011
e) Physician Referral (Spanish); Version 3, 12/21/2011
f) Newspaper Ad (Spanish); Version 2, 12/21/2011
g) Radio Ad (English); Version 2, 12/21/2011
h) Introduction and Screening (English); Version 4, 01/05/2012
i) Introduction and Screening (Spanish); Version 4, 01/05/2012
j) Radio Ad (Spanish); Version 2,12/21/2011

Informed Consents:

a) BAILA-C (English); Version 4, 12/21/2011
b) BAILA-C (Spanish); Version 4, 12/21/2011

Please note the Review History of this submission:

Receipt Date	Submission Type	Review Process	Review Date	Review Action
11/30/2011	Amendment	Convened	12/13/2011	Modifications Required
01/05/2012	Response To Modifications	Expedited	01/10/2012	Approved

Please be sure to:

→ **Use only the IRB-approved and stamped consent documents enclosed with this letter when enrolling subjects.**

→ Use your research protocol number (2011-0763) on any documents or correspondence with the IRB concerning your research protocol.

→ Review and comply with all requirements on the enclosure,
"UIC Investigator Responsibilities, Protection of Human Research Subjects"

Please note that the UIC IRB #3 has the right to ask further questions, seek additional

Appendix A (Continued)

information, or monitor the conduct of your research and the consent process.

Please be aware that if the scope of work in the grant/project changes, the protocol must be amended and approved by the UIC IRB before the initiation of the change.

We wish you the best as you conduct your research. If you have any questions or need further help, please contact the OPRS at (312) 996-1711 or me at (312) 355-2764. Please send any correspondence about this protocol to OPRS at 203 AOB, M/C 672.

Sincerely,

Betty Mayberry, B.S.
IRB Coordinator, IRB # 3
Office for the Protection of Research Subjects

Enclosures:

1. **UIC Investigator Responsibilities, Protection of Human Research Subjects**
2. **Informed Consent Documents:**
   a) BAILA-C (English); Version 4, 12/21/2011
   b) BAILA-C (Spanish); Version 4, 12/21/2011
3. **Recruiting Materials:**
   a) Flyer (English); Version 2, 12/21/2011
   b) Newspaper Ad (English); Version 2, 12/21/2011
   c) Physician Referral (English); Version 3, 12/21/2011
   d) Flyer (Spanish); Version 2, 12/21/2011
   e) Physician Referral (Spanish); Version 3, 12/21/2011
   f) Newspaper Ad (Spanish); Version 2, 12/21/2011
   g) Radio Ad (English); Version 2, 12/21/2011
   h) Introduction and Screening (English); Version 4, 01/05/2012
   i) Introduction and Screening (Spanish); Version 4, 01/05/2012
   j) Radio Ad (Spanish); Version 2,12/21/2011

cc: Charles B. Walter, Department of Kinesiology and Nutrition, M/C 517

Appendix B

Approval Notice
Continuing Review

June 5, 2018

David Xavier Marquez, PhD
Kinesiology and Nutrition
Phone: (312) 996-1209 / Fax: (312) 413-0319

RE: Protocol # 2015-0497
"iBAILA-Investigating Brains and Activity to Improve Latino Aging"

Dear Dr. Marquez:

As part of future Continuing Review submissions, please be reminded to complete the most recent version of the Continuing Review Application form to avoid a possible rejection of the submission.

Your Continuing Review was reviewed and approved by the Expedited review process on June 5, 2018. You may now continue your research.

Please note the following information about your approved research protocol:

Protocol Approval Period: June 21, 2018 - June 21, 2019
Approved Subject Enrollment #: 50 (32 subjects enrolled – Closed to enrollment)
Additional Determinations for Research Involving Minors: These determinations have not been made for this study since it has not been approved for enrollment of minors.
Performance Sites: UIC, Alivio Medical Center
Sponsor: NIA/NIH
PAF#: 00001396
Grant/Contract No: 2P30AG022849-11
Grant/Contract Title: Midwest Roybal Center for health Promotion and Translation

Research Protocol:

a) iBAILA Investigating Brains and Activity to Improve Latino Aging; Version #3; 06/10/2016

Recruitment Materials:

a) N/A - Research is closed to enrollment

Informed Consents:

a) N/A - Research is closed to enrollment

HIPAA Authorizations:

a) N/A - Research is closed to enrollment

Your research continues to meet the criteria for expedited review as defined in 45 CFR 46.110(b)(1) under the following specific categories:

Appendix B (Continued)

(4) Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving X-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. (Studies intended to evaluate the safety and effectiveness of the medical device are not generally eligible for expedited review, including studies of cleared medical devices for new indications.)
(7) Research on individual or group characteristics or behavior (including but not limited to research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Please note the Review History of this submission:

Receipt Date	Submission Type	Review Process	Review Date	Review Action
05/25/2018	Continuing Review	Expedited	06/05/2018	Approved

Please remember to:
→ Use your **research protocol number** (2015-0497) on any documents or correspondence with the IRB concerning your research protocol.

→ Review and comply with all requirements on the guidance document,
"UIC Investigator Responsibilities, Protection of Human Research Subjects"
(http://tigger.uic.edu/depts/ovcr/research/protocolreview/irb/policies/0924.pdf)

Please note that the UIC IRB has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Please be aware that if the scope of work in the grant/project changes, the protocol must be amended and approved by the UIC IRB before the initiation of the change.

We wish you the best as you conduct your research. If you have any questions or need further help, please contact OPRS at (312) 996-1711 or me at (312) 355-2939. Please send any correspondence about this protocol to OPRS at 203 AOB, M/C 672.

Sincerely,

Jewell Hamilton, MSW
IRB Coordinator, IRB # 2
Office for the Protection of Research Subjects

Enclosure(s): None

cc: Kelly Anne Tappenden, Kinesiology and Nutrition, M/C 517
OVCR Administration, M/C 672

UNIVERSITY OF ILLINOIS AT CHICAGO
Office for the Protection of Research Subjects
201 AOB (MC 672)
1737 West Polk Street
Chicago, Illinois 60612
Phone (312) 996-1711

Appendix C

RUSH UNIVERSITY MEDICAL CENTER
1653 WEST CONGRESS PARKWAY
CHICAGO, ILLINOIS, 60612-3833

OFFICE OF RESEARCH AFFAIRS
312.942.5498
312.942.2874 (FAX)

RUSH UNIVERSITY MEDICAL CENTER

Rush Institutional Review Board
FWA #: 00000482

Notification of Expedited Continuing Review Approval

The following research activity has been re-reviewed and re-approved by the Institutional Review Board (IRB) at Rush University Medical Center in accordance with the Common Rule (45CFR46, December 13, 2001) and any other governing regulations or subparts. The Institutional Review Board at Rush also confirms that the project still meets the following categories under 45CFR46.110 for expedited review:

In accordance with 45 CFR 46.109(f)(1)(iii), the Rush IRB has determined this study to be research:

- **Eligible for expedited review in accordance with 45 CFR 46.110 and involves no more than minimal risk**

Continuing review is not required for this project, however, the Principal Investigator must still:

- Submit amendments for project changes,
- Report Unanticipated Problems (UPs), and
- Terminate the project once it ends, or when personal identifiers are removed from the data/biospecimens and all codes and keys are destroyed
- Rush IRB may re-evaluate its Continuing Review/No review decision for a project depending on the type of change(s) proposed in an amendment (e.g., protocol change that increases subject risk), or as an outcome of the IRB's review of an unexpected problem.

ORA Number: 16102101-IRB01-CR02

Principal Investigator: Melissa Lamar
Project Title: 2019 Review for: Myelin markers and modifiable risks of vascular aging in African Americans

Date of approval: 3/1/2019

It is your responsibility to follow the guidelines below:

Appendix C (Continued)

- Conduct the study in accordance with the relevant, current protocol and only make changes in the protocol after notifying the IRB, except when necessary to protect the safety, rights or welfare of subjects.
- Record and track number of subjects accrued as well as information regarding study drop-outs or withdrawals.
- Provide brief updates on the changing scientific literature as that literature pertains to the efficacy and safety of the specific procedure or intervention under study.
- Report any complaints from subjects as well as any and all serious or unexpected adverse events related to this study to the IRB.
- Maintain and use copies of the currently approved consent document related to this project (if applicable).
- Maintain a file of the consent documents bearing the signature of the subjects enrolled in this study.

(The below is a representation of an electronic record that was signed electronically and is the manifestation of the electronic signature.)

John Cobb
3/5/2019 10:32 AM
Signing for Crista Brawley

Crista Brawley, PhD, CCRP
Rush University Medical Center
Assoc. VP, Research Regulatory Operations

VITA

A. ADDRESS & TELEPHONE

University of Illinois at Chicago
Department of Kinesiology and Nutrition
1919 W. Taylor St., Room 613, MC 994, Chicago IL, 60612
E-mail: gbalbi2@uic.edu

B. EDUCATION:

Ph.D.	Fall 2016 – present	Department of Kinesiology & Nutrition. Concentration in exercise science and health promotion. University of Illinois at Chicago. *Advisor*: Dr. David Xavier Marquez.
M.S.	2011 - 2013	Department of Physical Education. Concentration in psychosocial and motor factors regarding human performance. Maringa State University (Brazil). *Advisor*: Dr. Lenamar Fiorese Vieira.
B.S.	2007 - 2010	Department of Physical Education, Maringa State University (Brazil).

C. RESEARCH EXPERIENCE:

Summer 2017 – Fall 2019	Healthy Brain Research Network (HBRN) (Illinois Prevention Research Center, Centers for Disease Control and Prevention, 3U48DP005010PI, PI: David X. Marquez)	Role: Graduate Research Assistant
Summer 2017 - Present	ACTION (Physical Activity in Minority Women with Asthma) Intervention (National Heart, Lung, and Blood Institute (NHLBI), K01HL133370, PI: Sharmilee Nyenhuis)	Role: Graduate Research Assistant
Fall 2016 - Present	The Influence of Multicomponent Factors in the Experience of the Latino Caregiver (UIC Department of Kinesiology and Nutrition Funding, PI: David X. Marquez)	Role: Graduate Research Assistant
Fall 2016 - Present	BAILA: Being Active, Increasing Latinos' healthy Aging (National Institutes of Health (NIH): National Institute of Nursing Research, R01 NR013151-01, PI: David X. Marquez)	Role: Graduate Research Assistant
Fall 2016 - Present	iBAILA - Investigating Brains & Activity to Improve Latino Aging (Midwest Roybal Center for Health Promotion and Translation, National Institute on Aging of the National Institutes of Health, P30AG022849, PI: David X. Marquez)	Role: Graduate Research Assistant

2012 - 2013	Validation to Brazilian population of Telic Dominance Scale (TDS) in sport context (Maringa State University, Department of Physical Education, Advisor: Dr. Lenamar Fiorese Vieira)	Role: Master thesis
2011 - 2013	The impact of psychological variables in healthy behaviors (Maringa State University, Department of Physical Education, PI: Dr. Lenamar Fiorese Vieira)	Role: Graduate Research Assistant
2011 - 2013	Psychological and behavioral aspects regarding exercise and sports context (Maringa State University, Department of Physical Education, PI: Dr. Lenamar Fiorese Vieira)	Role: Graduate Research Assistant
2010	Analysis of flow mental state in practitioners of adventure sports. (Maringa State University, Department of Physical Education, Advisor: Dr. Lenamar Fiorese Vieira)	Role: Undergraduate thesis

D. TEACHING EXPERIENCE

Fall 2016 – present	University of Illinois at Chicago, Department of Kinesiology & Nutrition	Teaching Assistant for KN 335 Exercise Psychology
02/2014 - 02/2016	West Parana State University (Brazil), Department of Physical Education	Adjunct Instructor for undergraduate level courses of: Human Growth and Development, Motor Development and Learning, Psychological Dimensions of Sport and Physical Activity, Biostatistics and Swimming
02/2011 – 11/2012	Maringa State University (Brazil), Department of Physical Education	Teaching assistant for Sport and Exercise Psychology.

E. AWARDS AND HONORS

2019	The Gerontological Society of America (GSA) Mentoring and Career Development Technical Assistance Workshop Junior Investigator Diversity Fellow Travel Award.
2019	American College of Sports Medicine (ACSM) Aging Interest Group Student Research Award - First place in the Student Research Award granted from the ACSM Aging Interest Group and Strategic Health Initiative – Aging.
2019	Alzheimer's Association Travel Scholarships for HBRN Scholars - Awarded granted to participate at the 65th Annual Meeting with 9th World Congress on Exercise is Medicine® and World Congress on the Basic

Science of Exercise, Circadian Rhythms and Sleep of the American College of Sports Medicine.

2018 Alzheimer's Association Travel Scholarships for HBRN Scholars - Awarded granted to participate at the 2018 Alzheimer's Association International Conference.

2017 UIC Graduate College Student Presenters Award - Award granted to present a poster at the 65th Annual Meeting and World Congress on Exercise is Medicine®, and World Congress on the Basic Science of Exercise and the Brain of the American College of Sports Medicine

2017 UIC Graduate Student Council Travel Award - Award granted to present a poster at the 38th Annual Meeting and Scientific Sessions of the Society of Behavioral Medicine

2017 Level 2 Participant of Leadership and Mentoring Program - Midwest Regional Chapter of the American College of Sports Medicine

2016 Level 2 Participant of Leadership and Mentoring Program - Midwest Regional Chapter of the American College of Sports Medicine

F. ARTICLES IN REFERRED JOURNALS:

1) Montoya, Y., **Balbim, G.M.**, Glover, C., Marquez, D.X. "My parent's body is sacred": Perspectives from family members about brain donation for Alzheimer's disease research. *Alzheimer Disease & Associated Disorders (in press).*
2) **Balbim, G.M.,** Maldonado, A.M., Early, A., Steinman, L., Harkins, K., Marquez, D.X. Evaluation of public health messages promoting early detection of dementia among adult Latinos with a living older adult parental figure. *Hispanic Health Care International (in press).*
3) Nyenhuis, S.M.; **Balbim, G.M.**; Ma, J.; Marquez, D.X.; Wilbur, J.; Sharp, L.K., Kitsiou, S. Feasibility of a Walking Intervention supplemented with mHealth tools in Sedentary African American Women with Asthma. *Journal of Medical Internet Research Formative Research (in press).* https://dx.doi.org/10.2196/13900
4) **Balbim, G.M.,** Marques, I.G., Cortez, C., Guzman, J., Rocha, J.S., Magallanes, M., Marquez, D.X. (2019). Coping strategies utilized by middle-aged and older Latino caregivers of loved ones with Alzheimer's disease and related dementia. *Journal of Cross-Cultural Gerontology*, 34(4), 355-371. https://doi: 10.1007/s10823-019-09390-8
5) **Balbim, G. M.**, Magallanes, M., Marques, I. G., Ciruelas, K., Aguiñaga, S., Guzman, J., & Marquez, D. X. (2019). Sources of Caregiving Burden in Middle-Aged and Older Latino Caregivers. *Journal of Geriatric Psychiatry and Neurology*. https://doi.org/10.1177/0891988719874119
6) Bustamante, E. E., Santiago-Rodriguez, M. E., Ramer, J. D., **Balbim, G. M.**, Mehta, T. G., & Frazier, S. L. (2019). Physical activity and ADHD: evidence on developmental trajectories, transient and durable neurocognitive effects, and real-world applications. *Pensar en Movimiento: Revista de Ciencias del Ejercicio y la Salud*, 17(1), e34662-e34662. https://doi.org/10.15517/PENSARMOV.V17I1.34662
7) Aizava, P.V.S**, Balbim, G.M**., Nascimento Junior, J.R.A., Vissoci, J.R., Papke, S., Vieira, L.F. (Accepted). Quality of life and self-efficacy in high-performance volleyball

athletes. Manuscript submitted for publication. *Brazilian Journal of Physical Education and Sport.*

8) Nascimento Junior, J.R.A., **Balbim, G.M**., Vissoci, J.R., Moreira, C.R., Passos, P.C.B., & Vieira, L.F. (2016). Analysis of the relationship between state-anxiety and team cohesion among handball athletes. Revista Psicologia: Teoria e Prática, 18(2), 89-102. http://dx.doi.org/10.15348/1980-6906/psicologia.v18n2p89-102.
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12) Nascimento Junior, J.R.A., **Balbim, G.M**., & Vieira, L.F. (2014). Pre-competitive psychological stress and volleyball: a study on the role of gender and the positions of the game. *Revista Mackenzie de Educação Física e Esporte (Online)*, 13(2), 93-105. http://editorarevistas.mackenzie.br/index.php/remef/article/view/4224
13) Mizoguchi, M.V., **Balbim, G.M**., & Vieira, L.F. (2013). Parenting style, motivation and satisfaction of baseball athletes: a correlation study**.** *Revista da Educação Física (UEM. Online),* 24(2), 215-223. http://dx.doi.org/10.4025/reveducfis.v24.2.16282
14) Nascimento Junior, J.R.A., **Balbim, G.M**., & Vieira, L.F. Group cohesion in volleyball context of the state of Paraná (2013). *Revista de Psicologia: Teoria e Prática (Online),* 15 (1), 105-115. http://editorarevistas.mackenzie.br/index.php/ptp/article/view/3773
15) **Balbim, G.M**., Nascimento Junior, J.R.A., & Vieira, L.F. (2013). Analysis of the level of satisfaction and perfectionism of futsal professional athletes of the state of Parana. *Conexões (Campinas. Online),* 11(2), p. 15-30. https://doi.org/10.20396/conex.v11i2.8637615
16) **Balbim, G.M**., Nascimento Junior, J.R.A., & Vieira, L.F. (2012). Analysis of group cohesion levels and pre-competitive psychological stress in volleyball athletes. *Revista Brasileira de Cineantropometria & Desempenho Humano (Online),* 14 (6), p. 704-712, 2012. http://dx.doi.org/10.5007/1980-0037.2012v14n6p704
17) Vieira, L.F., **Balbim, G.M**., Pimentel, G.G.A., Hassumi, M.Y.S.S., & Garcia, W.F. (2011). Flow state in climbing and skate downhill practitioners. *Motriz: Revista de Educação Física (Online),* v. 17(4), 591-599. http://dx.doi.org/10.1590/S1980-65742011000400003

G. ARTICLES UNDER REVIEW:

1) Guzman, J., Marques, I.G., **Balbim, G.M.**, Aguiñaga, S., Lamar, M., Marquez, D.X. The effects of the BAILAMOS^{TM} Latin dance program on self-reported physical activity and hippocampal volume in older Latinos. *Alzheimer Disease & Associated Disorders Journal.*

2) Croff, R., Tang, W., Friedman, D.B., **Balbim, G.M.,** Belza, B. Training the Next Generation of Aging and Cognitive Health Researchers. Manuscript submitted for publication. *Health Promotion Practice.*
3) Steinman, L., Harkins, K., Marquez, D.X., Miyawaki, C.E., Pruitt, A., **Balbim, G.M.**, Croff, R., Belza, B., Karlawish, J. Evaluating public health messages to promote early detection of dementia among African-American, Asian-American, Latino, and LGBT adult children. Manuscript submitted for publication. *Health Communication.*

H. MANUSCRIPTS IN PREPARATION:

1) Bustamante E.E., Santiago-Rodriguez, M.E., **Balbim, G.M.,** Ramer, J., DuBois, D., Brunskill, A. Effect of Chronic Physical Activity on Symptom Severity and Functional Impairment of Children with ADHD and Disruptive Behavior Disorders: A Systematic Review and Meta-Analysis. Manuscript in preparation.
2) Marquez, D.X., Wilbur, J., Hughes, S., …, **Balbim, G.M.,** Wang, T. B.A.I.L.A. – Latin Dancing to increase Physical Activity in Spanish-speaking older Latinos.
3) **Balbim, G.M.**, Aguiñaga, S., Lamar, M., Ajilore, O., Erickson, K., Bustamante, E.E., Marquez, D.X. The effects of the BAILAMOS^{TM} Latin dance program pilot randomized trial cognition in older Latino adults.
4) **Balbim, G.M.**, Lamar, M., Ajilore, O., Erickson, K., Aguiñaga, S., Bustamante, E.E., Marquez, D.X. Associations of physical activity levels and white matter integrity in older Latino adults.
5) **Balbim, G.M.**, Ajilore, O., Lamar, M., Erickson, K., Aguiñaga, S., Bustamante, E.E., Marques, I.G., Marquez, D.X. The effects of a Latin dance program on brain functional connectivity and cognition in older Latino adults.
6) Marques, I.G., **Balbim, G.M**., Aguiñaga, S., Kitsiou, S., Gerber, B., Bustamante E.E., Marquez, D.X. Impact of a Latin Dance Program with mHealth on the Health and Physical Activity of Middle-Aged and Older Latinos.

I. INVITED PRESENTATIONS:

1) **Balbim, G.M**., Marques, I.G., Guzman, J., Aguiñaga, S., Vasquez, P., Marquez, D. X. Per-protocol Analysis of BAILAMOS^{TM} Dance Program on Self-reported and Device-assessed Physical Activity in Older Latinos. Oral presentation at the Aging Interest Group at 65th Annual Meeting with 9th World Congress on Exercise is Medicine® and World Congress on the Basic Science of Exercise, Circadian Rhythms and Sleep of the American College of Sports Medicine, Orlando, FL, May, 2019.
2) **Balbim, G.M.** The Exercise Psychology Laboratory. Presented to the UIC Honors College of the President Awards Program, University of Illinois at Chicago, Chicago, US, July 2017.
3) **Balbim, G.M.**, Marquez, D.X. Physical Activity, Cognition, and Alzheimer's Disease. Panel discussion presented at the Longest Day, Woodlawn Community Center, Chicago, US, May 2017.
4) **Balbim, G.M.** Motivation, Body, and Sport: 21st-century conceptions. Panel discussion presented at 1st National Congress of Human Movement, Sport, Recreation and Dance, Rio Claro, Brazil, November, 2012.

J. REFEREED CONFERENCE PRESENTATIONS:

1) **Balbim, G.M**., Garcia, M., Aguiñaga, S., Vásquez, P.M., Marques, I.G., Guzman, J., Marquez, D. X. Senior Center Directors' Perceptions of the Sustainability of BAILAMOS^{TM} Dance Program. Poster to be presented at 41st Annual Meeting & Scientific Sessions of the Society of Behavioral Medicine, San Francisco, CA, April 2020.
2) **Balbim, G.M**., Aguiñaga, S., Vasquez, P., Marques, I.G., Guzman, J., Marquez, D. X. Middle-aged and Older Latinos' Satisfaction of the BAILAMOS^{TM} Latin Dance Program. Poster presented at The Gerontological Society of America's 71st Annual Scientific Meeting, Austin, TX, November, 2019.
3) **Balbim, G.M**., Marques, I.G., Guzman, J., Aguiñaga, S., Vasquez, P., Marquez, D. X. Per-protocol Analysis of BAILAMOS^{TM} Dance Program on Self-reported and Device-assessed Physical Activity in Older Latinos. Thematic poster presented at 65th Annual Meeting with 9th World Congress on Exercise is Medicine® and World Congress on the Basic Science of Exercise, Circadian Rhythms and Sleep of the American College of Sports Medicine, Orlando, FL, May, 2019.
4) **Balbim, G.M.**, Marques, I.G., Kitsiou, S., Aguiñaga, S., Gerber, B., Buchholz, S. W., Bustamante, E.E., Marquez, D. X. Impact of an mHealth Latin Dance Intervention on Physical Activity and Health Outcomes on Middle-Aged and Older Latinos. Poster presented at the 40th Annual Meeting and Scientific Sessions of the Society of Behavioral Medicine, Washington, DC, March, 2019.
5) **Balbim, G.M**., Marques, I.G., Guzman, J., Gomez, S., Marquez, D.X. Cognitive health perceptions of middle-aged and older Latinos. Poster presented at the 40th Annual Meeting and Scientific Sessions of the Society of Behavioral Medicine, Washington, DC, March, 2019.
6) **Balbim, G.M.**, Marques, I.G., Cantoral, J., Guzman, J., Marquez, D.X. Using a Physical Activity Wearable Tracker: Older Latinos' Perceptions. Poster presented at The Gerontological Society of America's 70th Annual Scientific Meeting, Boston, MA, November, 2018.
7) **Balbim, G.M**., Aguirre, K., Zavala, M., Davila, K., Marquez, D.X. Evaluation of Public Health Messages to Promote Early Detection of Dementia Among Adult Latino Children. Poster presented at The Gerontological Society of America's 70th Annual Scientific Meeting, Boston, MA, November, 2018.
8) **Balbim, G.M**., Marques, I.G., Guzman, J., Aguiñaga, S., Vasquez, P., Marquez, D. X. Impact of BAILAMOS© program on self-reported physical activity in older Latinos. Poster presented at the 65th Annual Meeting with 9th World Congress on Exercise is Medicine® and World Congress on the Basic Science of Muscle Hypertrophy and Atrophy of the American College of Sports Medicine, Minneapolis, MN, May, 2018.
9) **Balbim, G.M**., Marques, I.G., Magallanes, M., Rocha, J.S., Marquez, D.X. Perceptions of caregiving burden among older Latino caregivers. Poster presented at the 39th Annual Meeting and Scientific Sessions of the Society of Behavioral Medicine, New Orleans, LA, April, 2018.
10) **Balbim, G.M**., Marques, I.G., Aguiñaga, S., Marquez, D.X. Perceptions of Physical Activity of Middle-aged and Older Latinos. Symposium presented at the 45th Annual

Midwest American College of Sports Medicine Conference, Grand Rapids, MI, November, 2017.

11) **Balbim, G.M**., Marques, I.G., Magallanes, M., Rocha, J. S., Marquez, D. X. Motivators for Physical Activity in Older Latino Caregivers. Poster presented at the 64th Annual Meeting and World Congress on Exercise is Medicine®, and World Congress on the Basic Science of Exercise and the Brain of the American College of Sports Medicine, Denver, CO, June, 2017.
12) **Balbim, G.M**., Marques, I.G., Magallanes, M., Rocha, J. S., Marquez, D. X. Coping Strategies among Older Latino Caregivers. Poster presented at the 38th Annual Meeting and Scientific Sessions of the Society of Behavioral Medicine, San Diego, CA, March, 2017.
13) **Balbim, G.M**., Vissoci, J.R.N., Nascimento Junior, J.R.A., Vieira, L.F. Leadership styles of futsal coaches from Parana: a study in function of competitive levels. Oral presentation presented at 5th Brazilian Congress of Metabolism, Nutrition and Exercise, Londrina, Brazil, August, 2014.
14) **Balbim, G.M.,** Mori, G.H., Aizava, P.V.S. Aggressiveness in Jiu-Jitsu practitioners from Maringa-PR. Poster presented at 37th International Symposium of Sports Science, São Paulo, Brazil, October, 2014.
15) **Balbim, G.M.,** Nascimento Junior, J.R.A., Baraviera, Y.L., Codonhato, R., Vieira, L.F. Level of state-anxiety in handball athletes from Parana state. Oral presentation presented at 8th International Congress of Sport and Exercise Psychology, Florianopolis, Brazil, November, 2013.
16) **Balbim, G.M.,** Prates, M.E.F., Vieira, L.F. Analysis of self-concordance goals in Youth Games athletes from Parana. Oral presentation presented at 1st International Congress of Sport and Exercise Psychology, Maringa, Brazil, September, 2012.
17) **Balbim, G.M.,** Nascimento Junior, J.R.A., Caruzzo, N.M., Mizoguchi, M.V., Vieira, L.F. Self-efficacy and motivation in handball athletes from Parana. Oral presentation presented at 4th Iberoamerican Congress of Sport Psychology, São Paulo, Brazil, November, 2012.

K. ASSOCIATION MEMBERSHIPS

2016 – Present	Society of Behavioral Medicine (SBM)
2016 – Present	American College of Sports Medicine (ACSM)
2017 – Present	Gerontological Society of America (GSA)
2018 - Present	Alzheimer's Association