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Impact of Dance Complexity on Computer-Based and Movement-Based Cognitive Performance

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IMPACT OF DANCE COMPLEXITY ON COMPUTER-BASED AND MOVEMENT-BASED COGNITIVE PERFORMANCE

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BACKGROUND: Exercise improves cognition, but the specific mechanisms underlying these changes are not clear. Two proposed mechanism are aerobic demand and cognitive demand inherent in varying degrees to specific exercise tasks. This study compared two kinds of dance that differed in instruction complexity and aerobic intensity, ballroom (BR) and aerobic dance (Aero). The primary aim of this study was to determine if the cognitive benefits of exercise are more responsive to the complexity or aerobic overload.
METHODS: Fourteen subjects aged 40-80 were randomly assigned to 8 weeks of Aero or BR dance classes. Aero classes were designed to emphasize low instructional complexity and high aerobic intensity. BR classes were designed to emphasize high complexity and low aerobic intensity. Motor and cognitive functions were assessed before and after participation. The six-minute walk (6MW) and timed up-and-go (TUG)were used to measure aerobic function and agility, respectively. A computer-based cognitive battery (Neurotrax Tests) was used to evaluate global cognitive function, executive function, attention, and memory. The Walking Response Inhibition Test (WRIT) was used to evaluate cognition using whole-body movements through a physical environment.

RESULTS: Significant main effects for time were observed for 6MW, TUG, memory, and WRIT. Performance for the 6MW, memory, and WRIT improved, whereas TUG performance worsened. Although neither group exhibited significant change in the 6MW; there was an interaction effect and subsequent pairwise analysis revealed that the change seen for Aero was higher than BR.

CONCLUSION: We observed differences in aerobic demand between the groups, with greater, though non-significant, aerobic response by the Aero group. There were improvements in both memory and WRIT for both groups. Improvements in WRIT favored the BR group compared to the Aero group, although between group differences failed to reach significance. Our preliminary data suggest a role for both aerobic demand and movement complexity in driving cognitive adaptations. More research with larger sample sizes is needed to support these findings. Future research should control the complexity of the exercise conditions and assess the learning effects and cognitive demand of the subjects.

Key Words: dance, cognition, complexity, movement, executive function

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CHAPTER 1: INTRODUCTION

The relationship between exercise and cognition has been explored in a number of controlled studies. Both acute exercise up to 60 minutes (Tomporowski, 2003) and chronic exercise programs (Angevaren et al., 2008) of varying intensities, frequencies, and durations have been shown to improve cognition. Self-described "exercisers" have been shown to have superior cognitive performance compared to sedentary persons (Clarkson-Smith & Hartley, 1989). A meta-analysis of the cognitive effects of fitness training in older subjects revealed cognitive benefits of exercise (Colcombe & Kramer, 2003), and exercise has also been linked to neurogenesis across systems involved in learning and memory (Erickson et al., 2011).

One of the most common exercise interventions associated with increases in cognitive capacity is cardiovascular (aerobic) exercise. Reviews suggest that demands placed on energy homeostasis by aerobic exercise stimulate neurotrophic factor production and subsequently improve cognitive health (Cotman & Engesser-Cesar, 2002; Vaynman & Gomez-Pinilla, 2006). The need for high aerobic intensity is supported by the findings of Colcombe et al. (Colcombe et al., 2006), which demonstrated that standard aerobic exercise, but not stretching and toning exercises, produced an increase in brain volume. However, it would appear that improvements in aerobic capacity do not fully explain these changes, since the effects of exercise on cognition are not correlated with cardiovascular fitness (Etnier, Nowell, Landers, & Sibley, 2006). Additionally, a meta-analysis showed that the beneficial effects of exercise on depression were not mediated by improvements in cardiovascular fitness (Craft & Landers, 1998), suggesting the role of another factor besides cardiovascular adaptation. These findings imply that although aerobic demand is necessary, increased aerobic capacity alone is not sufficient for inducing cognitive benefits, suggesting that other factors are necessary to optimize benefits

One factor that may play an important role in producing cognitive benefits is movement complexity. Plautz et al. (2000) presented one theory explaining the importance of movement complexity in neuroplasticity. While simple repetitive activity did not produce cortical changes as assessed by neurophysiological mapping (Plautz et al, 2000), complex repetitive tasks exhibited significant changes in the cortical structure of monkeys (Nudo et al., 1996). Plautz et al. suggested that cortical plasticity depends on the acquisition of skills and not simply improvements in cardiovascular capacity. In addition, the cognitive effort inherent to processing a complex task can induce adaptations in neuroplasticity, as proposed by Carey et al. in a review of neuroplasticity and task complexity (Carey et al., 2005). The theories of Plautz et al. and Carey et al. are supported by human studies showing that skill acquisitions produced neurological adaptations to a greater degree than comparative movement tasks without skill acquisition (Pascual-Leone, et al. 1995). In addition, rats exposed to conditions of complex movement, such as obstacle courses, show greater increases in synaptogenesis (Kleim et al., 1996) and neurotrophic factors (Klintsova et al., 2004) than their counterparts exposed to simple movement tasks. In further support of the theories indicating that some form of cognitive processing or demand underlies synaptogenesis, increases in the expression of neurotrophic factors in rats have been shown to follow tasks involving spatial learning (Kesslak et al., 1998). Similarly, adult rats kept in enriched housing conditions for 12 months demonstrated significantly higher levels of nerve growth factor in the hippocampus, visual and entorhinal cortices compared with animals housed in an isolated condition, and performed better than their counterparts in tests of spatial learning (Pham et al., 1999).

In summary, results of controlled studies suggest the possibility that, though aerobic training intensity may play a necessary role in the positive effects of exercise on cognition, a learning component may also be necessary if exercise is to be a successful tool for stimulating cognitive adaptations. If this is so, theories of cognition, learning and adaptation, as well as the exercise interventions on which they are based, should reflect these results.

Purpose of the Study

The purpose of this study was to determine if cognitive adaptations to exercise differ according to levels of movement complexity and aerobic overload. Specifically, we evaluated the effects of two types of dance-related exercise interventions, ballroom dance (BR) and aerobic dance (Aero) on cognition and physical performance. These two styles were selected due the feasibility of adjusting complexity and intensity within the two interventions. By comparing changes in cognitive performance between the BR dance, which was considered more complex due to the variations in style and the need to work interactively with a partner, and Aero dance, which was of higher intensity, we examined whether an intervention emphasizing complexity would produce different adaptations than one that emphasizes aerobic intensity. Based on animal models examining adaptations to simple repetition (Plautz et al., 2000) and complexity (Carey et al., 2005), we hypothesized that the BR dance condition would result in greater adaptations on computer- and movement-based tests of cognition than the Aero dance condition, even in the face of lesser gains in aerobic capacity.

CHAPTER 2: METHODS

Participants

Fifty participants, aged 40-80 (men: n=13; 67.9±10.6 y; women: n=37, 64.7±9.3 y), were recruited from local community centers to participate in this study. Participants were excluded if they scored less than 23 on the Mini-mental State Exam (MMSE, see Appendix A), presented with pre-existing musculoskeletal conditions that would contraindicate dance exercise, or had any uncontrolled psychological diagnoses. Participants had no recent dance training. Subject characteristics are presented in Table 1.

Of 50 recruited subjects, 28 were randomized into either the Aero or BR group. Fourteen subjects, seven in each group, completed both pre- and post-testing. Only subjects who completed post-testing were used in the analyses. Drop-outs were due to scheduling, vacations, and disinterest in their specific dance intervention. No subjects discontinued training due to injury.

Research Design

All procedures were approved by the Subcommittee for the Use and Protection of Human Subjects and all participants provided written consent. After participants underwent baseline testing, individuals were randomized into exercise groups using a simple coin toss. Following the exercise intervention, participants repeated the testing. All tests were administered at the Max Orovitz Laboratory Complex or University of Miami Hospital. A CONSORT flow chart detailing the number of participants recruited, screened, enrolled, tested, and analyzed is shown in Figure 1.

Procedures

Subjects were randomly assigned to either Aero dance class (considered a high-aerobic/low complexity condition) or BR dance class (considered a low aerobic/high complexity condition). For each group, a qualified instructor taught lessons two times per week for a period of eight weeks. Neither group had participated in formalized dance instruction previously.

Aerobic Dance Intervention. For the Aero class, subjects mimicked the instructor's callisthenic movements and simple patterns. Although the patterns varied from class to class, the instructor kept the learning component nominal and minimal verbal instructions were provided. Class duration was between 45 and 60 min.

Ballroom Dance Intervention. The BR dance condition was taught as a classic ballroom dance class. In this class, subjects learned a variety of dance styles. Each class built on prior classes to create a continued learning process of complex movements combined with the necessity for cooperation with a partner. Similar to the Aero intervention, class duration was between 45 and 60 min.

Test Procedures

Pretests and post-tests were performed within a 2-week period before and after the intervention, respectively. Tests were administered by the same tester to eliminate inter-rater reliability concerns.

*The Six-Minute Walk Test***.** (Rikli & Jones, 2013)

The six-minute walk (6MW) was used to measure aerobic demand and adaptation. Results from the 6MW test have been shown to be highly correlated with maximal oxygen consumption (VO_{2max}) test results (Laskin et al., 2007). In performing the test the participant walked as quickly as possible around a 30 m linear course delineated by 2 cones. At the word 'go,' the subject walked at a pace that allowed him or her to cover the greatest distance in 6 min and stopped at the ‘stop’ command. The tester announced the time remaining after each minute that passed. Distance was calculated as the distance covered from the 'go' signal until the 'stop' signal.

Timed Up-and-Go Test (Rikli & Jones, 2013)

The timed up-and-go test (TUG) measures agility and dynamic balance (Rikli and Jones, 2013). The participant began the TUG test seated in a chair (23cm seat height) with a cone positioned directly in front of the chair 8 feet away. The tester counted “3-2-1-go”. At the word “go", the subject rose from the chair, walked around the cone and returned to the seated position as quickly as possible. The faster of two attempts was recorded (Podsiadlo & Richardson, 1991).

Cognitive function computer battery

A computer battery (Neurotrax tests. Neurotrax Corp., Huston, TX) was utilized to evaluate computer-based cognitive function, including executive function, memory, and attention (Doniger, 2014). The battery included the Verbal Memory test, the Go–NoGo Response Inhibition test, the Stroop Word Color test, and the Catch Game.

The Verbal Memory test is a modification of the Logical Memory test of the Wechsler Memory Scale, 3rd Edition (WMS-III). Immediate and delayed recognition memory of verbal paired associates are tested. Ten monosyllabic word pairs are studied. During an immediate recognition test, one member of a previous pair is presented and the associated word must be chosen from four possible choices. The subject presses a button on the keyboard to indicate the pair that was previously presented. Up to four consecutive repetitions follow immediately. After a 10 minute delay, an additional recognition test is administered. The subject is not presented the same word-pairs across pretests and post-tests. Outcome variables include accuracy for each of the four immediate recognition tests, total accuracy across tests, and accuracy for the delayed recognition test (Doniger, 2014).

The Go–NoGo Response Inhibition test measures attention and executive function, specifically of response time and response inhibition. A series of colored squares appear. The participant responds as quickly as possible by mouse click, unless the square is red. Response variables include accuracy, errors of omission and commission, and response time with its variance. There are 30 trials, 18 of which are red-square trials. A composite score is calculated as accuracy divided by response time, number of omission errors, number of commission errors, and response time associated with errors of commission (Doniger, 2014).

The Stroop Word Color test is a test of attention and executive function, specifically the ability to suppress habitual responses. Two colored squares and a colored word are presented. The participant selects one of the two squares by clicking the corresponding mouse button. The test consists of three parts. During the first part (no interference: letter color. 10 trials), the participant rapidly selects the square that shares the same color as the word presented on a screen. During the second part of the test (no interference: word meaning. 15 trials), the participant selects the square corresponding to the color written in white letters. During the third part of the test (interference: color vs.

meaning. 15 trials), the participant selects the color in which the word was written, rather than the color denoted by the word.

The Catch Game is a test of executive function and motor skills. The participant catches a descending white rectangle on a paddle controlled by clicking the mouse buttons. The rate of fall of the rectangle increases incrementally. There are 20 total trials possible; however, if performance is poor, the test stops and the participant receives fewer trials. Outcome parameters include response time and associated variance for the first move, number of direction changes per trial, error for missed catches, and a total performance score (Doniger, 2014).

The Walking Response Inhibition Test (WRIT)

The WRIT was designed to evaluate executive function (EF) during a walking task incorporating full-body directional changes in a physical environment (Arturo Leyva, personal communication). A schematic of the WRIT is presented in Figure 2. Subjects walked along a short course (nine meters) and performed four tasks involving supervisory attention and cognitive control in response to visual stimuli presented on a screen. The first task was to stop upon presentation of a red circle. This task was used to determine if the participants could perform the basic tasks of walking, stopping, seeing and understanding visual cues.

The second task was to turn in the direction of a green arrow. This task activated attention and other components of EF including time perception, volition or initiation, motor control of an executed task, working memory, and response inhibition (Diamond, 2013; Suchy, 2009; Yogev-Seigman et al., 2008). WRIT2 also included a reactive agility component so that physical, cognitive, and decision-making skills were included (Serpell et al., 2011; Sheppard & Young, 2006). The third task was to turn in the direction of a green arrow if no blue circle was present; however, if a blue circle was present, the subject must turn in the direction opposite that indicated by the green arrow. In the fourth task all conditions could be presented and if a red light appeared all other instructions were to be ignored and the subject was to stop. The third and fourth tasks were designed as incongruent tasks to evaluate: (1) the inhibition of practiced or automatic responses; and, (2) the ability to overcome the predisposition to respond incorrectly while initiating a correct response (Diamond, 2013; Rusnáková et al; 2011, Suchy, 2009). Subjects performed 1 trial of WRIT 1, 2 trials of WRIT 2, 4 trials of WRIT 3, and 8 trials of WRIT 4. By combining the congruent tasks from WRIT 1 and WRIT 2 with the incongruent task in WRIT 3, the WRIT4 to incorporated all aspects of EF including: cognitive speed flexibility, response selection, inhibition, initiation and motor movement capacity (Diamond, 2013; Suchy, 2009). Approach speed and reaction time of subjects was determined by video analysis using 240 FPS high-speed camera and Kinovea video analysis software.

Acceptable levels of test-retest reliability in similar age groups have been established for the WRIT (Arturo Leyva, personal communication), Neurotrax tests (Schweiger et al., 2003), 6MW (Rikli and Jones, 1998), and TUG (Podsiadlo and Richardson, 1991).

Statistical Analyses

Separate between-group 2 x 2 ANOVA (condition x time) were used to assess the impacts of the dance interventions on physical performance measures, computer tests, and WRIT. Significant effects were followed by pairwise analyses. Homogeneity of variances and covariances were assessed by Levene's test of homogeneity of variance and Box's test of equality of covariance matrices, respectively, on all outcome variables. All statistical procedures were performed using the SPSS statistical package (version 22.0; SPSS, Inc., Chicago, IL).

CHAPTER 3: RESULTS

There was homogeneity of variances and covariances, as assessed by Levene's test of homogeneity of variance ($p > .05$) and Box's test of equality of covariance matrices ($p > .001$), respectively, for all outcome variables. Several outliers were identified via box-plots. Upon further investigation, these were neither errors of entry nor departures from expected performance on the tests, and were thus included in the analyses.

No significant differences were detected at baseline between groups for age (p=.86), gender (p=.41), weight (p=.918), or height (p=.860). Nor were there differences between groups at baseline for the 6MW (p=.161), TUG (p=.122), executive function (p=.191), attention (p=.689), memory (p=.890), global computer score (p=.322), or WRIT (p=.922). Of the 16 possible classes offered during the 8-week intervention period, subjects in BR attended 12.4±2.9 classes and subjects in Aero attended 13.5±1.3 classes. There was no statistical difference in attendance between the conditions (p=.372).

Results of analyses of changes across the training period are presented in Tables 2 and 3. Changes are presented as mean difference (MD) ± standard deviation.

Physical performance tests

A significant group × time interaction was detected on the 6-minute walk ($F(1)=4.705$, p=.049, $\eta^2 p = .266$). Pairwise analysis revealed an improvement for Aero (MD = 49.94 ± 82.98 yards, p=.131, d=.73) andreduced performance for BR (MD = -27.79 ± 48.53 yards, p=.182, d=-.28), neither of which reached significance. There was a significant effect of time for TUG performance ($F(1)=6.253$, $p=.027$, $\eta^2p = .325$) with no interaction effect ($F(1)=.008$, $p=.931$, η^2p $=.001$). Pairwise analysis revealed a decline in performance (MD=.36±.54 seconds, p=.020, d=.30).

Computer battery

Two variables, memory and attention, were not normally distributed; therefore, these variables were transformed and re-tested for normality (Howell, 2010). All other variables were normally distributed. For variables that were not normally distributed, mean differences are expressed as original non-normalized values, and statistical analyses are run on the normalized data.

The changes in the global composite score ($F(1)=.101$, $p=.755$, $\eta^2p =.008$) and EF ($F(1)=.545$, $p=.473$, $\eta^2p =.04$) did not reach significance. Memory was negatively skewed; data were transformed by reflecting the data and taking the log of the reflected data ("reflect and log"); transformed data were normal. The untransformed memory data showed a mean difference of 3.53 ± 5.34. There was a significant effect of time for the transformed memory results ($F(1)=6.962$, $p=.020$, $\eta^2p = .349$) with no interaction effect ($p=.940$). A reflect and log transformation was also applied to attention scores. The untransformed attention data showed a mean difference of -1.73 ± 5.25. There was a significant decline in attention scores across time for attention ($F(1)=4.864$, $p=.046$, $\eta^2p = .272$) with no interaction effect ($p=.619$).

WRIT

There was a significant effect of time on the WRIT ($F(1)=20.648$, $p=.001$, $\eta^2p = .652$) with a MD of 33.28 ± 28.09. Although there was no significant interaction, visual inspection (see Figure 3) revealed an intersection between individual effects, suggesting that the mean difference for BR (45.34±35.02) was greater than that for Aero (25.74±21.96).

CHAPTER 4: DISCUSSION

The primary aim of this study was to evaluate the comparative roles of movement complexity and aerobic overload on cognitive adaptations to exercise. Two kinds of dance, BR and Aero, which differed in complexity and aerobic demand, were compared. Physical tests were used to evaluate changes in aerobic capacity and functional agility, computer tests were used to quantify changes in cognitive capacities including executive function, attention, and memory, and the WRIT was used to evaluate cognition and walking responses in a physical environment.

Physical Performance

Six-Minute Walk

The interaction effect in 6MW combined with the non-significant increase in aerobic and decrease in BR suggests a difference in aerobic demand between the two groups. These results differ from those of a previous study, which found that BR dance was a sufficient cardiovascular stressor to achieve 5.3-7.1 METS (18.55 – 24.85 $ml \cdot kg^{-1} \cdot min^{-1}$) in adults aged 18-24y using the Waltz, Foxtrot, Cha-Cha, and Swing (Lankford et al., 2014); however, two reviews examining the impact of dance on aerobic capacity indicated that this variable was not routinely evaluated in any of the BR studies included in the reviews (Hwang & Braun, 2015; Keough et al., 2009). Comparatively, classic aerobic dance programs, which closely resemble our Aero intervention, have been effective at increasing aerobic power (Keough et al., 2009). It is possible that, in our older subjects, aerobic adaptations in either group were limited due to the difficulty in learning the unique movement patterns inherent to both the Aero and BR dance styles. Finally, functional mobility and flexibility limitations prevalent in older adults (Ostchega et al., 2015) may have restricted subjects' movement capacities resulting in reduced cardiovascular demand.

The high variability of the mean difference scores for the 6MW suggests that individual responses to the dance interventions varied significantly. This may be related to the individual variations in the previously-mentioned functional mobility limitations or in the individual efforts provided, each of which would have affected cardiovascular demand.

The Timed Up-and-Go Test

The decrease in performance on the TUG test of .36 seconds is substantially less than the minimal detectable change score of 4.09s calculated in subjects with Alzheimer's disease (Ries et al., 2009) or the 1.0s change reported for older subjects with type 2 diabetes (Alfonso-Rosa et al., 2014). Our findings suggest that the dance training in this study did not provide sufficient challenge to improve or maintain agility. This result was unexpected, given that the dance classes, especially BR, required changes of direction and dynamic balance common to many agility training programs (Lennemann et al., 2013). A potential explanation for the lack of improvement in the Aero group may be the absence of environmental demands in this intervention compared to those commonly seen during agility training. The locomotor challenge of common agility protocols, in which there is maneuvering through a static environment while avoiding stationary obstacles, was not evident during Aero training. In contrast, BR dance involved agility related to a partner in response to auditory cuing, rather than environmental cues such as cones. These demands may not have transferred to the specific type of agility tested by the TUG. An alternate agility test with potentially more relevance to the agility demands of dance is the Dynamic Gait Index which addresses many sub-domains of agility (Shumway-Cook et al., 2013). A review paper on the topic (Sheppard and Young, 2006) presented a model of agility noting substantial variations in agility types, and stating that training effects were specific to the agility sub-domain trained.

Computer Tests

Executive Function

Previous studies have shown improvements in EF following both aerobic exercise (Masley et al., 2006; Leckie et al., 2014) and resistance and agility training (Forte et al., 2013). An analysis of seven studies found that the effect size for aerobic training on EF was 0.16 (95% CI: -0.20, 0.51) (Angevaren et al. 2008). Following our interventions, however, we found negligible changes in EF. It is possible that the absence of improvements in both the Aero and BR groups could be due to insufficient aerobic stimulus, as a meta-analysis by Smith et al. (2010) has shown that EF responds to aerobic exercise. The effect sizes calculated by Smith et al. revealed aerobic exercise to have a moderate effect, with no relationship between intensity, duration, or age and improvements EF. This finding is supported by studies showing that improvements in EF depend to some extent on aerobic demand (Colcombe et al., 2006); however, motor-skill training without concomitant aerobic demand, such as juggling (Driemeyer et al., 2008) and playing music (Herdener et al., 2010), has been shown to stimulate functional neuroplasticity. Specifically, Driemeyer et al. (2008) showed increases in grey matter in the occipito-temporal cortex, whereas Herdener et al. (2010) observed alterations in hippocampal activity in response to novel sound patterns. In addition, these types of motor-skill training have been shown to improve measures of EF (Moreno et al., 2011).

EF is assessed via separate tests intended to address different components, such as task switching, selective attention and inhibition, and updating working memory (Guiney and Machado, 2012). The Neurotrax tests used in this study test EF using the Go/No-Go and Stroop tests, which Guiney and Machado (2012) included under selective attention and inhibition. However, Guiney and Machado (2012) showed that the greatest benefit of aerobic exercise was to working memory updating. In the Neurotrax tests, memory was treated as distinct from EF. In addition, tests of individual components of EF are often used as proxies for EF itself (Leckie et al., 2014), which may lead to generalization of results of a single EF-component to the entire EF-construct.

Given the consistency of improvements in EF reported with aerobic demand in past literature (Masley et al., 2006; Leckie et al., 2014; Angevaren et al. 2008), and the presence of aerobic demand in the Aero group, it is unclear why this group failed to improve measures of EF. One possibility is the use of dissimilar components of EF and different tests used to measure these components during individual studies. We did see improvements in memory, similar to improvements in studies using memory as a proxy for EF (Guiney and Machado, 2012). Alternately, given the improvements in EF due to aerobic exercise (Masley et al., 2006; Leckie et al., 2014), aerobic demands may have been insufficient or movement patterns may not have been complex enough to produce sufficient overload to improve EF.

Memory

Memory improved across both groups. This improvement may have been due to the need to remember instructions. The observation that participants in the Aero dance group improved memory was unexpected; but may be attributed to a demand that, while small, was adequate to produce these changes as subjects were required to remember moderately demanding, unique movement patterns and how to respond with those patterns to verbal and visual cues. Future research should attempt to simplify the “simple movement” conditions even further, so that memory demand is absent.

A Cochrane review examined the impact of aerobic exercise on cognition and found that improvements in memory as a result of aerobic training were negligible (Angevaren et al., 2008). In addition, Lennemann et al. (Lennemann et al., 2013) reported that in comparison to running and calisthenics, agility training produced greater improvements in memory. Both Aero and BR dance classes had elements similar to agility training, though they failed to produce improvements on the TUG test. The tendency of the agility-oriented protocols to improve memory may relate to the differences between agility training (dance or non-dance), which requires adaptations to shifting environmental variables, and standard aerobic training protocols such as running or cycling. Thus, the factor that produced the improvements in memory in Aero may be not the aerobic component as much as the memory demands specific to the instructions.

Attention

Although there was no interaction effect, the large magnitude difference between effect sizes for BR (d=-.87) compared to Aero (d=-.01) suggest that Aero was capable of attenuating losses in attention while BR could not. Cognitive declines are observed in adults and elderly persons (Park, O'Connell, & Thomson, 2003); however, these have been observed over years, rather than over the 8-week time span of this study. In addition, a meta-analysis by Smith et al. (2010) has shown that aerobic exercise has a moderate effect on attention, regardless of duration, intensity, or subject age.

If Aero dance did attenuate attention declines over this short time period, this would suggest that the class provided a greater need for cognitive systems related to attention than BR. It was observed that the nature of the Aero classes involved responding to quickly changing instruction, as opposed to prolonged learning of a specific pattern as in BR. Perhaps the rapidly changing instructions inherent to the Aero protocol could have required frequent shifts in focus, introducing task switching demands (Hyafil et al., 2009). This is consistent with results showing that contemporary dance can improve attentional shifting (Coubard et al., 2011); however, given the short duration of this study, and the low probability that deterioration would occur over 8 weeks, any such conclusion must be approached with extreme caution. Further exploration is warranted for determining whether attention is challenged in aerobic-type classes.

WRIT

Both Aero and BR dance groups improved performance on the WRIT. Although not statistically significant, visual inspection of the patterns of change between testing periods revealed an interaction between the interventions (see Figure 3). This visual representation, however, and should be interpreted with caution. In addition, the magnitude of the effect size for BR was considerably greater than that for Aero (Cohen's d: BR = 1.805; Aero = .567). Although clinically meaningful changes have yet to be determined for this test, the mean score observed during its development in subjects over

60 years of age is 103.4±32.8 (Arturo Leyva, personal communication) while the pretest and post-test scores during the current study were: pretest=94.7±38.2, post-test=120.4±51.6 and pretest=86.8±20.5, post-test=132.1±29.0 for Aero and BR, respectively.

The increase in performance on the WRIT by both groups suggests that dancing improves reactive agility and/or inhibition. To our knowledge, the relationships between dance and reactive agility or inhibition have not been studied; however, dance has been shown to improve cognitive outcomes (Kim et al., 2011; Coubard et al, 2011). It is unclear why both dance groups improved on the WRIT, but failed to improve on the computer-based EF testing. One possible explanation is that these results are reflective of the biomechanical specificity associated with movement-based training. Both Aero and BD were predominantly lower body dominant training interventions as was the WRIT. The computer-based battery, in contrast, required only small movements of the upper shoulder, elbow and wrist joints. Therefore, these results support our findings during development of the WRIT that, due to its concentration on walking (lower body dominance), this test is a more appropriate measure of responses during activities of daily living requiring incorporation of large muscle mass than existing computer-based mouse and keyboard tests since it is biomechanically reflective of locomotor performance in a physical, rather than virtual, environment (Arturo Leyva, personal communication).

The greater increase in performance on WRIT for BR compared to Aero should be interpreted with caution due to the absence of statistical significance. Having acknowledged this, the greater response to BR may be due to the greater coordination demands required to perform complex movements while working with a dance partner and adapting to the unique rhythms and cadences of each ballroom dance type. This idea is in agreement with findings that dance improves proprioception as a measure of joint position sense (Marmeleira and Pereira, 2009). In addition, the greater improvements in memory in the BR group may have worked synergistically to improve the ability of subjects to retain instructions during performance of the WRIT.

Comparative Impacts of Aerobic Intensity and Movement Complexity

It has been observed in previous studies that aerobic intensity appears to be necessary for cognitive adaptation; however, the level of aerobic adaptation does not appear to correlate with the level of cognitive adaptations (Etnier et al., 2006). In our study, we observed improvements in both memory and WRIT for both groups, despite the lack of aerobic adaptation in the BR group. However, it was not possible in this study to determine if attention responded more to the potential inherent complexity of Aero, including attentional shifting, or to its aerobic demand. It is important for this to be addressed in future research.

A review paper evaluating dance interventions found that 80% of the reported cognitive outcomes were positive (Hwang & Braun, 2015). One study in this review used a ballroom dance, the Cha-Cha, as a 6-month intervention in elderly subjects with metabolic syndrome. This study, using the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) as a measure of cognitive performance, showed improvements in the domains of verbal fluency, delayed recall, and recognition memory function without concomitant improvements in markers of cardiovascular/metabolic health (Kim et al., 2011). Metabolic adaptations to exercise may not be necessary for stimulating cognitive adaptations when the exercise is a form of dance.

The current study expands upon these findings, demonstrating that both dance interventions produced cognitive adaptations regardless of aerobic demand. Although both Aero and BR improved memory and WRIT, BR showed a tendency toward greater improvements on the WRIT. Improvements in memory, despite the observation that memory does not improve with aerobic exercise (Angevaren et al., 2008), suggest that there may be an inherent complexity to dance that challenged memory-related cognition.

The "cardiovascular fitness hypothesis" of exercise-induced cognitive adaptations suggests that it is the aerobic adaptation to exercise that produces improved cognition (Etnier et al., 2006). A meta-analysis by Etnier et al. (2006), however, indicated no relationship between cardiovascular fitness and cognitive performance. This suggests that other factors, beyond aerobic demand, play a role in driving the cognitive adaptations to exercise (Plautz et al., 2000). A likely contributing factor to these cognitive adaptations is the cognitive effort inherent to complex task performance (Carey et al., 2005).

Etnier et al. (2006) proposed that the relationship between cardiovascular activity and cognitive function, in the absence of correlation between these variables, may be due to mechanisms that are impacted by physical activity, but not reliant on changes in aerobic fitness. Alternately, these researchers suggested that two mechanisms by which aerobic fitness may enhance cognition are improved oxygen transport to the brain and neurotransmitter availability. BDNF, a key mediator of cognitive improvement to physical activity (Leckie et al., 2012), has been shown to respond to acute (McDonnell et al., 2013) and chronic (Zoladz et al., 2008) aerobic demand, as well as non-aerobic spatial learning tasks (Gomez-Pinilla et al., 2001). Taken together with the suggestion that BDNF strengthens neural connections during the learning process (Gomez et al., 2001), it is possible that BDNF played a role in cognitive improvements in both groups, for different cognitive outcomes.

Limitations

Several limitations may have affected our results. First, the dance selection and administration may be problematic. Cognitive declines with aging (Park, O'Connell, & Thomson, 2003) make it difficult to determine if the lack of change in certain outcomes was a form of attenuation due to the intervention, or an insufficient level of overload to affect adaptation. It is possible that twice-weekly classes for eight weeks provided insufficient training volume to cause adaptations across all variables measured. This possibility is supported by a study of aerobic frequency and cognitive outcomes by Masley et al. (2009), which revealed that improvements depended on the frequency of the intervention. Second, the tester was not blinded to exercise group assignment. This may have introduced potential bias. Third, no measures of complexity, cognitive demand, or learning effect were used to validate differences between the two conditions. Future research should include some measures of these tasks characteristics (complexity) and subjective responses (cognitive demand, learning effects). While we intended for complexity and aerobic demand to be the main difference between the two conditions, BR includes an extra element of human interaction; however, both groups involved a social environment. Future research should attempt to control the element of social interaction. Fourth, this study had a small sample size due to multiple factors. The low recruitment rate (50 participants recruited over 3 months) was due to the common perception that dance would be too difficult. There were 28 drop-outs due to scheduling conflicts throughout the recruitment, testing, and randomization processes. Subsequent to randomization, another 7 subjects dropped out after having begun participation in the dance classes due to scheduling conflicts and dissatisfaction with the dance style assigned. We expected drop-out rates to be lower based on other intervention-based studies in our lab. The difference in drop-outs (5 for Aero, 2 for BR) may suggest a difference in overall satisfaction between the dance styles. There was no measure to assess how much subjects' liked the dance style to which they were assigned. It should therefore be considered a limitation of this study that we did not use an intent-to-treat analysis.

A final concern when examining these results is the lack of consensus on definitions regarding cognition and executive function (Alvarez & Emory, 2006), which has resulted in many studies using different functional outcome measures for these terms. Studies designs have not always been consistent. For example, Masley et al. (2009) used a different computer battery, CNS Vital Signs, than us to assess attention and EF. In another study, a task-switching test was used as a proxy for EF (Leckie et al., 2014). One review (Smith et al, 2010) identified 22 different tests related to EF. And finally, measures of memory have at times been integrated into EF (Guiney and Machado, 2012).

CHAPTER 5: CONCLUSIONS

This study evaluates the differential roles of aerobic demand and movement complexity in producing cognitive adaptations. This proposition is based on the previously established models in which the evolution of the nervous system, cognition, and higher thinking is a response to the predictive challenges associated with the development of motricity (Llinás, 2002; Koziol et al., 2012). Rather than finding that BR dance produces superior cognitive adaptations than Aero dance, we found that participants in both dance groups improved similarly. Trends in the data suggest possible unique cognitive adaptations specific to the dance conditions, and should be examined further. A possible explanation for these findings is that the cognitive adaptation to an exercise in which there is an emphasis on rapidly changing instructions is different than the cognitive adaptation to an exercise in which there is an emphasis on remembering complex instructions. The theory of specificity can be applied to cognitive adaptations resulting from exercise tasks such as dance. This concept is supported by a study showing that older adults exposed to memory, reasoning, or processing speed training improved performance on the test specific to the targeted cognitive ability (Willis et al., 2006).

This study may support dance as a research tool for distinguishing movement complexity from aerobic intensity in the search for mediators of improved cognition. Other forms of exercise that can provide variable complexity include rock climbing as compared to ladder climbing, trail running as compared to treadmill running, and boxing as compared to skipping in place. Comparisons among these training modalities can be used to determine how various movement qualities, such as responding to a partner, solving a problem, or moving through a complex environmental "maze", can affect specific cognitive and neural adaptations. Our experience reveals that future investigations should attempt to control and quantify the degree of physical and cognitive overload placed upon subjects in the exercise tasks. Future research should look to better control complexity, as this study shows that a task designed for simplicity, such as our Aero dance task, can retain elements of complexity.

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FIGURES

Figure 1. CONSORT chart

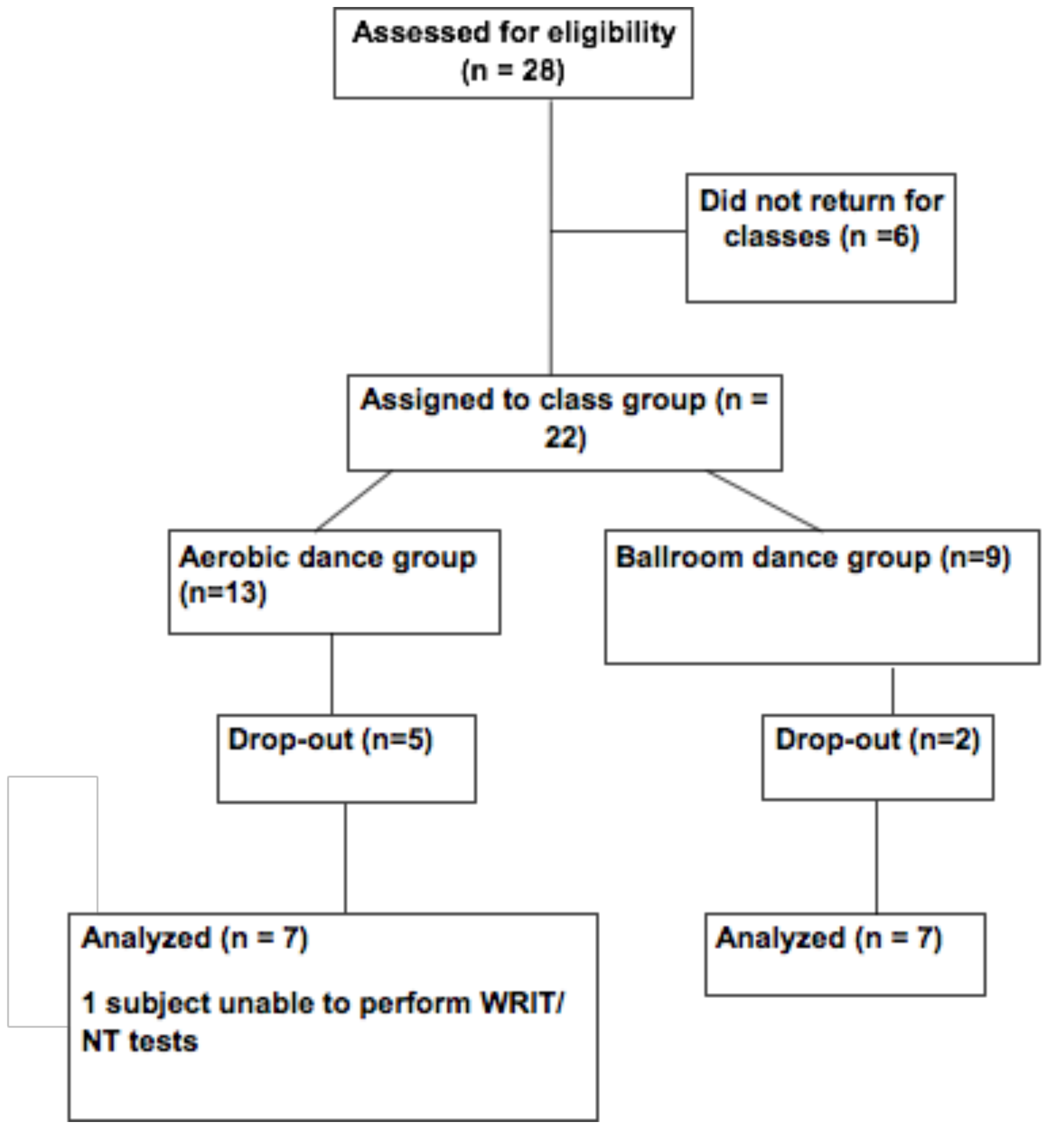


Figure 2. The Walking Response Inhibition Test (WRIT) schematic.

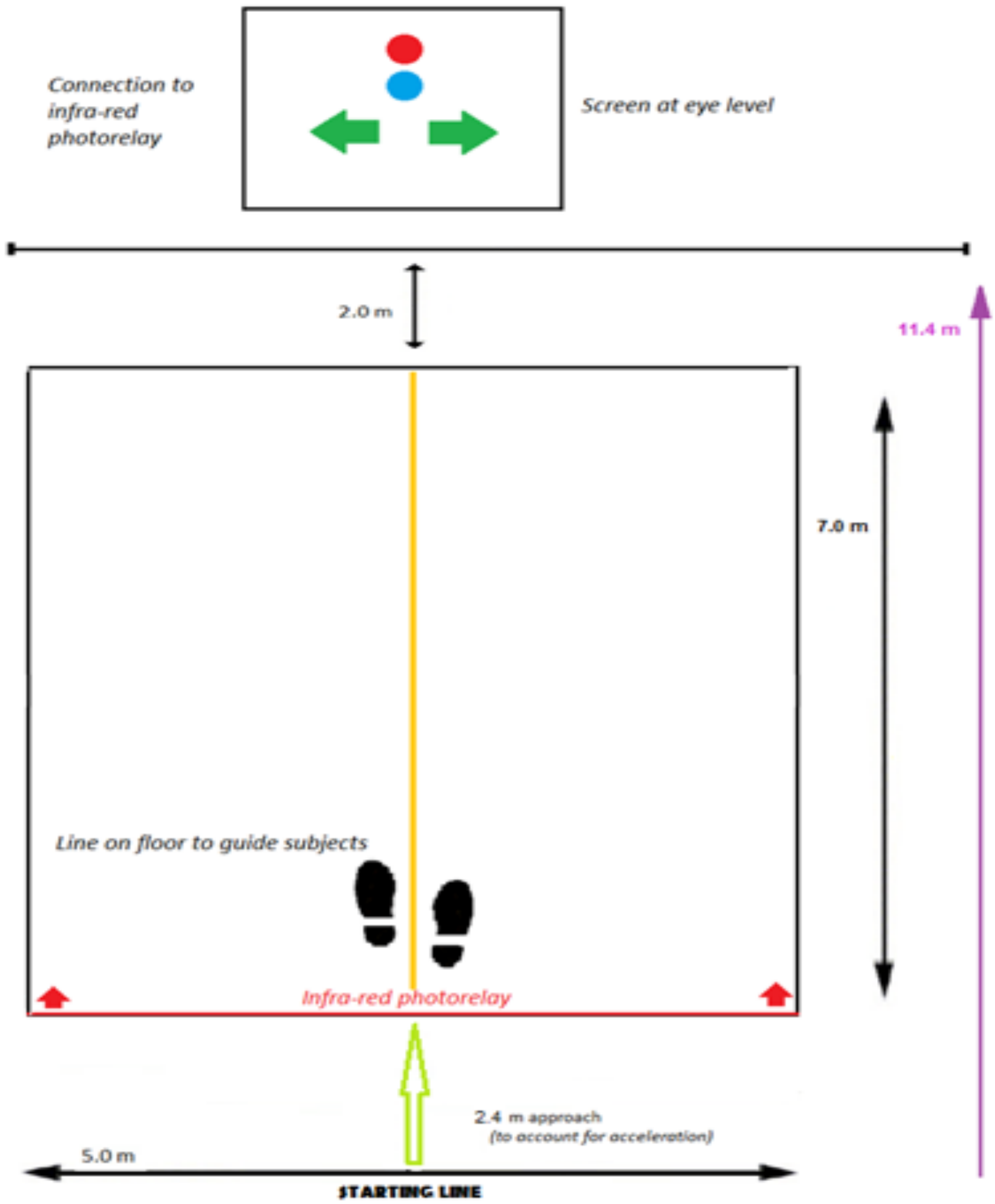
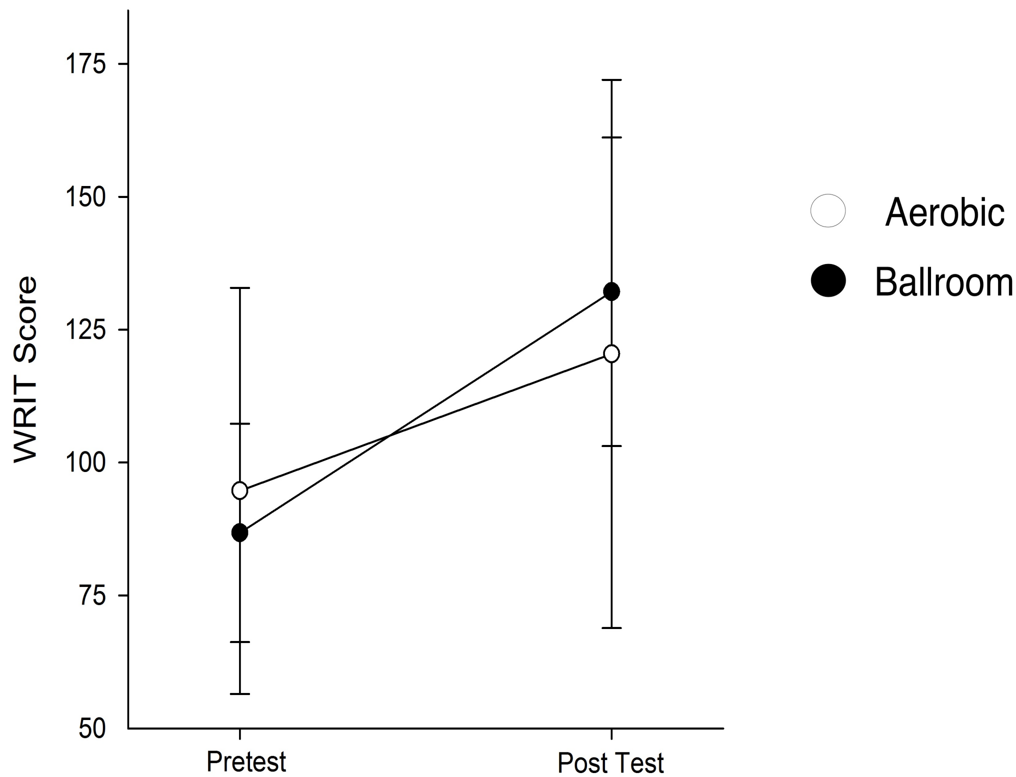


Figure 3. Patterns of change for the Ballroom ● and Aerobic Dance ○ groups on the Walking Response Inhibition Test (WRIT). No significant time x treatment interaction was detected.



TABLES

Table 1. Subject characteristics

	Aerobic Dance	Ballroom
Sample number	8	7
% female	75%	71%
Age (y)	65.1±12.6	65.1±5.5
Attendance	13.5±1.3	12.43±2.94
Height (m)	13.5±1.3	1.66±0.12
Weight (kg)	73.43±18.66	75.04±20.00

Table 2. ANOVA

	Main Effect of Time		Interaction Effect	
	p	Effect Size (η2p)	*p*	Effect Size (η2p)
Physical performance				
6MW (y)	0.55	0.03	**0.05**	0.27
TUG (s)	**0.03**	0.33	0.93	0.00
Computer battery				
Composite	0.76	0.01	0.79	0.01
Executive function	0.47	0.04	0.53	0.03
Memory[a]	**0.02**	0.35	0.94	0.00
Attention[a]	**0.05**	0.27	0.62	0.02
WRIT				
Composite	**0.00**	0.70	0.18	0.18

[a]Transformed data. 6MW = 6 minute walk, TUG = Timed Up-and-Go, WRIT = Walking reaction and inhibition test.

Table 3. Pairwise comparisons

	Condition	Pre-test mean ± SD	Post-test mean ± SD	Mean difference	Lower bound	Upper bound	p	d
Physical performance								
6MW (y)	Sample	501.9± 97.83	515.57± 79.02	13.67± 77.87	-29.45	56.79	0.51	0.15
	Aero	469.59± 85.83	520± 56.61	49.94± 82.98	-19.43	119.3	0.13	0.73
	BR	538.83± 103.71	511.00± 103.85	-27.79± 48.53	-72.67	17.09	0.18	-0.28
TUG (s)	Sample	6.08± 1.29	6.45± 1.18	.36± .54	0.06	0.66	0.02	0.30
	Aero	6.57± 1.13	6.92± 1.18	0.35± 0.59	-0.14	0.85	0.14	0.32
	BR	5.53± 1.31	5.91± 0.98	0.38± 0.53	-0.11	0.86	0.11	0.35
Computer battery								
Composite	Sample	106.56± 4.64	106.88± 5.69	.32± 3.55	-1.65	2.29	0.73	0.06
	Aero	107.71± 5.30	108.28± 5.92	0.56± 3.46	-2.33	3.45	0.66	0.10
	BR	105.24± 3.70	105.29± 5.38	0.04± 3.91	-3.57	3.66	0.98	0.01
EF	Sample	106.45± 9.74	105.51± 11.64	.95± 4.58	-3.49	1.59	0.44	-0.09
	Aero	109.64± 9.45	107.96± 12.27	-1.68± 4.86	-5.73	2.38	0.36	-0.16
	BR	102.81±	102.70±1	-0.11±	-4.25	4.02	0.95	-0.01

		9.38	1.10	4.47				
Memory	Sample	106.69± 5.85	110.21± 5.53	3.53± 5.34	0.57	6.48	0.02	0.62
	Aero	106.48± 5.87	109.81± 6.75	3.34± 4.70	-0.59	7.27	0.09	0.56
	BR	106.93± 6.29	110.67± 4.21	3.74± 6.38	-2.16	9.64	0.17	0.76
Attention	Sample	106.62± 4.53	104.89± 6.84	-1.73± 5.25	-4.64	1.18	0.22	-0.30
	Aero	107.07± 5.87	107.02± 7.34	-0.06± 5.37	-4.55	4.43	0.98	-0.01
	BR	106.10± 2.67	102.47± 5.78	-3.63± 4.77	-8.04	0.79	0.09	-0.87
WRIT								
Composite	Sample	91.65± 31.74	124.93± 43.20	33.28± 28.09	16.31	50.25	0.00	0.88
	Aero	94.69± 38.20	120.44± 51.55	25.74± 21.96	7.38	44.11	0.01	0.57
	BR	86.77± 20.51	132.12± 29.01	45.34± 35.02	1.86	88.83	0.04	1.81
Transformed								
Memory	Sample	0.79±.12	0.55±.09	-0.23±. 09	0.04	0.42	0.02	-2.23
	Aero	0.81±.42	0.57±.36	-0.24 ± .36	-0.54	0.06	0.10	-0.61
	BR	0.76±.47	0.53±.36	-0.23± .31	-.06	0.52	0.11	-0.55
Attention	Sample	1.00±.09	0.83±.08	-0.17±	0.00	0.33	0.05	-2.00

			.08				
Aero	0.74±42	0.87±.41	0.13± .37	-0.18	0.44	0.36	2.01
BR	0.92±.15	1.13±.19	0.21± .16	0.06	0.36	0.01	1.23

6MW = 6 minute walk, TUG = Timed Up-and-Go, WRIT = Walking reaction and inhibition test, EF = executive function

APPENDIX A

Mini Mental State Exam (MMSE)

Question #	Max. Score	Instructions
1	5	Ask for the date. Then ask specifically for parts omitted, "Can you tell me the (date), (year), (month), (day), (season) we are in?" Score one point for each correct answer
2	3	Ask in turn about the following locations. "Can you tell me the (state), (town), (county), (hospital), (floor) we are in/on?" Score on point for each correct answer.
3	3	Ask the participant if you may test his/her memory. Then say the names of the 3 unrelated objects (apple, table, penny), clearly and slowly, about one second for each. After you have said all 3, ask him/her to repeat them. The first repetition determines his/her score (0-3) but keep saying them until he/she can repeat all 3, up to 6 trials. If he/she does not eventually learn all 3, recall cannot be meaningfully tested. Tell the participant to remember those words. Alternate word sets if the first set becomes contaminated: (grape, chair, dime; peach, bed, nickel).
4	5	Ask the participant to begin with 100 and count backwards by 7. Stop after 5 subtractions (93, 86, 79, 72, 65). If the participant makes an error, correct him/her and ask them to continue. Score the total number of correct answers. If the participant cannot or will not perform this task, ask him/her to spell the word "world" backwards. The score is the number of letters in correct order, e.g. dlrow = 5, dlorw=3.
5	3	Ask the participant if he/she can recall the 3 words you previously asked him to remember. Score 1 point for each word he/she can recall.
6	2	Show the participant a wrist watch and ask him/her what it is. Repeat for pencil. Score 1 point for each correct response.

7	1	Ask the participant to repeat the sentence, "No ifs, ands or buts," after you. Allow only one trial. Score 1 point for a correct repetition.
8	3	Give the participant a piece of plain, blank paper and give the command, "Take a paper in your right/left hand (interviewer to select less-affected hand), fold it in half and put it on your lap."
9	1	Show the participant the piece of paper with the printed sentence, "CLOSE YOUR EYES." Ask him/her to read it and do what it says. Score 1 point ONLY if the participant actually closes his/her eyes.
10	1	Give the participant a blank piece of paper and ask him/her to write a sentence for you. Do not dictate a sentence; it is to be written spontaneously. It must contain a noun and a verb and be sensible. Correct grammar and punctuation are not necessary. If criteria are met, score 1 point.
11	1	Give the participant the piece of paper with the intersecting pentagons. Ask him/her to copy it exactly as it is. All 10 angles must be present and 2 must intersect to score 1 point. Tremor and rotation are ignored.

Description: The Mini-mental state exam (MMSE) is an assessment of overall cognitive function. (M. F. Folstein, Folstein, & McHugh, 1975)